Article

Auditory *Uta-Karuta*: Development and Evaluation of an Accessible Card Game System Using Audible Cards for the Visually Impaired

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Abstract: Playing board games is important for people with a visually impairment, as it promotes interactive socialization and communication skills. However, some board games are not accessible to them at present. In this study, we proposed an auditory card game system that presents a card's contents with auditory stimuli to all players, towards playing equally with others, regardless of whether they have a visual impairment or not as one of the solutions to make board games accessible. This proposal contributes significantly to expand the range of inclusive board games for the visually impaired. The purpose of this paper is to determine whether the game allows for fair competition for people with visual impairments and to clarify the effects of the valuable parameters of the system on the players. The effectiveness of the proposed system was verified by having experimental participants play "Auditory *Uta-Karuta*". The results suggested that the proposed system has the potential for an accessible board game design regardless of visual impairment. In the following experiment, we investigated the impact of each valuable parameter of the system on the player's perception of the board games to clarify the appropriate audio cue design method. The results of this experiment will greatly assist in designing an appropriate board game using the proposed system.

Keywords: accessibility; assistive technology; auralization

1. Introduction

Games as a means for social interaction and enjoyment were not initially included in digital technology. Multiple players had to exist in the same physical environment, and played game by manipulating tangible components made of wood or stone [1]. However, the development of digital technology has led to digital games, making it possible to play games without being in the same physical environment [1]. In spite of the shift from board games (which we define as all non-digital games) to digital games, board games have continued to be popular.

Playing board games is important for promoting interactive socialization of participants and improving problem-solving and communication skills [2]. Moreover, sharing a physical environment and game components facilitates concentration and verbal communication, which can help enhance relationships [3,4].

However, most board games are difficult to play with people with visual impairments because they are designed on the assumption that visual contact can be seen [5,6]. Further, board games can cause more difficulty due the need for interaction and special manipulation with the game components.

Although board games have these accessibility issues, the positive impact of board games on players is considered to be particularly significant for people with visual im-

pairments. Most people with visual impairments experience more social isolation and difficulties in interpersonal relationships due to their disability [7]. The positive effects of board games, such as improving problem-solving and communication skills, can solve these problems. In addition, to manipulate game components one's own self and participate in the game without the help of anyone, it could be able to contribute to further strengthening autonomy and increasing satisfaction of people with visual impairments. These contributions will able to promote the ability to live powerfully with disabilities: resilience [8,9]. Thus, it is important to give people with visual impairments the chance to have access to games for effective inclusion and participation in society. The efforts to improve board game accessibility have been made by devising rules or structures for the cards/pieces used in board game. "The Arabian Pots" [10] and "Nyctophobia" [11], which are typical examples of board games whose rules are designed for people with visual impairments, require only the ability to distinguish sounds. On the other hand, the newer versions of "Uno" [12] and "Hanabi" [13] are games that ensure accessibility by devising structures for the cards/pieces that they use. They use Braille or larger-than-usual cards to represent different colors and numbers for people with visual impairments. The solutions to making the cards/pieces used during board games accessible for people with visual impairments are mainly limited to enlarging the cards/pieces themselves or using tactile presentation. The former is the simplest solution, but it has the disadvantage of not allowing inclusion for completely blind players. The latter has the advantage of the inclusion of all visually impaired people in existing board games, but this solution alone is not enough to apply to all board games. It is necessary to memorize Braille script, as well as textures and their corresponding information, in advance, which is not intuitive. In other words, a solution that only presents tactile sensations has a risk of diminishing the enjoyment of the board game when integrated into existing games.

In this paper, we propose an auditory card game system that presents the card's contents by sound [14], with the aim to develop a board game that can be played in the same way by all players, regardless of whether they have a visual impairment or not. This is one of the solutions for making cards/pieces used during board games accessible for people with visual impairments. The purpose of this paper is to determine whether the game allows for fair competition for people with visual impairments and to clarify the effects of the valuable parameters of the system on the players. The remainder of this paper is organized as follows: in Section 2, we describe existing research and products from the community on games that are accessible to people with visual impairments. In Section 3, we introduce the configuration of the proposed game system. In Section 4, we describe the overview and results of a subject experiment on a new game that applies the proposed system to an existing card game. In Section 5, we investigate each valuable parameter of the system and explain the appropriate game design based on the results of various existing studies. Finally, the limitations of this study are described, followed by the conclusion.

2. Related Works

To solve accessibility issues for people with visual impairments in digital/non-digital games, various efforts have been deployed. In this section, we first describe the efforts by researchers and the community on the accessibility of digital games for the visually impaired. Next, we describe these efforts with respect to a non-digital game, breaking it down by the role of the components used in the game. Finally, we explain where our proposed system stands and contribution in relation to previous works.

In the digital game domain, audiogames that can be played with audio only are mainstream. Although audiogames is very small market compared to that of computer games, a lot of people with visually impaired enjoy audiogames, and the players and developers community is enhanced on internet site by introducing new audiogames and sharing player reviews [15]. However, audiogames do not appeal as much to sighted people because they don't have visual information. In fact, most audiogames are not interesting for most people, and the majority of players are people with visual impairments.

To create accessible games that can interest both camps, researchers have been contributing to the development of games that are not only audio but also visual and/or tactile. For example, "Terraformers" [16] uses sound propagation to convey the proximity of obstacles. "Terraformers" [16] and "AudioBattleship" [17] give feedback for every action using a voice over. "Sonic-Badminton" [18] enables play regardless of visual impairment by presenting the position of the wings of the badminton with stereophonic sound. Examples of the use of tactile sensation include "TiM games" [19] and "Digital Clock Carpet" [20] which can navigate in 2D environments by presenting different tactile stimulation with various materials. Further, "Kinaptic" [21] has enabled people with visual impairments to play a chasing game in a virtual environment by using sound and tactile feedback. These games aim to have same level of win rates between people with visual impairments and sighted people.

On the other hand, board games are far behind digital games when it comes to accessibility. In addition, most board game accessibility efforts have come from the community such as "Board Game Geek" [22] and "Meeple Like us" [23]. These efforts have been established by devising the rule or structure of the cards/pieces used in the board game. "The Arabian Pots" [10], which is a typical example of a board game, whose rules are designed for people with visual impairments, requires only the ability to distinguish sounds. It was designed after repeated tests so that only blind people can actually play. "Nyctophobia" [11] is a tactile maze game that does not assume the use of visual information. Players cannot see the board and have to rely on touch to play the game. On the other hand, "Splendor" [24] is a typical example of a game that ensures accessibility by devising the structure of the cards/pieces used in the board game. The first version of "Splendor" [24] used color as the only factor required to acquire a card, so players who could not distinguish between colors could not play the game, but the addition of iconography to the newer version makes this the game accessible to this audience. Similarly, the newer version of "Uno" [12] uses Braille to represent different colors and number. "Hanabi" [13] designed for people with visual impairments, has been modified to use larger-than-usual cards and card holders, but cannot be played by blind people because they still do not use non-visual modalities.

These board game's pieces and cards are generally called components, and they play the role of input/output interfaces between the game world and the players. The functions and entertaining properties of the components are realized because the components are real objects. The functions of components can be broadly classified into the presentation of information to all players and the presentation of information to specific players. In this paper, we define "public information" as the information presented to all players. They corresponds to the function of pieces used in Othello, Chess and Shogi. In contrast, we define "personal information" as the information presented to specific players. They corresponds to the function of deal cards used in Uno and Poker. Although players progress through the board games by manipulating the components, the physical constraints of the components may cause accessibility problems.

Table 1 shows a comparison of the aforementioned accessible board games classified according to the function of the components and the input/output between the players and the interfaces.

In order for people with visual impairments to correctly recognize the components of board games, it is necessary to use hearing and tactile sensation instead of sight. The work of making components accessible can also make existing board games accessible, which can also be an opportunity for people with visual impairments to enter the board game community of the sighted. As shown in Table 1, tactile presentation has been the main solution when components present public information in previous studies. The only solution that uses auditory stimuli is online competition, which does not guarantee face-to-face communication. Similarly, when the component presents private information, tactile presentation is the main solution. However, unlike public information, private information cannot be presented to other players, so it is not appropriate to use auditory stimuli that

can be transmitted to an indefinite number of players. Even if a headphone/earphone is used, it may interfere with face-to-face communication.

Table 1. Comparison between related works and proposal interfaces.

	UA-Chess [25]	Splendor [24]	Hanabi [13]	Uno [12]	Auditory Uta-Karuta [14]
The Role of Component	Public	Public/Private	Private	Private	Public
Equipment	PC	Card with Texture	Bigger Card	Card with Texture	Small Tablet-type Device
Input	Mouse, Keyboard, Voice	Touch Components	Look at Components	Touch Components	Game Master Operations
Output	Audio Cue, Screen reader	Haptic Sensation	Visual Sensation	Haptic Sensation	Auditory Sensation
Modality	Audio	Haptic	Visual	Haptic	Audio

In this study, we proposed an auditory card game system that presents a card's contents with auditory stimuli to all players, towards playing equally with others, regardless of whether they have a visual impairment or not. This is one of the solutions that presents public information of board games. Making board games components accessible will make it easier for visually impaired people to play existing board games with sighted people. Tactile presentation is the mainstream method for people with visual impairments to access board game components on their own, but it has the disadvantage that it requires touching every time the information is needed. This disadvantage cannot be applied when the game situation can change by touching board game components or when the game situation changes quickly. Furthermore, it is necessary to memorize Braille and textures and their corresponding information in advance, which is not intuitive. On the other hand, by presenting components with sound, players can obtain information about a component's contents and locations without touching them. Filho et al. [1] developed a game with textured card content to ensure accessibility for the visually impaired and designed guidelines, but some of their experimental participants requested audio feedback from the components. In addition to expanding the range of accessible board games, the use of auditory stimuli has the potential to increase immersion and make the game more intuitive and enjoyable. Furthermore, by digitizing the components of a board game, some of the physical constraints of the components can be lifted. This allows us to assign multiple components to a single device, or to increase the range of strategies by intentionally rewriting the information of the components. The final game design policy is to make the game fun for everyone, regardless of the degree of visual impairment.

3. Auditory Card Game System

3.1. Karuta

Karuta is a traditional Japanese playing card [26]. During the Heian period (794–1185), aristocrats had spent time writing elaborate poetry and playing *Kai-awase*. In *Kai-awase*, players depicted the poem or scenes related to the poem on the shells, face down, and competed to find the most pairs of shells. In the mid-1500s, Portuguese sailors introduced European playing cards that they called carta into Japan. During the ensuing Edo period (1600–1868), *Karuta* evolved from a Portuguese import into a Japanese traditional game, combining *Kai-awase* with carta.

One of the main types of *Karuta* is *Uta-Karuta*. Figure 1 shows the progression of *Uta-Karuta*. *Uta-Karuta* consists of multiple cards divided into two sets. One set is for reading and the other is for grabbing. Cards for reading are called *Yomifuda*, cards for grabbing are called *Torifuda*. *Yomifuda* and *Torifuda* exactly correspond to each other. The basic rule of *Uta-Karuta* is described below.
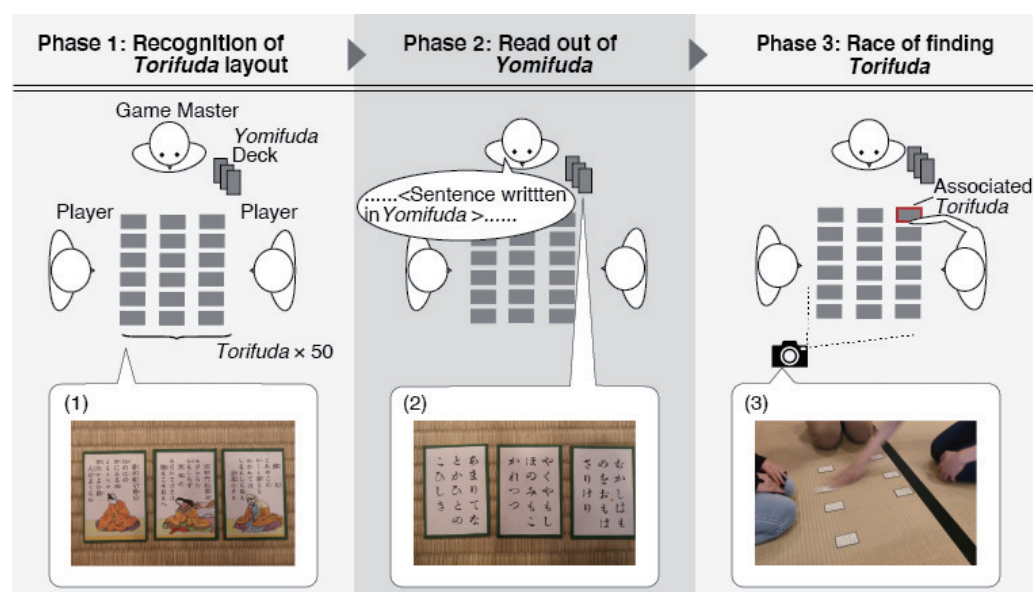
Figure 1. *Uta-Karuta* is a typical example of *Karuta*. *Uta-Karuta* consists of multiple cards divided into two sets: *Torifuda* and *Yomifuda*.*Yomifuda* and *Torifuda* exactly correspond to each other. (**1**) *Torifuda*: "grabbing cards" with pictures and/or written language, (**2**) *Yomifuda*: "reading cards" with written information, (**3**) The players position and cards placement during competition.

Phase 1: Recognition *Torifuda* layout
> Arrange the *Torifuda* face up on a flat surface in front of the players. Players memorize the contents and position of the *Torifuda* as much as possible.

Phase 2: Read out of *Yomifuda*
> The game master randomly draws a *Yomifuda* from the deck and starts reading it out.

Phase 3: Race of finding *Torifuda*
> Players race to determine which *Torifuda* corresponds to the *Yomifuda* and touch/grab/claim what they think is the correct *Torifuda*.

> Players repeat Phase 2 and Phase 3 until all the *Torifuda* are gone. The winner is the player who has the most *Torifuda*.

3.2. Auralization

While many researchers and communities have improved accessibility for the visually impaired by using sound in digital games, in the field of board games, they have designed accessible games mainly by using tactile feedback. Although some sound-based board games allow players to play against each other without relying on visual information by manipulating sound components, the idea of electronically generating sound from simple components such as cards and pieces made of paper or plastic is novel. The auditory card game system proposed in this study provides a new solution to board game accessibility by electronically generating sound from simple components. Figure 2 shows an overview of the auditory card game system. This system assumes a game with a game master. It comprises several "audible cards" and master device that is wireless connected to them. Small tablet devices, such as the iPod touch, can emit sound from individually mounted speakers. In addition, they are the same size as cards used in board games, making it easy for players to intuitively imagine them as cards. With this consideration, iPod touch devices were used for the audible cards. The audible cards correspond to the components used in the board game. The master device is a terminal operated by the game master to advance the game and make each audible card emit its sound. The audible cards hold the sound data used in the game and in our experiment. The master device operated by the game master and the multiple audible cards have a "one-to-many" type Bluetooth

communication. When a device ID and sound data are specified by the master device, the specified audible card will start playing a specified sound from its own sound set. The application was developed in Swift with "Multipeer Connectivity" frameworks. Each audible card emits its own unique sound stimulus, much like how playing cards correspond to pictures and symbols. The role of an audible card as a component of the board game is the presentation of public information. The aim of this system is to place these audible cards on the board as the game's components, as well as to make the players recognize what each card represents and the position of the card through auditory stimuli.
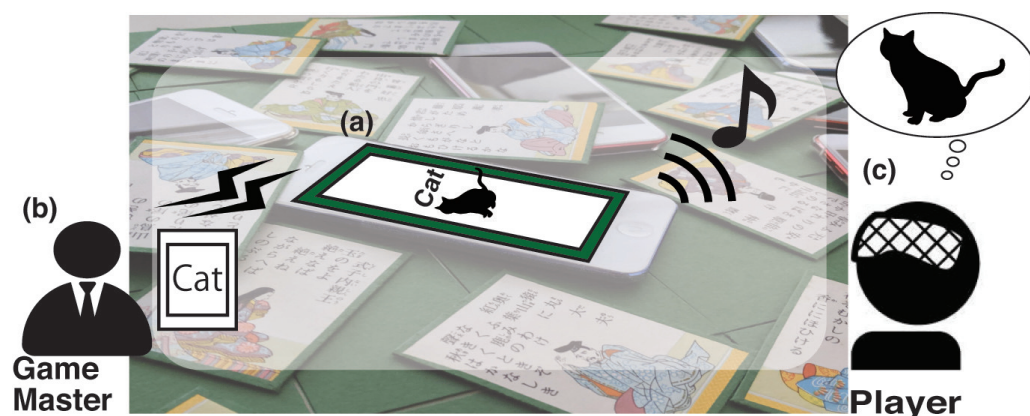

Figure 2. System overview: (**a**) a small tablet device regarded as a card: an audible card. (**b**) The game master plays an audio signal from the audible card by wireless connected device. (**c**) Players recognize the information of the card through acoustic sensation.

Auralization has been used in many solutions for improving accessibility problems for the visually impaired [27–29]. The auditory card game system works by presenting the contents of the cards through sound rather than visual information. This is a process of making audible the components of a board game that originally relied on visual and tactile modalities.

3.3. Auditory Uta-Karuta

In normal card-style *Karuta*, both players need to recognize public information on the board without touching the cards. In order to do so, it is necessary to recognize the contents of the cards and the arrangement of the cards by looking at them, which causes a problem of accessibility for people with visual impairments. The aim of the auditory card game system is to represent information about the contents and arrangement of multiple cards using auditory stimuli rather than visual stimuli. This will improve accessibility for people with visual impairments because they can recognize the contents and arrangement of multiple cards simultaneously as a result of the presentation of sounds. We developed "Auditory *Uta-Karuta*" using an auditory card game system into *Uta-Karuta*, to create a new game that can give people with visual impairments access to certain games for effective inclusion. Figure 3 shows the system configuration and procedure of "Auditory *Uta-Karuta*". "Auditory *Uta-Karuta*" consists of multiple audible cards and a parent device operated by the game master. Multiple audible cards are called *Torifuda* devices, and correspond to *Torifuda* in *Uta-Karuta*. The parent device is called a *Yomifuda* device, and corresponds to *Yomifuda* in *Uta-Karuta*. The *Yomifuda* device can not only read out *Yomifuda* but also make *Torifuda* devices emit sound by wireless connection to each *Torifuda* device. Each *Torifuda* device emits a unique sound stimulus, much like playing cards correspond to pictures and symbols, according to the *Yomifuda* device's instruction. *Yomifuda* presented by *Yomifuda* device, and *Torifuda* devices exactly correspond to each other. In this experiment, no information was shown on the screen of the audible cards. The rules of "Auditory *Uta-Karuta*" are described below.
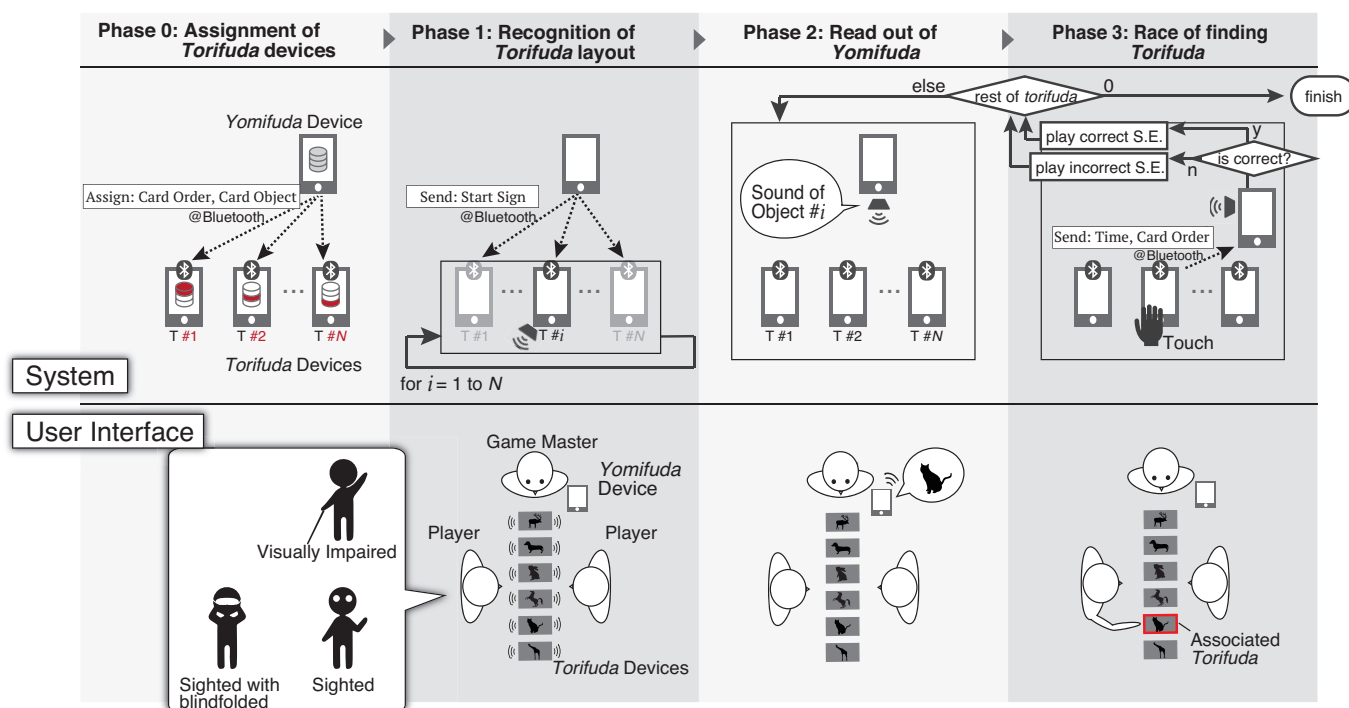
Figure 3. The behavior of the auditory card game system when playing "Auditory *Uta-Karuta*" and the procedure of the game. All devices are communicated by signal. A game master operates the *Yomifuda* device to proceed the game. The players obtain the card by touching/grabbing the *Torifuda* device corresponding to the sound presented by the *Yomifuda* device.

Phase 0: Assignment of *Torifuda* devices

The first step is to establish wireless communication between the *Torifuda* devices and the *Yomifuda* device. The wireless communication was implemented using Apple's "MultiPeer Connectivity" framework, and all communication was done in signal to avoid delays as much as possible. After communication is established, the *Yomifuda* device randomly assigns content from its own sound data set for each of the *Torifuda* devices. At the same time, *Yomifuda* device gives the numbers to the *Torifuda* devices. This number indicates the order in which the *Torifuda* devices are presented with the sounds in Phase 1.

The *Torifuda* devices hold the sound data used in the experiment. When given signal indicating a particular sound from the *Yomifuda* device, the *Torifuda* devices find the appropriate sound in its own sound data and prepares to play it. Similarly, when given signal indicating the order of read out, the *Torifuda* devices set the waiting time until playback according to the value of the signal.

Phase 1: Recognition of *Torifuda* Layout

Arrange the *Torifuda* devices face up on a flat surface in front of the players. When the game master presses the "Start" button displayed on the *Yomifuda* device, a signal the start of read out is given to all connected *Torifuda* devices. When the *Torifuda* devices receive a signal the start of read out from the *Yomifuda* device, they start reading based on the pre-set wait time and sound data. Players memorize the contents and position of the *Torifuda* devices as much as possible.

Phase 2: Read out of *Yomifuda*

The screen of the *Yomifuda* device shows the same number of buttons as the number of sounds used in the experiment. Each button corresponds to a sound, and when a button is pressed, the corresponding sound is played from the *Yomifuda* device. The game master operates the *Yomifuda* device, selects the *Yomifuda*, and presents the corresponding audio signal through the *Yomifuda* device.

Phase 3: Race of Finding *Torifuda*

Players race to determine which *Torifuda* devices corresponds to the *Yomifuda*, and touch/grab what they think are the correct *Torifuda* devices. In this phase, only the touched *Torifuda* device gives its own card order to the *Yomifuda* device. The *Yomifuda* device determines whether or not the correct *Torifuda* device was touched based on the card order given, and plays the correct/incorrect sound effect.

Subsequently, players repeat Phase 2 and Phase 3 until all the *Torifuda* devices are gone. If a player selects incorrect *Torifuda* device, the incorrect *Torifuda* device is re-arranged among the players, and his/her opponent obtain the correct *Torifuda* device. The winner is the player who has the most *Torifuda* devices. "Auditory *Uta-Karuta*" was prepared in two types: Type α and Type β. The details of these types are described below.

Type α: In Phase 2, all *Torifuda* devices do not present the sound.

Type β: In Phase 2, all *Torifuda* devices present the sound.

People with visual impairments are thought to have a higher capacity for processing auditory information than sighted people because they spend the majority of their daily lives using their hearing ability. In other words, auditory memory can also vary due to players' characteristics. Based on this possibility, Type α and Type β were prepared. Type α does not present the sounds from the audible cards in Phase 2, so players need to remember the arrangement of the six audible cards and what the sounds indicate. On the other hand, Type β is designed to ignore the differences in the players' auditory memory abilities because the audible cards present the cards' contents with sounds in Phase 2. As there is a difference between these conditions, we can conclude that the positions of the six audible cards and the recognition of their contents can vary according to the characteristics of the players.

4. System Evaluation

4.1. Overview

In this paper, we propose an auditory card game system that presents the card's contents by sound so as to make a game accessible for people with visual impairments. We developed a game called "Auditory *Uta-Karuta*" by using the proposed system, and conducted an evaluation experiment in which participants played against each other. The purpose of this experiment is to test the applicability of auditory card game system to board games. For this purpose, the game performance of three different types of players was revealed thorough the experiment. Since the proposed system assumes that people with visual impairments can participate in a board game together with sighted people, we prepared sighted people and people with visual impairments as experimental participants. In addition to those, we also prepared sighted players with blindfolds and conducted a game between sighted players and sighted players with blindfolds to clarify how much their game performance is affected due to the presence of vision. Furthermore, by examining a game played between a visually impaired person and a sighted person wearing a blindfold, it was possible to examine the difference in auditory abilities between people with visual impairments and sighted people. In this experiment, since the participants were required to touch/grab audible cards, the sighted participants who were able to recognize the positions of the audible cards through their vision were considered to have an advantage in the card-grabbing situation. On the other hand, visually impaired participants spend their daily lives using their hearing ability and, thus, have a higher capacity for recognizing auditory information than sighted participants. "Auditory *Uta-Karuta*" does not present visual contents to all of the participants, and it is necessary to recognize the audible cards mainly with one's hearing ability. As mentioned above, while sighted participants are expected to be better at touching/grabbing the audible cards, visually impaired participants are expected to be better at detecting the correct audible cards due to their high auditory abilities. Therefore, an evaluation experiment was conducted to find

the extent to which the respective advantages and disadvantages of people with visual impairments and sighted people affect the game's results. As a comparison, we prepared Braille *Karuta*, which is representative of existing tactile presentation methods.

4.2. Stimuli and Equipment

For each audible card, an iPod touch (6th generation) was used. Six audible cards were placed horizontally in a row between two participants, with a distance of 70 mm between each card. No information was shown on the screen of the audible cards, and the players had to obtain information only by hearing. The two participants sat face to face with a distance of about 1 m between them. The sounds used as stimuli were consisted of six different animal crying sounds obtained from [30]. All sounds were 5 s in length at Phase 1 to ensure clarity of the card's contents and positions. Sounds were sampled at 44.1 kHz with 16-bit resolution, normalized for amplitude across conditions, and presented in mono. The experiment was programmed in Swift and presented using the speaker of the iPod touch (6th generation).

We used bridge cards (56 mm × 88.9 mm), one of the common standards for playing cards, as the Braille cards for comparison. These cards had animal names written in Braille and Japanese characters on both ends of the card so that participants could understand them, whether they have a visual impairment or not. They were placed horizontally in a row between two participants, in the same position as the audible cards.

There were 18 participants (14 males and four females) aged from 19 to 42 years old. Among the participants, there were six people with clear vision (four males and two females), six people with visual impairment (five males and one female), and six people with a blindfold (five males and one female). All visually impaired participants could read Braille. In contrast, all sighted participants could not read Braille. All participants had normal hearing and no physical or language disabilities. They had practiced the game before the experiment and understood the rules well.

4.3. Procedure and Evaluation

At the beginning, the participants listened to the six sounds used in the experiment and grasped the meaning of the cards they indicated. For example, a cat crying sound corresponded to the card's content "Cat". The participants sat face-to-face and checked the positions of the six audible/Braille cards in front of them, either visually or by touching them with their hands. In addition, a test phase was set up—the sound used in the experiment was randomly generated by audible cards laid out in front of the participants, and the participants were asked to answer with the meanings of the sounds. The purpose of this phase was to make sure that the participants heard each audible card correctly. After confirming the position of the audible cards and the sounds and practicing touching and grabbing the audible cards several times, they moved on to the main experiment. In the main experiment, the participants played "Auditory *Uta-Karuta*" using the procedure described in Section 4.2. In addition, they played both Type α and Type β. The six sounds used in each experiment were not changed, but the order of the six types of cards and the cards to be read were randomly changed each time. In the case of using Braille cards, which is the comparison object, the sighted participants grasped the contents of the cards visually, and the visually impaired and blindfolded participants grasped the contents of the cards by touching the Braille. In this case, the time used in Phase 1 was 30 s, as in the case of audible cards. The game was played in the following three states.

Case 1: Person with a visual impairment vs. sighted person

Case 2: Person with a visual impairment vs. sighted person with a blindfold

Case 3: Sighted person vs. sighted person with a blindfold

Case 1 was a competition between a person with a visual impairment and a sighted person, the aim of which was to verify whether the "Auditory *Uta-Karuta*" allowed people with visual impairments to be equally competitive. If there was a difference in the results

in Case 1, we could conclude that the accessibility of "Auditory *Uta-Karuta*" for people with visual impairments was inadequate. Case 2 was a competition between a person with a visual impairment and a sighted person with a blindfold, the aim of which was to verify whether an equal match was possible when participants were completely deprived of visual information. Furthermore, if there was a difference in the results in Case 2, the difference in hearing ability between people with visual impairments and sighted people would be confirmed. Case 3 was a competition between a sighted person and a sighted person with a blindfold, the aim of which was to clarify the extent to which the sighted person was affected by their vision. If there was a difference in the results in Case 3, we could conclude that game performance in "Auditory *Uta-Karuta*" is affected due to the presence of vision for sighted players. The participants were informed about the degree of visual impairment of their opponents before the experiment.

The evaluation method is described below. One of the theories that examines the situations in which people find games interesting is flow theory [31]. According to this theory, people feel enjoyment when the difficulty of the challenge is in competition with their own abilities, and when it is close to the limit of their abilities. These "flow states" have been adopted in theories of game enjoyment [32–34]. Abuhamdeh [35] found that games with better opponents and closer games gave more enjoyment to people. In the game of *Karuta*, the winning rate and the strength of the opponent should be close to one's own, which is considered to be a condition that enables the game to be played for an interesting and close game. In addition, since *Karuta* is a game that includes an element of luck—it is possible to guess a card correctly before the read-out phase—it is hard to consider that the winning rate and the feeling of competitiveness are in perfect correspondence. Therefore, for the system evaluation experiment, we used the winning rate as a quantitative evaluation and the subjective evaluation of the opponent as a qualitative evaluation.

(a) Winning Rate:

Winning rate of the people with visual impairments in Cases 1 and 2 and of those with a blindfold in Case 3.

(b) Subjective Evaluation of the Opponent:

The opponent's strength [0, 100] when the player strength is 50.

The winning rate is determined based on players who do not have visual information (people with visual impairments and people with a blindfold) in *Karuta*. The more equal the competition is, the closer the winning rate will be to 50%. Subjective evaluations of the opponents were used for the purpose of subjectively evaluating the strength of an opponent's game performance based on the competition, regardless of the winning rate. The participants' own strength was defined as 50, and they chose an integer value from 0 to 100 to rate the strength of their opponent. The value of 0 is the weakest and 100 is the strongest. Thus, if the value is close to 50, which is the strength of the players themselves, the competition can be considered psychologically equal.

4.4. Results and Discussion

In this experiment, we evaluated the results by having participants play "Auditory *Uta-Karuta*" with three types of experiments: sighted person, visually impaired person, sighted person with a blindfold. Figure 4 shows the result of the evaluation experiment. For the winning rate, a Welch's *t*-test was conducted to examine the significant differences ($p < 0.05$) from the winning percentage of 50%. For the subjective evaluation of the opponent, Fisher's Least Significant Difference (LSD) test was conducted to examine the significant differences ($p < 0.05$) from the existing method using Braille cards.
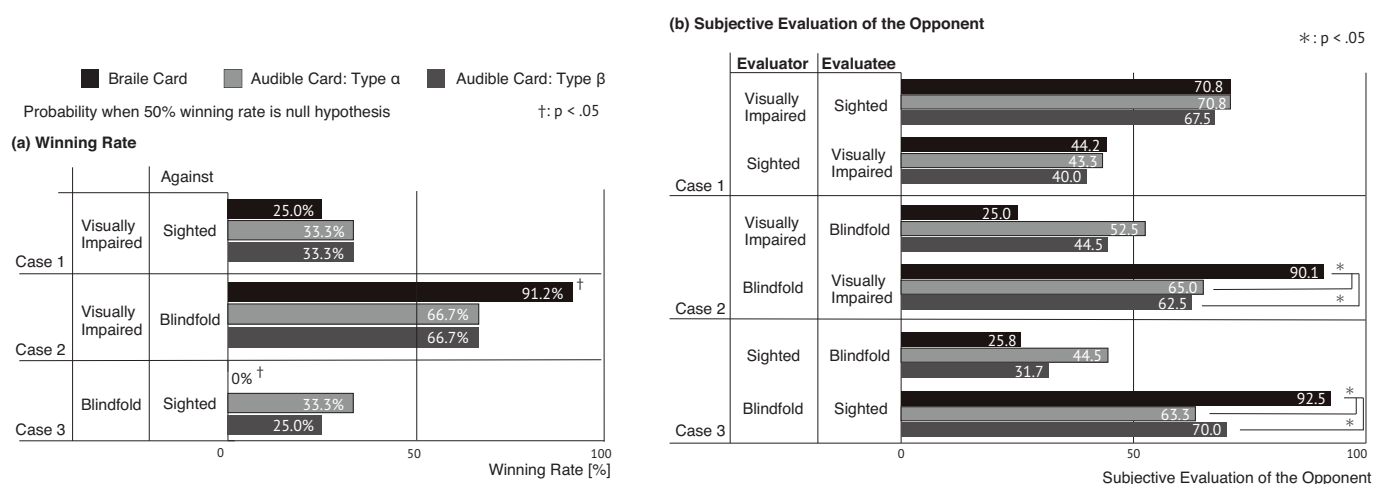
Figure 4. (**a**) Winning rate of the people with visual impairments in Cases 1 and 2 and those with a blindfold in Case 3, (**b**) subjective evaluation of the opponent: The opponent's strength [0, 100] when the player strength is 50.

Figure 4a shows the winning rate of the evaluation experiment. Although there were significant differences in the method using Braille cards, there was no significant difference in Cases 2 and 3. In other words, the null hypothesis that the winning rate was 50%, was rejected when the tactile presentation was used, whereas the null hypothesis was not rejected when the proposed method was used. Therefore, it was possible to enable fair competition, in which the players can be given the same degree of victory opportunity, even without visual information.

Figure 4b shows the subjective evaluation of the opponent of the evaluation experiment. There were significant differences between using Braille cards and using audible cards in Cases 2 and 3. In other words, the null hypothesis that there is no difference in the evaluation value of the opponents between the previous and proposed methods, was rejected. In addition, the results in the proposed method were close to 50. Therefore, the proposed method makes it possible to boost the sense of rivalry, even without visual information compared to using Braille *Karuta*.

Furthermore, Figure 5 shows the questionnaire results of the enjoyment of each game. The participants rated their enjoyment of playing Braille *Karuta* and "Auditory *Uta-Karuta*" on a scale of 1 to 5. Welch's *t*-test was conducted to examine the significant differences ($p < 0.05$) from the existing method using Braille cards. For all the participants in the experiment, "Auditory *Uta-Karuta*" was more enjoyable. While the sighted people can recognize the Braille cards by reading the characters on them, the people with visual impairments and the blindfolded people can only recognize Braille cards by touching them. Therefore, the sighted people could easily win the game when they played Braille *Karuta*, and could not feel enough enjoyment. Although the people with visual impairments can understand Braille cards, they were unable to win in a match against a sighted player. Similarly, when playing against a blindfolded player, it was impossible to realize close competition because blindfolded players could not understand Braille cards. For these reasons, it is assumed that the people with visual impairments were not able to feel enjoyment playing Braille *Karuta*. The blindfolded participants were not familiar with Braille and could not fully understand the Braille cards, so they did not enjoy Braille *Karuta*. On the other hand, in the game of "Auditory *Uta-Karuta*" all the participants recognized the cards by sound, and the game became closer to an equal match, which resulted in a sense of enjoyment. Furthermore, compared to Braille *Karuta*, the difference in the evaluation of enjoyment between the attributes of the experimental participants tended to be smaller for "Auditory *Uta-Karuta*". It is assumed that this is because the audible cards can make the performance of recognizing them closer to the same level regardless of the attributes of the experimental participants compared to the Braille cards.
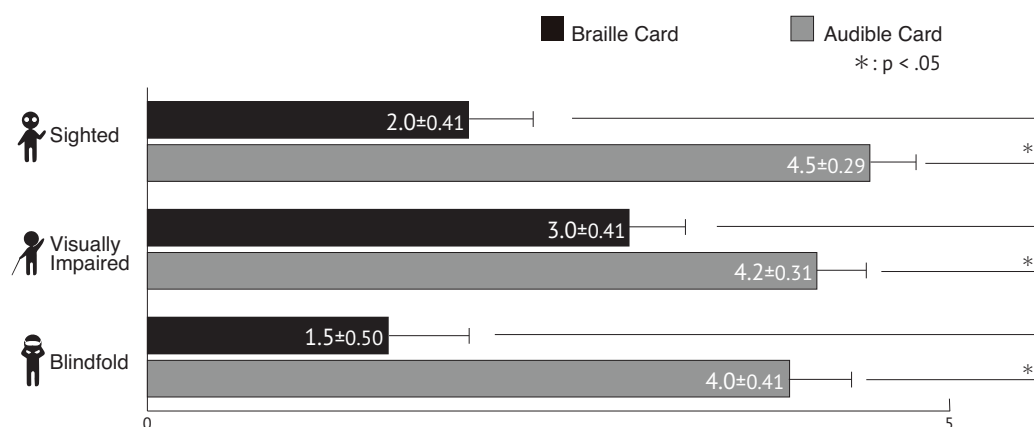
Figure 5. Results of the questionnaire. The participants of the experiment rated their enjoyment of playing Braille *Karuta* and "Auditory *Uta-Karuta*" on a scale of 1 to 5.

Thus, the results showed that "Auditory *Uta-Karuta*" has the potential to be played equally regardless of whether they have a visual impairment or not compared to using Braille cards. Furthermore, it proved to be possible to realize not only equal competition, but also more enjoyable games for the players. This result suggests that the proposed system may be used as one of the means to convey public information in board games that are accessible to the visually impaired. Although they showed that the game was significantly effective in a match between a visually impaired person and a sighted person with a blindfold, there was no significant difference in a match between a visually impaired person and a sighted person. In other words, the experimental game could not completely enable fair competition, regardless of visual impairment. However, it is interesting that the visually impaired persons had a higher winning rate compared with sighted persons with a blindfold, even though neither of them could obtain visual information. Similarly, the visually impaired persons were highly evaluated by sighted persons with a blindfold. These results suggest that the people with visual impairments may have better auditory memorization and directional resolution abilities than the sighted people. This suggestion is assumed would be proper in light of the fact that the visually impaired live mainly using their sense of hearing and touch instead of their sense of sight. This is verified by previous studies [36,37]. In spite of the above facts, the reason for the lack of significant difference between the visually impaired and the sighted is due to the way they touch/grab the audible cards. In fact, in the experiment, it was observed that many visually impaired participants failed to touch/grab the cards. In other words, in this game of "Auditory *Uta-Karuta*", the advantage of sighted people's ability to accurately recognize the positions of the audible cards had a greater impact on the outcome of the game than the high auditory abilities of the visually impaired people. However, it is easy to assume that it would be difficult for visually impaired people to perform as well as or better than sighted people in the card-grabbing situation, unless the sighted people were given a handicap or the visually impaired people were given an advantage. As mentioned above, the degree of usefulness of an auditory card game system can change depending on the characteristics of the players and the rules of the game. Therefore, in the future, it is possible to consider a flexible game design that presents images in order to control the game performance of sighted players. In order to design such a flexible game in the future, it is first necessary to verify the effects of an auditory card game system that uses only auditory cues for the players by changing each valuable parameter. This process reveals the values of the parameters that allow each player to maximize the recognition of audible cards, as well as the parameters that affect game performance depending on the players' characteristics. In the following sections, we investigate each valuable parameter of the system and explain the limitations of the proposed system and appropriate game design based on the results of various existing studies.

5. Suggestion for Suitable Auditory Cues in Auditory Card Game System

5.1. Overview

In the previous sections, we developed "Auditory *Uta-Karuta*" and verified the usefulness of this system by actually having the game played by visually impaired people, sighted people, and sighted people with a blindfold. As a result, we could not conclude that "Auditory *Uta-Karuta*" had a completely equal game design, as it favored the sighted participants. However, compared to Braille *Karuta*, "Auditory *Uta-Karuta*" approached a more favorable result. This result suggests that, compared to games that use tactile means of presentation, "Auditory *Uta-Karuta*" has a greater potential to make games accessible, regardless of visual impairment. Although we used animal calls and arranged the audible cards horizontally in "Auditory *Uta-Karuta*", we believe that we can find specific valuable parameters that will enable even more equal games by considering a comprehensive range of possible game designs. In other words, it is necessary to search for the elements required for an equal game design that takes the characteristics of sighted people—who have vision—and visually impaired people—who have high hearing abilities—into account.

In this section, we investigate each valuable parameter of the system and explain the limitations of the proposed system and appropriate game design based on the results of various existing studies.

5.2. Valuable Parameters

The main components of our system are the degree of visual impairment, the selection of the audio type, and the style of sound playback. Details are described below.

(1) Degree of visual impairment: Since the proposed system assumes that people with visual impairments can participate in the same board game together with sighted people, we prepared sighted people and people with visual impairments as parameters indicating the degree of visual impairment. Furthermore, in order to clarify how much the visual information contributes to grasping the contents and position of the components for the sighted, the sighted people with a blindfold were prepared.

(2) Audio types: As shown in Table 2, the presentation of information using auditory stimuli can be divided into verbal sounds and nonverbal sounds, the latter of which can be further divided into representational sounds and abstract sounds. A typical of representational sounds is "auditory icons" [38], and a typical of abstract sounds is "earcons" [39]. Representational sounds are real world sounds that have a direct association with an object, and abstract sounds are synthetic sounds that have no direct association with an object. Each of these types of sound have advantages and disadvantages. The advantage of verbal sounds is the meaning of the message is relatively unambiguous [38]. However, users have to listen to the whole message to understand the meaning. Moreover, verbal sounds have language limitations. The advantage of representational sounds is that they can convey complex messages in a single sound. In addition, representational sounds are easy to identify by analogy. However, they cannot be assigned real world sounds for all events. The advantage of abstract sounds is flexibility. They can present information in a systematic way [38]. Further, they can represent hierarchies by controlling their parameters such as timbre and pitch. However, they have difficulties associated with learning and remembering. In this experiment, we prepared three types of audio to be used: A: verbal sounds, B: representational sounds, and C: abstract sounds.

(3) The style of sound playback: We prepared two types of sound playback. Type α, presents the auditory stimuli one by one in order, and Type β presents the sound for all audible cards at the same time. While Type α has the advantage that players can clearly recognize the information of the audible card one by one, Type β has the advantage that players can obtain the information of multiple audible cards at once.

Hence, as shown in Table 3, we prepared parameters for three types of degree of visual impairment, three audio types, and two types of sound playback.

Table 2. The list of audio types using experiment.

	A: Verbal Sounds		Non-Verbal Sounds	
			B: Representational Sounds	C: Abstract Sounds
Summary	Sound presentation using real world sounds		Real world sounds that have a direct association with an object	Synthetic sounds with artificial correspondence without using real world sounds
Advantage	Provide clear information		Intuitive understanding by analogy	Systematic presentation
Disadvantage	Language limitations		Cannot represent all the events	Lack of meaningful relationship with their referent

Table 3. The composition of valuable parameters.

Degree of Visual Impairment	Audio Types	The Style of Sound Playback
1: Sighted	A: Verbal	Type α: Play sounds one by one in order
2: Visually impaired	B: Representational	Type β: Play sounds simultaneously
3: Sighted with blindfold	C: Abstract	

5.3. Stimuli and Equipment

For the audible cards, iPod touch devices (6th generation) were used. A total of 12 audible cards were placed in front of the participants, and each card was arranged as shown in Figure 6. No information was shown on the screen of the audible cards, and the participants had to obtain information only by hearing. Sounds were sampled at 44.1 kHz with 16-bit resolution, normalized for amplitude across conditions, and presented in mono. The experiment was programmed in Swift and presented using the speaker of the iPod touch (6th generation). The representational and abstract sounds were obtained from [30]. The verbal sounds were an adult female voice (Kyoko) in Japanese, created using Apple's speech reading software. Representational sounds were environmental sounds which were selected based on a strong relationship between the sound and the event with which it was associated. For example, a cat crying sound was used for the card's content "Cat". The detail of correspondence between the card's contents and the verbal/representational sound is shown in Table 4. Abstract sounds were designed to enable discrimination between multiple abstract sounds and to ensure localization performance, referring to guidelines and experimental results in previous studies [40–42]. Brewster [40] suggested using musical timbres with multiple overtones and including a range from 0.125 to 5 kHz in his guidelines for abstract sound design. In addition, Brewster recommended to add delay of about 0.1 s between each abstract sound when playing them one after another. Patterson [41] found that similar rhythms can confuse abstract sounds even when there are large differences in spectra. Morikawa [42] concluded that auditory stimuli consisting of only frequencies below 2 kHz or above 12 kHz cannot provide sufficient horizontal sound localization.
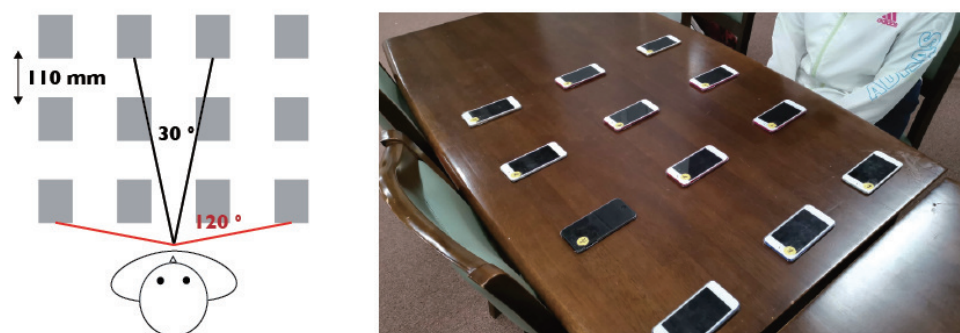
Figure 6. The state of experiment: The subject sat on the chair and described the content and position of the audible cards laid out in front of them.

Table 4. Verbal Sound and representational sound sets used in the experiment. Verbal Sound sets are pronounced in Japanese, and written in international phonetic symbols.

Card Contents	Verbal Sound	Representational Sound
Cat	ne\ko	Cat's meow
Glass	gɯ$^\beta$ \rasɯ$^\beta$	Pouring water into a glass
Cow	ɯ$^\beta$ \ɕi$^-$	Cow's bark
Toad	ka\erɯ$^{\beta-}$	Frog's croak
Knife	na\iɸɯ$^\beta$	Cutting food with a knife
Keyboard	k^{j}i/:bo\:do	Tapping a keyboard
Crow	karasɯ$^\beta$	Crow's caw
Dog	i/nɯ$^\beta$ \	Dog's bark
Scissors	hasam^{j}i	Scissors cutting paper
Dentifrice	ha/bɯ$^\beta$ \raɕi	Brushing one's teeth.
Hair Dryer	do\raija:$^-$	Drying one's hair with a hair dryer
Cicada	sem^{j}i	Cicada noise

Based on these guidelines and results, the abstract sounds were designed as follows. They consisted mainly of musical timbres with a wide bandwidth from 0.5 to 16 kHz and overtones as much as possible to ensure both the guideline and the localization performance. Furthermore, each abstract sound was designed with a different rhythm to reduce confusion. In the Type α experiment, a 0.1 s gap was inserted between each sound to enable the participant to determine when one sound ends and the next begins. Abstract sounds were randomly assigned to the contents of the card.

Participants were tested on six stimulus combinations of three audio types and two methods of presenting multiple sounds. Blocks of demonstrations and experiments were presented to participants with a new random order of stimuli in each block. In the blocks of demonstrations, the participants listened to the 12 sounds used in the experiment and grasped the meaning of the cards they indicated. The maximum memorization time was 10 min for each audio type. The participants sat and checked the positions of the 12 audible cards in front of them, either visually or by touching them with their hands. In addition, the test sounds were played from each of the 12 cards in turn, and the participants had to confirm correspondence between the sound source and the card's position. In the experiment block, each of the 12 audible cards emitted a different sound. In the Type α experiment, all sounds were presented randomly for 5 s each. The participants described orally the meaning and the position of the sound presented by each audible card. There was no time limit for this, and the participants were asked to describe as much as possible. In this experiment, the identification rate and recognition rate were evaluated. The identification rate indicates how many of the 12 audible cards the participants were able to distinguish. The recognition rate indicates how many of the 12 audible cards of which the participants were able to correctly grasp the location and contents.

There were 18 participants (10 males and eight females) aged from 19 to 42 years old. Among the participants, there were five people with clear vision (four males and one females), seven people with visual impairments (three males and four females) and six people with a blindfold (three males and three females). All participants had normal hearing and no physical or language disabilities.

5.4. Results

Figure 7 shows the differences in experimental performance according to the degree of visual impairment. In this analysis, a Tukey Honestly Significant Difference (HSD) test was conducted to examine the significance of the differences ($p < 0.05$). In the case of Type α, both the identification rate and recognition rate were significantly different for the visually impaired compared to the sighted or blindfolded sighted. In other words, the null hypothesis that there is no difference in the ability to recognize sounds between sighted and visually impaired was rejected. This shows that the people with visual impairments had a better ability to discriminate and localize sounds in verbal and representational sounds than sighted people and blindfolded people. In the case of Type β, there was no significant difference in either the identification rate or the recognition rate.
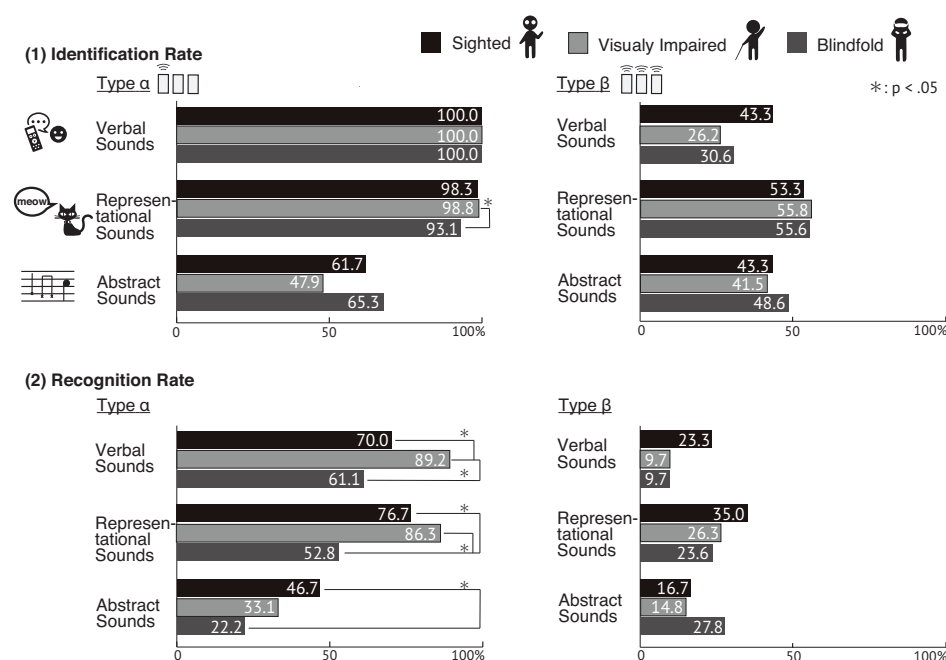

Figure 7. Differences in performance by degree of visual impairment.

Figure 8 shows differences in experimental performance according to the audio type. In this analysis, a Tukey HSD test was conducted to examine the significance of the differences ($p < 0.05$). In the case of Type α, the abstract sounds were significantly different from the other two audio types for all participants in both the identification rate and the recognition rate. In other words, the null hypothesis that the effect of the abstract sound on the identification/recognition rate of the player is not different from that of the other two types of sound was rejected. This suggests that verbal and representational sounds were effective in this system in presenting the content and location of the audible cards for all experimental participants. In the case of Type β, there was no significant difference in either identification rate or recognition rate. As a general tendency, representational sounds tended to obtain higher identification and recognition rates. In addition, we obtained the opinion from the participants that "Verbal sounds were mixed up and became unintelligible when they were emitted at the same time". These results suggest that it may be inappropriate to use verbal sounds in Type β.
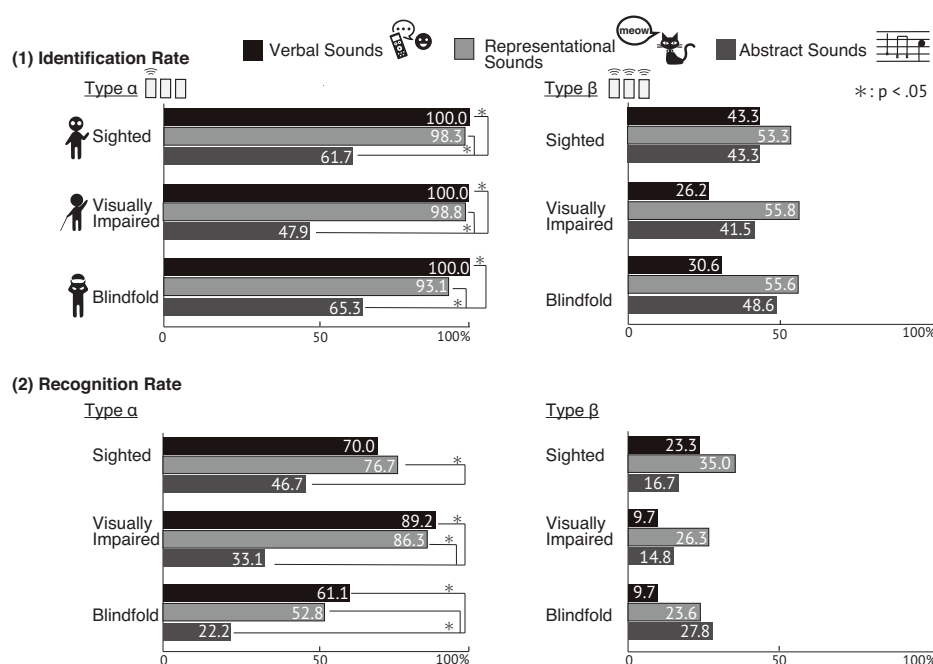
Figure 8. Differences in performance by audio types.

Figure 9 shows the differences in experimental performance according to the style of sound playback. In this analysis, Welch's *t*-test was conducted to examine the significance of the differences ($p < 0.05$). Type β has the advantage that players can obtain the information of multiple audible card at once compared with Type α. There was a significant difference for all participants in both the identification rate and the recognition rate compared to Type α. In other words, the null hypothesis that there is no difference in the effect of the style of sound playback on the player's identification/recognition rate was rejected. This suggests that Type β is not effective for accurately recognizing multiple audible cards.
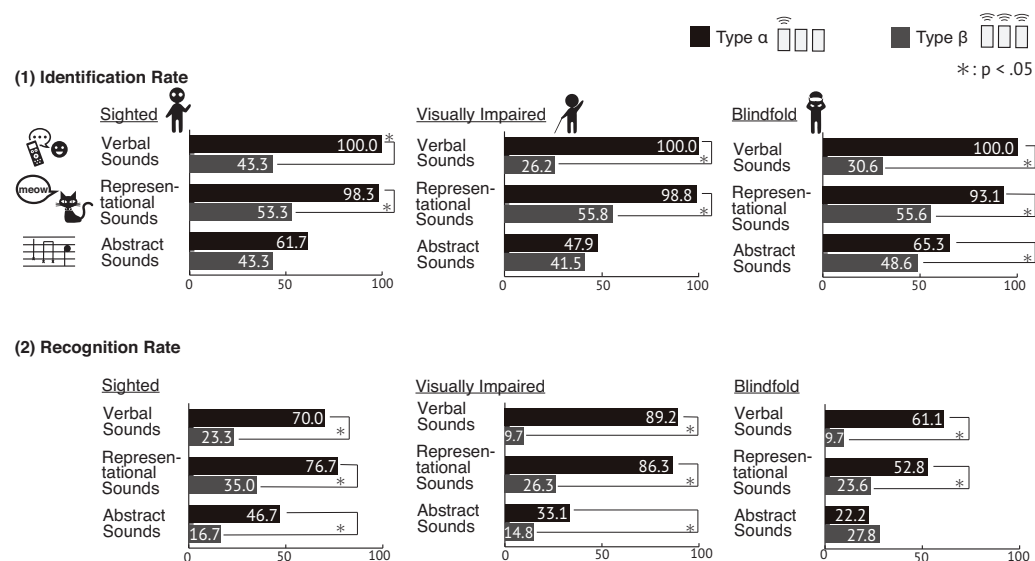
Figure 9. Differences in performance by the style of sound playback.

5.5. General Discussion

This experiment was conducted to clarify the effect of each valuable parameter of the proposed system on the player's game performance. We prepared parameters for three

types of degree of visual impairment, three audio types, and two types of the style of sound playback.

Comparing the experimental results according to the difference in the degree of visual impairment showed that the people with visual impairments had a better sound discrimination and localization ability than the sighted people. In addition, a better sound discrimination and localization ability of people with visual impairments has been mentioned in previous studies [43,44]. Therefore, people with visual impairments were able to recognize the audible cards as well as or better than the sighted people. In other words, we found that sound presentation was effective as a solution for presenting public information indicated by components in board games.

Comparing the experimental results according to audio types, the results showed that representational and verbal sounds enabled players to accurately recognize the information indicated by the components. Although the verbal sounds were able to convey the information correctly to all the participants in the experiment, one participant commented that the verbal sounds prompt confusion when they are produced simultaneously. In addition, the fact that verbal sounds are easily masked by background noise has been mentioned in previous studies [45]. Thus, it is undesirable to use multiple verbal auditory stimuli in this system. Further, verbal sounds should not be used in board games where verbal communication is active, because players can miss the information indicated by the components. In other words, verbal sounds should only be used as audio feedback at times when verbal communication is not occurring, such as before and after a competition. As with the verbal sounds, the representational sounds were able to convey information correctly to all participants. This shows that representational sounds have a great potential to be used effectively in an auditory card game system. In addition, they are superior in terms of intuitiveness, learnability, memorability, and user preference according to previous work [45–47]. These advantages suggest that representational sound has the potential to make board games even more fun. Compared to verbal sounds, they are less likely to be masked by background speech [45], so they are more effective when presenting multiple sounds stimuli simultaneously. When representational sounds cannot fully express information, abstract sounds should be used. Since abstract sounds are not easily masked by background sounds as well as representational sounds [45], they can also be effective when multiple auditory stimuli are required. However, unlike representational sounds, abstract sounds are obviously limited in the size they can be learned. The experimental results obtained in this study also confirmed that abstract sounds can cause recognition errors. According to the experimental results, when abstract sounds were used as stimuli, the maximum number of audible cards correctly recognized by the participants was from about 5 to 8, regardless of the degree of visual impairment. Similarly, previous studies [41,48] have recommended limiting the set of abstract sounds to a maximum size of 5 to 8. For these reason, it is appropriate to keep the number of abstract sounds within the range of 5 to 8. We recommend the use of abstract sounds as feedback for player actions and changes in the game, rather than indicating component contents.

Comparing the experimental results according to the style of sound playback showed that using many cards at the same time has a negative impact on recognizing components. The number of audible cards that the participants could recognize correctly was about 3, even if the auditory stimuli were given at the same time. Therefore, it was suggested that the players could recognize the audible cards correctly if the number of these was about 3. However, verbal sounds are easily masked by background speeches, so representational/abstract sounds should be used when multiple audible cards are presented simultaneously.

Finally, in order to clarify what caused the errors of the participants, we investigated the error composition in the experiment. Errors consist of the following three types.

1.　Sound identification error: experimental participants misinterpreted the meaning of the audible card presented them.

2. Vertical localization error: experimental participants misplaced the audible card presented them in the vertical direction.
3. Horizontal localization error: experimental participants misplaced the audible card presented them in the horizontal direction.

Figure 10 shows the average number of errors per trial for the experimental participants. In this analysis, a Tukey HSD test was used to examine the significance differences ($p < 0.05$) in the number of errors between players. The null hypothesis is that there is no difference in the average number of errors between players.
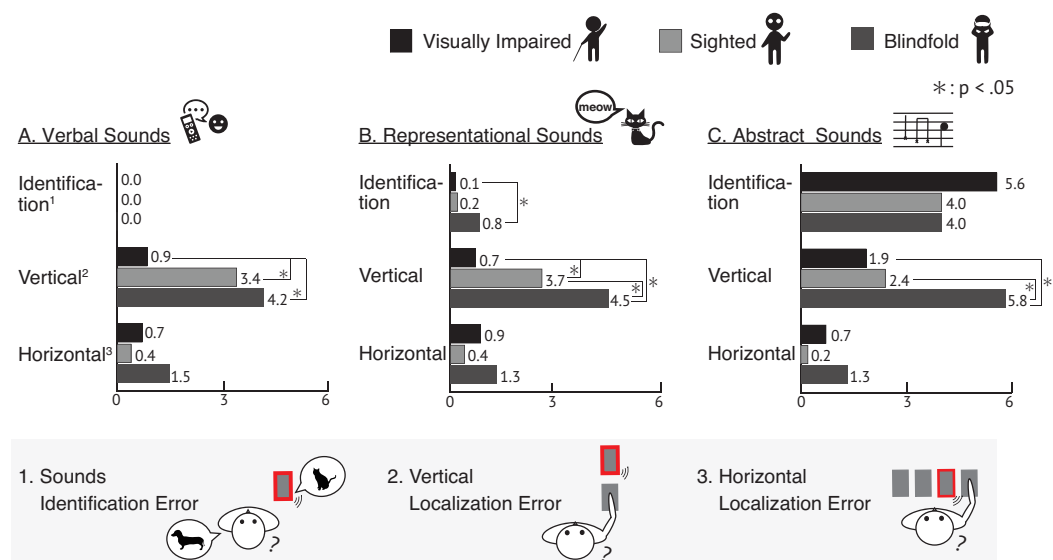

Figure 10. The average number of errors per trial for the experimental participants. There were three types of errors: sound identification errors, vertical localization errors, and horizontal localization errors.

Sound identification errors were generally not significantly different regardless of the audio type. However, there was a significant difference between the visually impaired and the blindfolded in the representational sound. This suggests that the presence/absence of visual information can have an effect on the sound discrimination itself.

The number of vertical localization errors for the visually impaired was significantly lower in verbal and representational sounds than for the sighted. The reason for this result is considered to be that the speaker of the iPod touch is located at the bottom of the device. It was predicted that the sighted people were influenced by the visual information and mistook each device for the lower device. However, the number of errors for the visually impaired was significantly lower than that for the blindfolded participants, who were excluded from visual information. In other words, people with visual impairments showed a higher vertical directional resolution than the sighted people. Ohuchi [43] and Voss [44] concluded that people with visual impairments tend to have higher horizontal directional resolution and distance resolution than sighted people. Therefore, the results of the high vertical resolution of the visually impaired in this experiment can be attributed to their high distance resolution. However, in the vertical localization of abstract sounds, people with visual impairments did not show a significant difference in the number of errors compared to the sighted people. Therefore, the results suggest that people with visual impairments can have difficulty with the source vertical localization of abstract sounds compared to verbal and representational sounds. In other words, the use of abstract sounds in the proposed system can interfere with the high vertical resolution of people with visual impairments. As a result, it is not desirable to use abstract sounds in situations where we want to ensure the vertical directional resolution of visually impaired people, such as when we want to accurately convey the position of a component. However, abstract sounds have

the advantage of being freely designable, so reflecting the component's position in the rhythm, pitch, and timbre of the sound could make it easier to locate the component.

Horizontal localization errors did not differ significantly among participants, regardless of the audio type. Horizontal localization seems to be easier for all subjects because it reduces misrecognition of sighted participants due to the position of the speaker and increases auditory cues such as interaural level difference and interaural time difference. Therefore, if the component's position is to be shared by all players, it is recommended that the components be aligned as horizontally as possible. Furthermore, it is possible to control the placement of the cards to give an advantage to people with visual impairments.

To allow for more flexible board game design, it is also possible to include visual information on the audible cards. At this time, it is easy to assume that visual stimuli affect the recognition of components to sighted people. In fact, in previous studies [49], it has been concluded that the type of sound and its congruency with visual information can affect reaction time. Therefore, it is possible to induce confusion by providing visual content that differs from auditory content to sighted people.

5.6. Expandability

The components used in board games are responsible for presenting public/private information to the players. The auditory card game system proposed in this paper is a means of presenting public information to players. The previous solution was tactile presentation methods, such as adding Braille and textures to game components. The situation where the proposed method is superior to the tactile presentation method is considered to be when the components of the board game present public information to the player. The public information is presented to all players continuously, and its content changes as the game progresses. Therefore, as the game progresses, the players need to touch each and every game component to obtain public information. This behavior of the players can cause the game to lose its fun and gameplay. On the other hand, the proposed method enables the player to progress the game without touching the components of the board games. Therefore, this system can provide positive impact to a style of board game similar to that of *Uta-Karuta*, in which a small amount of public information is presented by appropriately controlling parameters, such as the placement of components and the type of sound to be presented. For example, "Concentration" [50] and "Spot it!" [51] are considered to be suitable games for auditory card game systems because they are simple games consisting of only a small amount of public information. Furthermore, the proposed method has the advantage of promoting intuitive understanding by using representational sounds. The typical cards used in the *Uta-Karuta* contain poems on themes such as love and nature. In other words, *Uta-Karuta* is not only a memorization game, but also an emotional fun game. In order to keep the original fun of the *Uta-Karuta* as much as possible, it will be important for players to be able to intuitively understand the components when they get information about them. Thus, games such as "Cobra Paw" [52], which is a speed game, can be considered in order to improve accessibility while maintaining the immersiveness of the game.

As described above, the auditory card game system is preferably used for presenting small amounts of public information, but it can also be used when private information is included. The solution is to wear devices such as earphones or headphones. However, a board game that includes private information requires more strategy than a game that consists only of public information. In this case, communication, such as conversations between players, is necessary, and using earphones or headphones may interfere with such communication. Therefore, it is possible to apply auditory card game systems in board games that include private information, but it may impair the enjoyment and elements of the game.

When an auditory card game system is applied to a board game with a large amount of information, the disadvantage is that it is necessary to play the sounds used in the game in order, as shown in our results, and it takes time to present all the information to the

players. Although it is not impossible to apply an auditory card game system when there is a large amount of information, such as by orally explaining the movements over squares when playing a chess game without a board or pieces, it is feared that intuitiveness may be impaired.

Therefore, in order for auditory card game systems to play a role in improving accessibility while effectively guaranteeing the enjoyment of a game, we believe that games should use small amounts of public information and be played in fast-paced situations that require intuition.

6. Conclusions

We proposed an auditory card game system that presents the card's contents by sound, towards playing equally with others, regardless of whether they have a visual impairment or not. This is one of the solutions that presents public information of board games. Although this proposal cannot improve the accessibility of all board games, it contributes to expand the range of inclusive board games for the visually impaired. Furthermore, clarifying the impact of element of the system to the players will greatly assist in designing an appropriate board game using the proposed system. The purpose of this paper is to determine whether the game allows for fair competition for people with visual impairments and to clarify the effects of the valuable parameters of the system on the players. In the system evaluation, we developed "Auditory *Uta-Karuta*" and verified the usefulness of this system by having the game played by visually impaired people, sighted people, and sighted people with a blindfold. The purpose of this experiment is to test the applicability of auditory card game system to board games. We found that "Auditory *Uta-Karuta*" has the potential to be played by all players, regardless of whether they have a visual impairment or not. The following experiment was conducted to measure the effect of the design of the audio cue on the player in the proposed system, and several major considerations were obtained.

1. Abstract sounds can adversely affect sound localization abilities and should not be used where component location sharing is required.
2. In order for all players to correctly recognize the position of the components, audible cards should be aligned horizontally.
3. It is preferable that the sounds stimuli used in the audible card be composed of representational sounds as much as possible.
4. When using abstract sounds, it is recommended to limit the number of auditory stimuli from about 5 to 8 in order to reduce recognition error.
5. It is effective to sound the audible cards one by one so that players can accurately recognize the location and information of multiple audible cards.
6. When presenting multiple audible cards at the same time, it should be limited to about three cards, and no verbal sound should be used in this case.

These results show that it is necessary to design audio cues appropriately due to the characteristic of public information indicated by the components in order to make the auditory card game system effective. In particular, for a board game that requires accurate information presentation for players, such as *Uta-Karuta*, it is considered that playing representational sounds one by one is effective. However, in Section 4, despite the game design described above, the sighted players had an advantage, so it would be effective to adopt a vertical layout that gives an advantage to the visually impaired.

As described above, the results of the experiments in Section 5 can be used to create an appropriate board game design that allows players with different visual states to achieve the same level of game performance. However, the enjoyment of a game depends not only on the winning rate, but also on factors such as strategy and communication. Therefore, further experiments will be needed to construct a board game that is fun for players regardless of whether they have visually impaired or not, with a view to the qualitative factors that may influence the enjoyment of the game. In addition, as mentioned in Section 5.6, the results of this study can even be used for games in which private information is used, and we will

consider applying them to the case of games that include private information in future research. Furthermore, in order to reduce the cost and broaden the range of board games that can be supported, it is necessary to consider not only the iPod touch, but also many other component shapes and types.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by Ethics Review Committee of the University of Faculty of Engineering, Information and Systems, University of Tsukuba (2019R314, 24 May 2019).

Informed Consent Statement: Informed consent was obtained from all participants in the study.

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