Supplemental Sonification of a Bingo Game

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ABSTRACT
Visual cues are typically used in video games to indicate to the player what input to provide and when. Cues represented in multiple modalities that are presented simultaneously can be detected at lower thresholds, faster and more accurately than when presented separately in each modality. This characteristic has not been explored in playing video games to reduce errors. This paper explores the use of supplemental audio feedback to reduce errors in playing Bingo, a game which is typically played in crowded and noisy environments by a demographic, which -due to their age- are more likely to suffer from sensory impairments such as low vision or hearing impairments. A user study explored three different types of sonification (pitch, timbre, and audio icons) versus using no sonification and found that supplemental sonification using timbre or audio icons significantly reduces player's errors.

Keywords
Sonification, Multimodal Feedback, Games.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Auditory Feedback

General Terms
Human Factors, Performance.

1. INTRODUCTION
Video games rely primarily on visual feedback to indicate to the player what input to provide and when [29]. Though games may provide sound and haptic feedback these are typically used to indicate the result of a particular player action or are part of game, such as music and they rarely contain cues that the player must interpret as to decide what input to provide. Lack of sight is therefore considered a greater barrier to playing a game than playing without audio or haptic feedback.

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Figure 1: An Electronic Dauber for playing Bingo.

Sonification (also known as auditory display) is the process of displaying data in an audio format (other than traditional speech) [7]. Sonification may use changes in pitch, volume, timbre, patterns or frequency to represent data. A Geiger counter is a well-known example that uses the frequency of audible clicks to indicate the level of radiation. Sonification has been pioneered in sensory substitution [5] to communicate information to users who are visually impaired [16, 26]. Although sonification is still considered in its infancy, it has become an emerging modality of information representation for able-bodied users. Various studies with users performing choice response tasks (e.g. providing a particular input based on a certain stimulus) have shown that a stimulus represented in multiple modalities simultaneously can be detected at lower thresholds, faster and more accurately than when information is provided separately in each modality [14, 18]. This characteristic has been recently explored in the domain of complex data representation and interpretation where studies found that supplemental sonification, e.g., in addition to visual representation is beneficial [22, 25].

Sonification has only been sparsely explored in the domain of video games. Supplemental sonification of cues that indicate to the player what input to provide and when could reduce errors in playing games. In this paper we explore supplemental sonification in playing electronic Bingo. This paper is organized as follows. Section 2 provides background and Section 3 discusses related work. Section 4 discusses the design of a simulator used in user studies that are discussed in Section 5. Section 6 and 7 discuss the results and future work and the paper is concluded in Section 8.

2. BACKGROUND

Bingo is a game of chance, where players compete against one another for a prize. A player receives one or more preprinted cards that contain 24 numbers (one of the squares is usually designated the "free space" and is not a number) arranged in a 5 x 5 matrix. The player must match his or her cards to the numbers randomly drawn for the game. If the drawn numbers match a particular pattern on the player's card the player calls out the word "Bingo!", to alert other players of a possible win. Typical patterns include a horizontal, vertical or diagonal line, though there are many other patterns including requiring all the numbers to be matched up to cover the entire card. Single games often have multiple Bingos; for example, the players first play for a single line; after that, play goes on until a full card is covered. All wins are checked for accuracy before the win is officially confirmed and a new game is begun. The game mechanisms of Bingo have been used in educational settings to teach math [9] or biochemistry [28].

Players typically play with multiple cards to increase their chances of winning. To mark cards faster the players usually use special markers called daubers. Cards used for playing Bingo are typically printed on paper but increasingly electronic versions of Bingo are played on portable devices called an electronic dauber (see Figure 1), which allows for increasing the number of cards that the player can play with to near unlimited. In some jurisdictions regulations call for players to insert the called number into the electronic dauber upon which all cards will be marked, whereas other jurisdictions allow automatic play. The electronic dauber shows a limited number of cards that are closest to achieving a Bingo and the electronic dauber will identify the winning pattern and show "Bingo" on the screen, but the player is still required to call the Bingo to stop the game.

Bingo can be traced back, in some form or another, to Italy in the 1500s when it was played as lottery game [24]. In the United States, Bingo is mostly played as a charitable game and it is usually the domain of churches, youth organizations, and other non-profits. Bingo is also played for profit by casinos and Native American Bingo halls. Despite its mostly charity status, Bingo is big business. The National Association of Fundraising Ticket Manufacturers reports that in 2009 over 1.8 billion dollars was spent on charitable Bingo in the United States [11], which dwarfs any current AAA video game title. Although Bingo is often assumed to be a game that is only played by "little old ladies", recent studies show the stereotype of the average Bingo player has been steadily changing. It is true that the majority of players are female (57%), but only 11% are age 65 or above [2]. In the UK, the proportion of players under 45 years of age has increased from 46 percent to 62 percent in the last decade [3] where players aged 18 to 24 currently make up 20% of the Bingo demographic. This growth is primarily attributed to the emergence of online Bingo, which currently makes up 20% of the UK market.

Playing video games can be considered to be a form of performing choice response tasks [29], which are perceptual-motor tasks that are typically used in psychology in user studies to study the content, duration, and temporal sequencing of cognitive operations. When playing a video game the player provides input based on the feedback the game provides, upon which the game may generate new feedback based on the players input, which may elicit new responses from the player. For example, in a first person shooter an approaching enemy elicits a particular response from the player, such as shooting or fleeing.

The mechanics of Bingo represent a simple choice response task in a gaming context. This task consists of the player marking the called number if it exists on the player's card and calling a Bingo if that card matches a particular pattern. It is interesting to study the effectiveness of supplemental sonification in a game context as this adds time pressure and competition, which is different from the contexts in which sonification has been studied in the past. Supplemental sonification of how close a player is to achieving a Bingo may be useful in playing Bingo to avoid a "sleeper", which occurs when the player does not realize he or she has a winning card. This occurs occasionally because: (1) Bingo halls and casinos can be noisy environments where it can be hard to follow the game; (2) due to their specific demographic, players are more likelier to suffer from sensory impairments such as low vision or hearing impairments; and (3) players play the game using a large number of cards which make it more difficult to identify a winning pattern. There have been several studies to determine the best methods and techniques for representing information using audio for different types of applications. Some methods include using pitch, volume, tempo, timbre, auditory icons [13], i.e, abstract sounds used in operating systems to alert the user, and earcons [8], e.g., structured sounds that follow musical conventions. Many video games use real life sounds (explosions, footsteps) as audio cues but this is not considered sonification (nor is speech).

3. RELATED WORK

Sonification has primarily been explored in sensory substitution for creating audiogames that can be played by players with visual impairments. An extensive overview of audiogames can be found in Yuan [29]. Most audiogames use audio cues, but the following games use sonification. The puzzle game the towers of Hanoi has been sonified [20] where timbre, pitch and frequency of a pulse signal are used to individuate the size and location of the discs. A sonified version of the boardgame Go [23] exists where timbre is used to indicate black and white stones and pitch indicates their distance with respect to the center of the board. Speed Sonic Across the Span [21] is a platform game where objects, such as a platform or animals, emanate different audio cues and changes in pitch and frequency are used to convey the distance and height of these objects. Metris [15] is a musical version of Tetris where pitch, frequency and length of an audio cue are used to indicate the type and orientation of the different puzzle pieces. Finger Dance [17] is a dance game that is played using fingers and a keyboard where different audioIcons indicate what input to provide. AudioQuake [4] is an FPS that uses earcons [8] to alert the player to an object or event. We identified only one game that uses supplemental sonification. Terraformers [27] is an FPS that can be played by players with visual impairments as well as able-bodied players. Terraformers uses an audio compass using pitch and a sonar like mechanism is used to for conveying how far objects are in front of the character.

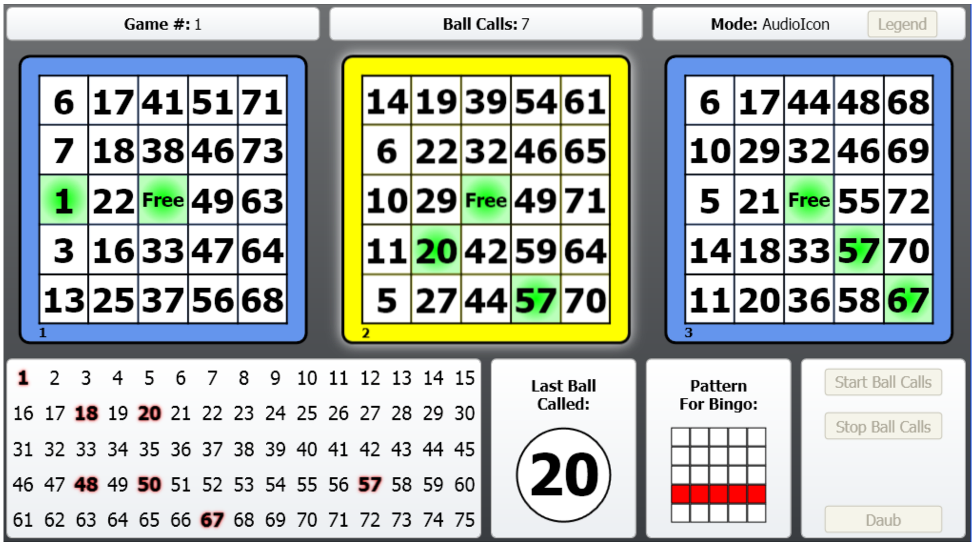

Figure 2: Screenshot of the Bingo Simulator. Away count for the middle card has changed and is sonified.

4. BINGO SIMULATOR

To evaluate what type of sonification works best for playing Bingo we developed a simulator application that can simulate a standard Bingo game. This application is a Windows program written in C# using Microsoft's .NET Framework and Windows Presentation Foundation technologies.

In the simulator, each player gets three cards with randomly generated numbers in each square (see Figure 2). The use of three cards is motivated though most electronic daubers can support a large number of cards, only a small number of cards is usually displayed on the screen those that are closest to a Bingo. Though electronic daubers can render up to 24 cards simultaneously, players most commonly play with three cards (See Figure 1). The pattern needed to achieve Bingo is a straight line either with all called numbers in a row, column or diagonal. When the player presses the "Start Ball Calls" button the application will start drawing random numbers from 1 to 75 every six seconds and display them in a grid below the cards. Six seconds is a common interval to allow paper players enough time to daub their cards. The last ball called and sample patterns are displayed next to the grid. To mark a called number on his or her card, the player must type that number with the keyboard and press enter or click the "Daub" button. Each card will then be daubed in sequence from left to right and a green background will be rendered behind the daubed number (see Figure 3). If the user gets five daubs in a straight line, they win and the game restarts.

4.1 Sonification Strategies

In Bingo, the number of daubs needed to achieve a Bingo is known as the *away count*, e.g., if the player requires two daubs to make a five number straight line, then the player's away count is two and hence for straight line patterns on a 5x5 card the away count varies between 1 and 4. We seek to sonify the away count for each card. Although sonification is generally useful for enhancing program usage, there are some potential pitfalls that could cause problems. This is more likely to occur when sonifying multiple variables and mapping them into one audio stream. Neuhoff, Kramer, and Weyand [19] performed a study to investigate the interaction between pitch and volume sonification methods. They showed that pitch and volume interact to mask the actual data being sonified. Specifically, rising intensity sounds were perceived to change more than equivalent falling intensity sounds. In our study we will avoid this problem because we will sequentially sonify variables using one type of sonification at a time using the "Ears-Lead-Eyes" [6] sonification design pattern.

Sonification solutions have been cataloged using a technique known as *design patterns*, which is a concept that has been pioneered in describing object oriented design solutions [12], but patterns collections for other domains exist, such as interaction design for video games [10]. The Ears-Lead-Eyes design pattern involves designing a sonification solution for when users need to be notified of intermittent, but critical, information while they are busy with another task using their eyes. This is helpful because it reduces the need to keep switching visual attention between different areas in an application or keep the user from potentially missing important information. For our study we explore the following three types of sonification:

- **Pitch:** an audio cue is played at different pitches (99Hz, 119Hz, 156Hz and 193Hz) to represent the away count. A lower frequency indicates a low away count.
- **Timbre:** a different instrument plays a middle C note to represent a certain away count. The instruments used were a piano, cello, organ, and pan flute.
- **Audio Icons:** one of four completely different audio cues is played to represent a certain away count. We used the following audio icons, a dog barking, a jackhammer, a cash register bell ring and an audience clapping. The cash register and audience clapping were used for low away counts to signal that a Bingo was close to happening.

Volume was also considered but previous sonification studies found [25, 30] volume to be inferior to pitch and timbre. Sonification types such as increasing the frequency between audio cues are not applicable since we use discrete sonification, e.g. we briefly play one sound to convey the value of the variable as opposed to a continuous representation.

All sounds were selected from open source sound libraries and pitch shifts of were created using Audacity [1] audio software where pitch was iteratively increased with approximately 150% for each cue. For both timbre and audio icons we selected instruments and audio icons that sounded asa different as possible from each other. Figure 4 shows the respective spectrograms for the used audio Icons that reveals their differences. All sounds had a length of approximately 1 second.

Each time a number is daubed on the player's cards, the away count may change. We only sonify changes in the away count rather than the current value for the away count for each card as this could potentially overwhelm the player with audio feedback, which may be detrimental to the their gameplay experience. If a card's away count is changed, the sound corresponding to that away count is played while the card is highlighted. Figure 2 shows that the away count for the middle card changes and that this card is highlighted while sonified. In the case all away counts for all cards change the sounds are played back to back in the six-second interval between ball calls.

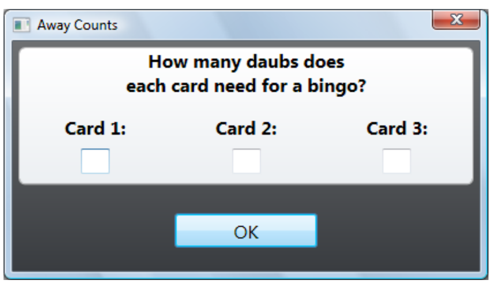

Figure 3: Away count test for each card.

4.2 Measures

While playing a game, players are randomly tested. The game is paused and a screen that blocks the view on the cards pops up upon which the player is asked to provide the away count on each of their cards (see Figure 3). Players type in the away count using the keyboard.

The idea behind testing for away count is that although our hypothesis is that sonification may help avoid a sleeper, it is difficult to test for a sleeper as that can only be observed over a large number of games. However, it can be assumed that the more aware the player is of the current away count for each card, the less likely a sleeper will occur.

After the player is tested on each method the application ends and the results are recorded to a log file. We record for each game (using one unique type of sonification): (1) total playing time; (2) number of away count prompts; (3) time it took the player to answer the away count prompts; (4) away count; and (5) player provided away count for each card.

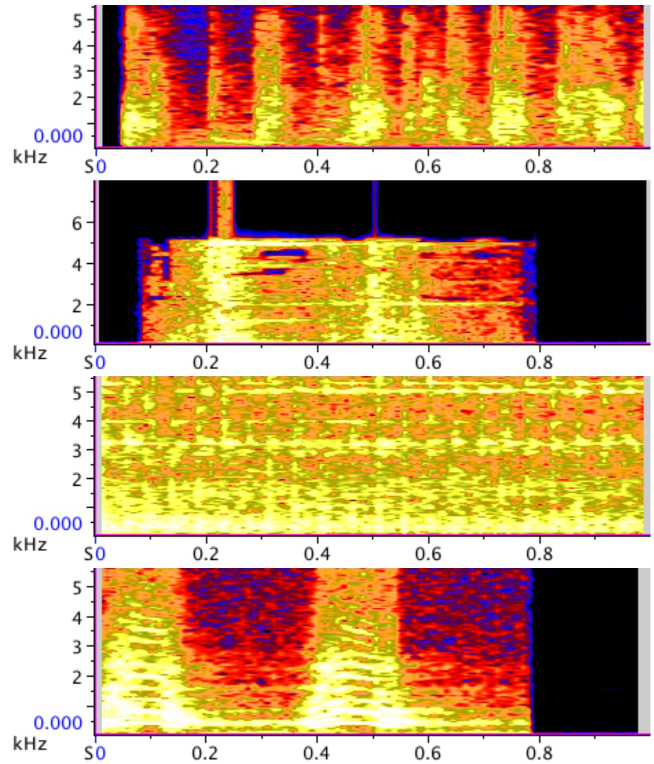

Figure 4: Spectrograms for the four audio icons.

5. USER STUDY

The Bingo Simulator application was evaluated with nine adult volunteers (2 female, age M=41.2 SD=12.8). Subjects were recruited from a local gaming company that specializes in developing Bingo systems, and as such all subjects could considered to be expert Bingo players. All subjects were in good health, with no hearing or vision impairments (some had corrected vision) that could possibly impede their ability to play the game. Each user was given a brief explanation and walk-through of the application, a demonstration of the different sounds and subjects were able to play a number of games using different sonification techniques.

Subjects were tested alone in a room using a laptop. There were no other background noises and the laptop's built-in speakers (4Ω, 2 Watt, stereo) were used for sonification, which was motivated by that electronic daubers systems often have similar speakers. The effectiveness of the three different types of sonification (pitch, timbre, audio icons) as well as using no sonification was evaluated using a within-subjects design. The users played through four games, each using one of the four sonification methods, in random order. The game would end if the user achieved a Bingo or was tested a total of four times, which ever came first. On average it takes 24 ball calls to achieve a Bingo and we assigned the random test as such that there were on average 6 ball calls between each test.

After the test, the subjects filled in a brief questionnaire where they were asked which sonification method they felt helped them the most in determining the cards' away counts.

Table 1: Results of Bingo simulation.

Type	Error	σ	Time (ms)	σ (ms)
NONE	0.241	0.19	16,554	22,677
PITCH	0.105	0.14	9,879	5,672
TIMBRE	0.074	0.11	9,149	8,510
AUDIOICON	0.059	0.06	6,954	1,815

6. RESULTS

Performance data were gathered from the logs and Table 1 lists the results from our study. Our analysis focuses on two variables: (1) error rate (second column) which is the ratio between incorrect answered away counts and total away counts; and (2) time to complete away count prompts (fourth column). The third and the fifth column list the found standard deviations.

For all tests, α was set at 0.05. When using an ANOVA with repeated measures with a Greenhouse-Geisser correction, the mean errors were statistically significantly different ($\boldsymbol{F}_{1.574,24} = 4.67$ $p < 0.05$). Post-hoc tests revealed that using no sonification yields a significantly larger number of errors than timbre ($p = 0.047$) and audio icons ($p = 0.034$) but no significant difference was found between pitch and using no sonification ($p = 0.085$). No significant difference was found between timbre and audio icons ($p = 0.521$). Due to our small sample size no corrections were applied. Using the same ANOVA, the mean values for time were not found to be statistically significantly different ($\boldsymbol{F}_{1.049,24} = 1.036$ $p > 0.05$).

Results from the questionnaire revealed that all subjects felt sonification in general helped them play Bingo. The majority of the participants preferred audio icons; but two preferred the use of pitch; one user preferred timbre; and one user preferred both timbre as well as pitch.

7. DISCUSSION AND FUTURE WORK

The results of our user study show that supplemental sonification of visual information increases performance in performing choice response tasks that rely upon interpreting this visual information. Our findings could potentially affect other types of games. For example, puzzle games like Bejeweled or Drop 7 often use visual indicators, such as a progress bar that indicates how far the player is in the current level before the player will go to the next. Such values could be sonified using the ears leads eyes patterns and discrete audio icons could be used to indicate different levels, which could make the player more alert of an upcoming level transition and which may increase player's performance.

Sonification can already be facilitated on most electronic daubers. Though in some jurisdictions no sounds may be played while playing Bingo, many electronic daubers have a headphone jack where sonification could be facilitated using a headset, which would allow the player to hear the sonification but would also leave one ear free for listening to the called numbers.

Using audio icons and timbre gave the best results. The semiotics of what audio icon to use for representing what value could significantly affect performance and error. For example, we used the cash register bell and applause for low values of the away count, sounds which the player is more likely to associate with winning. Had we used different sounds, maybe players would not have made these associations and different performances may be observed.

Bingo is typically played in crowded and potentially noisy environments and the demographic that plays bingo is more likely to suffer from sensory impairments. Though multimodal representation using supplemental sonification can be useful in these contexts, audio feedback may not be the best modality to use for multimodal representation. Newest electronic daubers also allow for providing vibrotactile feedback as they contain one or more vibrotactors. Future research will focus on exploring the effectiveness of sonification versus haptification using vibrotactile feedback.

8. CONCLUSION

In this paper we explore the supplemental sonification of information required to play the game of Bingo. Bingo halls and casino environments are often crowded and potentially noisy and Bingo is typically played by players who -due to their age- are more likey to suffer from visual or hearing impairments. Supplemental sonification may be useful for Bingo to avoid players not realizing they have won. A user study with nine subjects assessed the performance of three different types of sonification (pitch, timbre, and audio icons) as well as using no sonification. Results show that sonification using timbre and audio icons significantly reduces player errors. Sonification could be used for other types of games such as puzzle games to reduce player errors.

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