Inducing Flow in Board Games Through Augmented Audio.

André Sousa, Eduardo Magalhães, João Jacob

Faculty of Engineering of the University of Porto
Rua Dr. Roberto Frias, s/n 4200-465 Porto
andre.gustavo.sousa@gmail.com

Abstract. Games provide high levels of enjoyment and fun through closed systems with concrete objectives. These characteristics enhance a state of concentration known as flow. Many modern board games provide good gaming experiences. However, it is possible to use various resources to further enhance the experience. This study proposes that augmented audio technology can be used to induce flow during a board game playthrough. For this purpose, a prototype was developed to be tested with the board game Rising Sun. The main concept behind this approach was to deliver to the players real time sonic feedback through an augmented sound environment mapped to in game actions, by triggering spatialized contextual sound events related to the user's in-game actions and game phases. A study was conducted using the aforementioned prototype to validate the proposal, and the results have shown that augmented audio may induce the state of flow.

Keywords: Board Games, Augmented Reality, Augmented Audio, Flow.

1. Introduction

The board game industry has boomed over the last decade, having an expected Compound Annual Growth Rate of 13% between 2021 and 2026, specially in France, Germany, and UK [1]. The major transformation in board game design began two decades ago with Catan, followed by other games with improved game design and aesthetics. The new generation of games was focused on exploring new mechanics, aimed at increasing the player's sense of agency, challenging them with problem-solving situations, and engaging them thoroughly in the game [2]. With the evolution of game design, certain games tried to merge technology with the analogue elements of a board game. The first game merging both was "Clue: The VCR Game" [3] in 1985. Recent examples include "Lord of the Rings: Journeys for Middle Earth" [4], "Descent: Legends of the Dark" [5], and "Return to the Dark Tower" [6].

The most common technology found in games is mobile apps, making the game being categorized as app-driven game. These allow to store and process game information such as player stats, game events, and audio narration [2]. In both cases, the player must change their focus and manually enter the information into the application to get the desired result, which may lead to disruption of the game experience. If the experience contains too many disruptive elements, it may be difficult

to make the flow state appear or maintain it, limiting the pleasure of the experience [7]. With various technologies on the market, there may be other solutions that merge with the game more seamlessly. They may also be able to provide the addition of virtual elements that may enhance the game, helping inducing flow state. In this work, we proposed a different approach by using augmented audio to enhance the game experience.

Board games tend to create social experiences due to the way they are designed to be played. It tends to be social experiences that create positive reinforcement and engagement with the game [2]. They can, however, be "uncompensated" in other layers such as feedback and sensory immersion. Two of the big areas that allow for extending the sensory realm are virtual reality and augmented reality. The purpose of VR is to transfer the player from a physical environment to a virtual environment, eliminating his connection with real elements. Its application involves the use of hardware equipment such as Oculus rift and closed-back headphones that alter the user's perception [8]. Video games have benefited from this technology that enhances the elimination of external elements. On the other hand, AR allows the incorporation of virtual elements into the real world, favouring social agents through collaboration and a shared space with which all participants can interact with [9].

AR can be seen as a potential technology to boost sensory feedback and immersion in board games. Although board game design has improved over the past two decades, audio remains an unexplored element in many board games. The branch of augmented reality that this study focuses on, is augmented audio. Augmented audio solutions have become available on the market through a few companies. These solutions apply to everyday life, cinema, and the automobile industry. Augmented audio proposes layering real-time generated audio assets within the physical acoustic environment, both sharing a common 360º degrees sonic space around the user [10].

This merge between board games and augmented audio is the focus of this paper. The aim is to analyse the impact of augmented audio on the flow state of players while they play a game. For this purpose, a prototype including a sound device and an application was developed to be used with the game "Rising Sun" [11]. The main concept behind it was to deliver to the payers' real time sonic feedback through an augmented sound environment mapped to in game actions.

1.1 Background

Traditionally, research related to analog games is usually about abstract classical games, such as chess, and role-playing games (RPGs). Nevertheless, there are some efforts such as Stewart Woods book "Eurogames: The Design, Culture, and Play of Modern European Board Games" and online communities proved to be a valuable resource for the study of Modern Board Games. Board games are recognized by many people as fully analog games, which can be played on a board or without a board. But there seems to be a rather widespread idea that board games are archaic, based mostly on mass-market and classic games [2]. However, one should observe that compared to video games, board games are centuries old. One of the oldest games to be documented is Senet, found in the third Egyptian dynasty in 2686 B.C. [12]. Over the centuries,

board games have introduced new mechanics and elements that video games have adopted and adapted, such as technology trees and critical hits [2].

Board games are divided into three main categories: classical, mass-market, and hobby games [2]. The definition of modern board games is set after the game Catan [13]. Their definition usually consists of games that incorporate a variety of game mechanics inspired by their antecedents: RPGs, collectible card games and German games, also known as "Eurogames". This combination of mechanics allowed the development newer game concepts and to correct many problems of old games like the elimination of players, which increases emotions like frustration and disinterest. Modern board games can contain mechanics that involve social interaction between players blurring the boundary between playing and social experience [2].

1.2 Board Game Characteristics

The various elements present in board games ranging from the components to the players, define a system. This system works based on their interaction. In the Järvinen framework, he defines three types of components. The systemic, compound and behavioural [14]. The systemic elements described by Järvinen are the components and the environment. On board games, there is the board, the cards, the meeples, and the tokens. Components are all the elements in a game that a player can manipulate or interact with. Components can be moved during the game by the player (component-of-self), by other players (components-of-others), or by the game system itself (components-of-system). Usually, the components contain or are associated with game information. These interactions allow the information to be updated [14]. The other type of elements in games and described by Järvinen are compound elements. In board games, they are the rule book, game mechanics, information, interface, and theme. According to Woods, these elements serve as a link for the systemic elements and the behavioural elements [2]. The last element is the behavioural element being constituted by the player and the context of the game. In the case of the player, the system affects his behaviour or interactions. The system presents options to the player which he will have to choose from. The context of the game involves the various social and cultural variables between the player and the game, which may generate a greater degree of affinity between the game and the player.

1.3 Flow

The theory of flow was developed by Csikszentmihalyi between 1975 to 2000 [7] when trying to understand why people pursue certain activities or desire to repeat them, also seen as autotelic activities (they maximize immediate, intrinsic rewards). Csikszentmihalyi interviewed different people about their activities, and all reported a similar subjective experience about the activities they enjoy. They described an intense concentration and involvement in the activity which caused them to forget about external and internal stimuli like time, fatigue, and hunger.

In the same theory, Csikszentmihalyi describes the sensation as: "The defining feature of flow is intense experiential involvement in a moment-to-moment activity.

Attention is fully invested in the task at hand, and the person functions at his or her fullest capacity". This intense involvement in the activity generates subjective characteristics that people commonly report like:

- Merging of action and awareness.
- The sense of control.
- Altered sense of time.
- Intense concentration.
- Loss of self-conscious.
- Experience the activity as intrinsic rewarding.

Although the state of flow can happen in any activity, some contain elements that enhance flow. Games, sports, reading, and others contain specific challenges that can be tackled with the right level of skill.

Cowley [15] summarizes why games provide an easier way to experience flow: "Games give immediate access to their inherent potential for optimal experience, and that potential is facilitated by the structured nature of further gameplay. Thus, there is a common correlation between simply completing computer games and getting "in the flow". The three flow inducing factors according to Csikszentmihalyi are [7]:

- Balance between perceived challenges and perceived skills.
- Clear set of goals.
- Clear and immediate feedback.

Gaming flow is a group of concepts and theories based on the original flow theory from Csikszentmihalyi. The theories of gaming flow are based on adapting the elements of flow to games and the consequences that can happen. Sweetser and Wyeth [16] conceptualized a model for evaluating flow in games called GameFlow. Enjoyment according to Sweetser and Wyeth, occurs when a person is fully engaged in the game losing their spatial and temporal awareness. When in a state of flow players play games without expecting any external reward like fame or money. The model contains eight characteristics adapted to games but based on the original flow theory, and it is not necessary for the game to contain all the elements to reach the flow state:

- The Game: is the task that can be completed.
- Concentration: is the ability to focus on the task.
- Challenge/Player skills: are the balance between perceived skills and challenges.
- Control: is the sense of controlling their actions minimizing their error.
- Clear goals: are the main goals that a task should have.
- Feedback: is clear and unambiguous feedback.
- Immersion: is the deep and effortless involvement, the merging of action and awareness.
- Social interaction: although does not belong to flow theory has an impact on games.

Games are made of multiple layers of stimulus that should be able to grab the player's concentration (sound, visual, tactile). To maintain concentration, games should avoid meaningless tasks. In games, it is very important that the challenges are balanced with the player's abilities. Challenges can increase gradually or must be adjustable to the level of the players. Dynamic Difficulty Adjustment defines a relationship between the skills and the challenges of the player during the game. This relationship makes it easier to keep players in the flow zone, which in turn will lead to player satisfaction with the games [17]. The development of the player's skills happens gradually and constantly by the amount of time the players devote to the games. It is, however, possible to enhance this development through tutorials and audio or visual feedback. When players are fully engaged with the game, they tend to have a sense of control, a meaning to their actions. The goals of the game are commonly established in the first minutes, but each level or mission should have specific goals. This is what gives the player a sense of direction in games [16].

Doing actions in games generate consequences and answers from the game system, for example, in a rhythm game the player receives constant and immediate feedback if he is staying on the rhythm or not. The game can use multiple cues to pass the necessary feedback on how the player is performing towards the objectives [16]. Sound and visuals can be used to deliver feedback to the player. In a fight scene, if the player gets damaged sound cues can be used to alert the player of the damage taken or as an identifier for the action taken.

Games demand the full attention of players, hence the need for absorbing them into the full experience. The challenges, if well balanced do not give space for external distractions. An emotional link with the game can happen, increasing immersion. If the game has content that resonates with the player like visuals, audio, and narrative, they can impact player's feelings or attachment for the game [18]. The social element covered in the GameFlow model does not correlate with any flow component. According to Sweetser and Wyeth, games should have the opportunity for players to interact. Playing against other players has been demonstrated to have positive impact on flow [18]. Social interaction can disrupt the virtual environment making players aware of their surroundings, but it proved to be a very strong element for game enjoyment [16]. In board games, the social element is one of the most important elements according to Woods [2].

1.4 Augmented Reality Principles

Augmented reality is presented as a method of interacting with and consuming virtual information in the real world. Unlike virtual reality, the goal is not to place the user in a completely virtual environment but to place virtual elements in the real world. As Schmalstieg and Hollerer claim, AR serves as an immediate and easy interface to access computer-generated information that is displayed over real objects. It emphasizes the interaction between computer and human, being able to amplify all human senses [8].

The definition of AR according to Azuma is [19]:

- The combination of real and virtual elements
- Interactivity
- 3D registration

Another important characteristic of AR is the establishment of local virtuality, where people use technology to communicate in space, allowing them to have a sense of transportation from the real world to an augmented one [9]. At its core, AR is considered a collaborative technology. Both AR and VR belong to the mixed reality continuum coined by Milgram and Kishino: "MR includes systems in which the virtual aspects are dominant as well as those in which the physical reality is dominant [20]. Within this range, augmented reality has more physical elements than virtual elements" [21].

2. Augmented Audio

Augmented Reality Audio (ARA) shares the same basic concept as augmented reality, populating reality with virtual elements. There are different approaches explaining how ARA works. Vasquez and Alverez [22] argue that ARA consists of a superimposed virtual soundscape in a real environment, while Tikander [10] affirms that ARA enhances the real environmental sound with virtual aural objects. In the first case, researchers like Mariette [23] have developed systems to create synthetic soundscapes to simulate the natural sound of the corresponding place according to the position of the user and the orientation of his head. In her research, she has focused on mobile devices capable of using binaural audio to completely replace the natural surround sound. The synthetic soundscape provides users with spatial information, allowing them to locate the objects that could trigger the sound. Her definition of these types of systems is "personal location sensitive-spatial audio".

Other research using the same approach of ARA has applied synthetic soundscapes to museum visits. EC(HO) is a project that conceptualizes a responsive and adaptive system for user localization, making constant predictions about the user's interactions in the museum. When the user is in front of a specific piece, sounds are triggered according to previous analyses on the user choices and the piece that is being observed [24].

Another project based on the same principle as EC(HO) is LISTEN, a wireless 3D hearing system that tracked participants in different areas of the museum. The participants listen to the dynamic ambiences, sound effects and speeches about the exhibition through headphones according to the route they take and the room they are in [25].

The second approach to ARA focuses on enhancing the sound of the natural environment with digital sounds instead of replacing it with synthetic sounds. Ramo and Valimaki describe the ARA system with the following purpose [26] "Augmented reality audio (ARA) combines virtual sound sources with the real sonic environment of the user. An ARA system can be realized with a headset containing binaural microphones. Ideally, the ARA headset should be acoustically transparent, that is, it should not cause audible modification to the surrounding sound.

A practical implementation of an ARA mixer requires a low-latency headphone reproduction system with additional equalization to compensate for the attenuation and the modified ear canal resonances caused by the headphones." Recent commercial

solutions have appeared on the market, launched by Sennheiser and by Bose. Both are based on the concept of enhancing the real-world sound environment.

The Ambeo Smart headset uses microphones on the headphones to deliver the pseudo-acoustics of the natural sound mixed with the digital content.

Possible applications for this technology include binaural telephony, binaural audio meetings, information services, object browsing, virtual tour guides, audio memos, contact management, audio-based games, and music creation [26].

2.1 Binaural Audio

Binaural audio is a recording and reproducing technique used to emulate the way humans perceive sound. It is reproduced in two channels, one corresponding to the left ear and the other to the right ear, providing spatial information about objects. To reproduce binaural audio, a pair of calibrated headphones using HRTF functions should be used. Binaural recordings are made using a dummy head with two microphones inside the ears. Recording using a dummy head alters the perception of sound due to the reflection and scattering with the dummy head and the shape of the ears, providing clues about the position of the sound sources.

The four common setups for binaural recording are as follows [27]:

- Microphones inserted in the ears of the human listeners.
- Microphones in the dummy head with torso, head, and ears.
- Microphones in the dummy head with head and ears.
- Microphones in the simulator with only ears.

Many VR and AR applications use binaural listening to create immersive audio ambiances for visual applications [28].

2.2 Head-Related Transfer Function

Humans can detect different sound characteristics such as timber, loudness, pitch, and spatial information. The head-related transfer function is a function that calculates how humans perceive sounds in their surroundings. When humans perceive sounds, they perceive direct, reflected, or scattered propagations of objects and of the anatomic human system (head, torso, and pinnae).

The way sound reaches the ears is what allows spatial information. Two important measures are made regarding sound, interaural time difference (ITD) and interaural level difference (ILD). ITD calculates the time difference between the moment a sound reaches the left ear and the right ear, enabling the brain to process the location of the sound. For example, if the sound source is placed on the left of the users, then the left ear will receive the direct sound and early reflections first than the right ear. ILD calculates the difference in sound level for each ear, and both the head and the torso act as an attenuator for sounds coming from different angles, making ILD also suitable for spatial information. In summary, to understand the position of a sound source it is necessary to know the sound level and the direction and distance to the listener's head [28].

As with binaural recording, HRTF measurements are made in the same way, using a dummy head with high-fidelity microphones in each ear. Binaural recordings are suited to reproduce statical spatial audio content. HRTF allows convolving a mono signal into binaural hearing. This is commonly used in AR and VR. Dynamic reproduction involves the use of computer vision techniques to reproduce content based on the user's movement and head direction.

One of the common problems with HRTF is that for precise reproduction of spatial audio content measurements must be specific to the person who will be listening. In general, spatial audio content uses average human measurements, which may present different results for different users [29].

2.3 Ambisonics

Surround techniques place audio sources in a 3D spectrum around the listener, sometimes depending on the number and position of speakers they can work with vertically. The best-known forms of surround technique are from Dolby, in the form of channel-based and, more recently, object-based techniques. To reproduce channel-based surround correctly a pre-established speaker array is required. The sound sources will be attributed to each channel according to the mixture.

Objected-base surround defines sounds as objects and, instead of attributing a sound to a specific channel, gives instructions on where to place the sound. This allows the use of different formats and numbers of speaker arrays. However, due to the multitude of objects, it is preferable to use larger speaker arrays [30].

Ambisonics was developed during the 1970s and its popularity increased during the last decade due to AR and VR applications. The concept of ambisonics is to create a sphere of sound that can be reproduced in any system, defined by the patterns of recording and reproduction. Ambisonics presents different formats, the A-Format is the recording pattern used in tetrahedral microphones each capsule records the audio signal from a specific direction. This format must then be encoded in B-Format, the standard ambisonics format. In ambisonics, orders mean the number of channels for recording and reproduction. The first order uses 4 channels, each one containing the audio from a specific coordinate [28]:

- W: omnidirectional having audio from all directions.
- X: representing the sound from front and back.
- Y: representing the sound from left and right.
- Z: representing the sound from up and down.

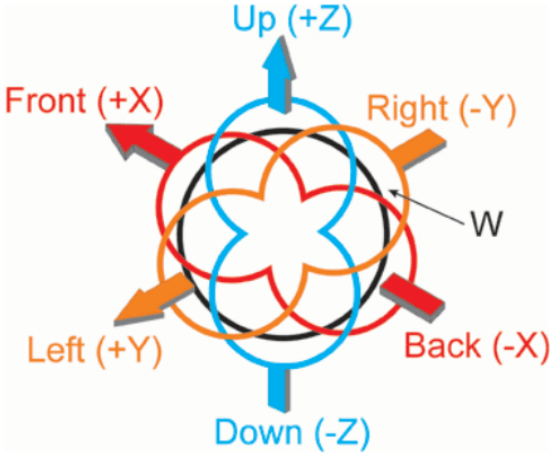

Fig. 1. B-Format

Each new ambisonics order increases the spatial resolution but also the number of audio channels and coordinates. For example, the third order ambisonics uses sixteenth channels. Other important aspects contained in ambisonics are the component order, (i.e., the order of each audio channel). The most common order by today's standards is ACN, although FUMA can still be used.

The last aspect to take into consideration is the normalization parameter that refers to the gain of each channel, the current most common use being SN3D. Ambix is a file format that contains the following parameters: B-Format ACN, SN3D [30].

Encoders can be used to transform mono and stereo signals into first-order or higher-order ambisonic signals. The contrary can also be done by using a decoder transforming an ambisonics file into stereo, binaural, surround channel-based, and others. The main advantage of ambisonics is to be able to reproduce 3D environments in different systems [28].

3. Game Experience

To understand whether it is possible to induce the state of flow in board games using an augmented audio system, it was necessary to develop a prototype to test this hypothesis. As demonstrated by Woods, board games, in addition to the various elements that make up the game system are also social experiences [2]. For this reason, the objective was to create a system that was able to maintain the natural characteristics of board games while avoiding any disruptions during the experience that could negatively affect the flow state of the players. Therefore, the system should be simple to interact with and be continuous, making it possible to work even if any detection problem occurs.

To induce flow during the game, two propositions were taken into consideration. The feedback of the player's actions and the thematic involvement that the sound can provide to the game's theme. For the hardware conceptualization, the choice was to develop the system according to the idea of enhancing the natural environment instead of synthesizing it. Initially, there was an attempt to contact Sennheiser asking permission to use their AMBEO SDK and Smart headset, but the final solution needed to be changed mostly due to the Covid global pandemic since it was not possible to get access to their equipment. Later, during the planning process, a new solution had to be found due to constraints caused by the global pandemic. The solution found remained true to the concept of enhancing the natural environment.

The final concept was to map the board with a webcam using augmented reality software to identify specific pieces and to use an ambisonics microphone to capture the environment. Finally, the middleware software used can generate and position the virtual aural elements in space. The choice of the game had to take several considerations into account, as it could affect the entire development process. The literature review suggests that modern board games contain elements that are better suited to keeping players interested in the game without generating disruption. Because of this, mass-market games were avoided. One of the important required elements was a game with player interaction, accessible in terms of complexity and easy to learn. For the detection of augmented reality, it was also important that the game contained features such as graphic art and components large enough to be easily recognized. From the games recommended in the top 100 of the "Board Game Geek" community, the game Rising Sun was chosen, a game published by CMON Limited in 2018.

3.1 Game Overview

The selected game Rising Sun is an area control game for three to five players and features negotiation, different paths to victory, variable player powers, and blind bidding. The theme of the game is a mythological feudal Japan. The premise of the game is that each player is a shogun (military title to describe a war general in feudal Japan) that controls a clan and wants to rebuild Japan. The game has four rounds which are known as seasons (Spring, Summer, Autumn, Winter). During each season seven actions are played, and each player needs to perform each action played. The actions in the game are Harvest, Betray, Marshall, Recruit, and Train. At the end of the game, the player with the most points wins. All the components of the game try to correlate with the theme which helped in the development of a cohesive soundscape.

3.2 Sound Design

It was important to investigate what sound design strategies could be used when applying ARA in board games. The first step was to analyze the game and understand which sounds would make sense to be played during gameplay. The areas taken into consideration were the following:

- The four rounds (seasons) of the game: Spring, Summer, Autumn, and Winter.
- The mythological monsters in the game.
- The political mandate actions.
- The era of feudal Japan.
- Japanese musical instruments.
- Japanese musical scales.

The ideas for the sounds needed to be able to fit well with the surrounding natural environment that the users would experience, using the ARA headphones. To fully combine the two layers of sounds the google resonance plug-in was used enabling binaural hearing and mixing the digital sounds with the environment.

Regarding the key ideas for the game, the first step was to choose which approach to take regarding the seasons and the political mandates. The seasons should be a constant presence during the game that changed every time the season track was full. For the political mandates, they should function as audio cues about the action played and should fade out after it finishes. For designing the sound for both the soundscapes and the political mandates research was conducted about traditional Japanese instruments and Japanese scales. In the end, four instruments were chosen although only three were used, the Koto a plucked string instrument, the Shamisen also a plucked string instrument, the Shakuhachi a wind instrument and the Taiko drums a percussion set of drums.

The instruments were assigned to different actions and soundscapes according to their sound. The Koto was assigned to the soundscapes, the Shamisen to the harvest mandate, Shakuhachi to the recruit mandate, and the Taiko drums to the Marshall mandate. The Japanese scales are commonly 5 notes with different intervals between them. The ones used were Akebono, Hirajoshi, Iwato, and Insen. Despite the use of musical instruments, music was avoided.

The soundscapes must take two important aspects into consideration, they should work as background thematic ambient without being too loud to interfere with the communication between players, and they should avoid repetition that could be detected by the players and create boredom or annoyance since the time can vary between seasons. The mandate tiles needed to play a short sound that represents the player action, however since these were played multiple times throughout the game, there were multiple variations of each sound in order to avoid repetition. Using FMOD is possible to randomize sounds and properties using the in-built different instruments. Four of the political mandates make all the players take the action, the betray mandate is the only one that benefits the player that played it. During the development, was tried to find a way to trigger the betray sound only to the other players but a way to do it was not found.

4. Prototype Architecture

The prototype pipeline consists of the game engine Unity, which analyses the visual inputs through the Vuforia API. Upon detection of a token (political mandate) placed

in the game area mapped, an instruction is sent to FMOD Studio to play the sound event corresponding to the mandate played using google resonance to spatialize it. Then Unity sends the output directly to the player's headphones. When all the seven spaces are filled, the game advances to the next season and the system makes a transition for the next soundscape. The microphone input is immediately detected and used as an input and output in Unity as soon as the program starts, allowing the players to communicate from the start.

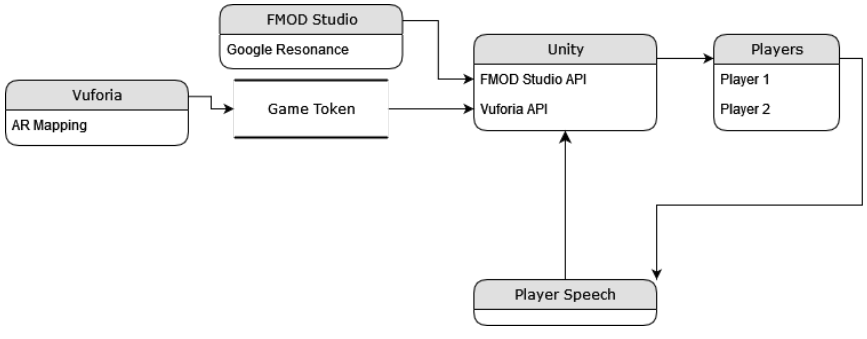

Fig. 2. Augmented Audio System Diagram

5. Validation

To evaluate the impact of the interaction between users and the augmented audio system, it was necessary to collect data that analyzes player emotions, concentration levels, and ease of use of the system. For this evaluation, it was necessary to have an element of comparison between the game with and without the augmented audio.

Each group of players would play the game twice, once with the audio turned up and once without. However, it was desirable to eliminate variables that could influence the groups' opinions due to the order in which they used the system, so each group had the order in which they used the system randomized. To collect the necessary data regarding the player's experiences, a questionnaire was made based on 2 models, the "game experience questionnaire" [31] and the "system usability questionnaire" [32]. In the first part of the questionnaire statements related to the state of flow, social influence, sensations and immersion, positive and negative emotions during and after the game and flow outcomes were analyzed.

The answers to the questionnaires were given using a Likert scale with 5 possibilities. For the game experience questionnaire, the answers range from "Not at all" to "Extremely". For the system usability questionnaire, the answers ranged from "Strongly Disagree" to "Strongly Agree". To achieve scientific relevance, quantitative analysis was planned on at least thirty participants. Contacts were made with different board game groups (Aveiro, Porto, Braga) and with the Quebra-Dados association. Participants were sent google forms where they could schedule the times they would participate. A video was also sent with an explanation of the rules, in order to avoid delays at the beginning of the experience. Since the experiments took place in the month

of August 2020, all hygienic precautions were taken regarding the Covid pandemic. Only one group of three people at a time was allowed and with defined schedules.

5.1 Experimental Design

The experiment had initially been designed for at least 30 participants with a similar number between men and women and would run for eight days. However, difficulties arose in getting this number of participants to participate due to the global pandemic. For the final tests, ten participants participated, nine men and one woman. To ensure safety, groups of two participants were made up, plus a researcher who could answer existing questions related to the game or the experiment. The experiment would take about 3 hours with the two game sessions.

At the end of each session, a questionnaire called A and B had to be filled out. All sessions were recorded with the consent of the participants for later analysis. The experiment ran in room i323 at FEUP and on August 9 had to be carried out in a private room of the "Quebra-Dados" association. During the enrollment process, participants were informed that they would have to play the Rising Sun game twice and that they would have to fill out a questionnaire at the end of each game. During the registration process, participants gave their email addresses and were sent a google form to schedule the date they wanted to participate and the time. A video explaining the rules was also sent to their emails. Additionally, any questions regarding the game rules were answered at the beginning of the tests. These two steps ensure that the players have a firm grasp on how to play Rising Sun, thus allowing for a smooth playthrough, avoiding any interruptions that could break the flow of the game.

Participants were also required to wear headphones throughout the experiment to analyze whether there were any negative impacts related to their use. All the equipment and the layout remained the same throughout the sessions. Although the game had variable decks and faction powers, the same decks were used throughout to avoid any changes that could compromise the results of the experiment. The participants could choose between two of the available clans (the Dragonfly and the Turtle clans) while the researcher always played with the Koi Clan. At the end of each game, the data was collected using the respective questionnaires, which were available for players to fill out on a computer.

Fig. 3. Players testing the prototype

The first part of the questionnaire had questions related to gender, education, time spent playing board games, and experience with AR. The second part of the questionnaire contained statements regarding flow, social interaction, sensory and imaginative immersion, in-game positive and negative feelings, post-game positive and negative feelings, as well as post-game flow outcomes. The last section of the questionnaire had some statements from the system usability questionnaire to evaluate the impact of the system on the user experience. Of the 10 participants, nine were men and one was a woman. Eight of the participants had higher education; one had secondary education, and one had basic education. Among the participants, six dedicated zero to two hours per week to playing board games, and four participants were between two to five. Related to experience with the game, six of them had little experience and four had some experience. The average experience with AR was very little to none.

6. Results

In this section the results of the user tests carried out with the participants will be presented, sorted by the various categories.

6.1 Flow Statements

In the questionnaire, there were six statements related to flow during the game. The questions referred to the level of absorption, concentration, the performance on the activity, elimination of external distractions, and distorted time perception.

When asked if they were completely occupied with the game in the control session, three participants answered “moderate”, four “fairly” and three “extremely”. In the augmented session, five participants responded “fairly” and the other five responded “extremely”.

Regarding concentration in the control session, three participants responded “moderate”, three “fairly” and four “extremely”. During the augmented session, five participants responded “fairly” and the other five “extremely”.

Concerning absorption, the participant’s responses showed that during the control session one responded “slightly”; three responded “moderate”, four “fairly”, and two “extremely”. In the augmented session, seven participants responded “fairly” and three “extremely”.

To evaluate external distractions, two statements were asked. In the first statement “I forget everything around me” six participants answered “moderate” and four “fairly”. In the augmented session, three of the participants answered “slightly”, one answered “moderate”, three “fairly”, and three “extremely”. The second statement aimed to assess whether the players had lost connection with the outside world, in the control session one participant answered, “not at all”, one “slightly”, three “moderate”, four “fairly”, and one “extremely”. In the augmented session, one answered “not at all”; another one answered “slightly”, four “moderate”, three “fairly”, and one “extremely”.

The last question related to flow in the game was regarding the distortion of time perception. The following statement was put to the participants: “I lost track of time”. In the control session, one participant responded “moderate”, seven “fairly” and two “extremely”. In the augmented session, three participants responded “moderate”, three “fairly”, and four “extremely”.

Table 1. Flow Statements Results

Statement: “I was deeply concentrated in the game.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	3	3	4
Augmented	0	0	0	5	5
Statement: “I was fully occupied with the game.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	3	4	3
Augmented	0	0	0	5	5
Statement: “I felt completely absorbed.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	1	3	4	2
Augmented	0	0	0	7	3

Statement: “I forget everything around me.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	6	4	0
Augmented	0	3	1	3	3
Statement: “I lost connection with the outside world.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	1	1	3	4	1
Augmented	1	1	4	3	1
Statement: “I lost track of time.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	1	7	2
Augmented	0	0	3	3	4

6.2 Social Statements

The social statements provided insight into how augmented audio could impact socialization between players or whether it could create communication problems. The first statement was intended to assess whether the participants felt connected to the other players even though they were using headphones.

Table 2. Social Statements Results

Statement: “I felt connected to others.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	2	6	2
Augmented	0	1	2	5	2
Statement: “I found it enjoyable to be with the other(s).”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	0	6	4
Augmented	0	0	0	4	6
Statement: “I was influenced by other players’ moods.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	2	1	4	1	2
Augmented	3	2	0	3	2

The following statement was put to the participants “I felt connected to others”. In the control session, two responded “moderate”, six responded “fairly”, and two “extremely”. In the augmented session, one of the participants responded “slightly”, two “moderate”, five “fairly”, and two “extremely”. The second statement asked was “I found it enjoyable to be with the other(s)”. In the control session, six participants

responded “fairly” and four “extremely”. Whereas in the augmented session it was the reverse, with four participants responding “fairly” and six responding “extremely”. The last statement asked was “I was influenced by other players’ moods”. In the control session, two participants responded, “not at all”, one “slightly”, four “moderate”, one “fairly”, and two “extremely”. Comparatively, in the augmented session the recorded responses were three participants responding, “not at all”, two “slightly”, three “fairly”, and two “extremely”.

6.3 Sensory and Imaginative Immersion Statements

The statements in this section were designed to assess whether the audio reinforced feelings related to the theme of the game that could make it more absorbing. The first statement was “It was aesthetically pleasing”. To this statement one participant responded “moderate”, six “fairly” and three “extremely” in the control session, while in the augmented session six responded “fairly” and four “extremely”. The second statement to which participants responded was “I felt imaginative”. The responses in the control session were three answering “slightly”, three “moderate”, and four “fairly”. In the augmented session one participant responded “slightly”, two “moderate”, five “fairly” and two “extremely”. The last statement was intended to evaluate the experience as a whole, “It felt like a rich experience”. The control session recorded one participant responding “slightly”, two “moderate”, five “fairly” and two “extremely”. The augmented session recorded four of the participants responding “fairly” and six of participants responding “extremely”.

Table 3. Sensory and Imaginative Immersion Results

Statement: “It was aesthetically pleasing.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	1	6	3
Augmented	0	0	0	6	4
Statement: “I felt imaginative.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	3	3	4	0
Augmented	0	1	2	5	2
Statement: “It felt like a rich experience.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	1	2	5	2
Augmented	0	0	0	4	6

6.4 In-Game Positive and Negative Emotions

Flow tends to generate positive emotions during games. Statements were made about negative and positive emotions during the game. Five statements were put to the participants about negative emotions. The first was “I felt annoyed”. In the control session, nine participants responded, “not at all” and one “slightly”. In the augmented session, six responded “not at all” and four responded “slightly”. The second statement asked was “I felt irritable”. In the control session, nine participants responded, “not at all” and one responded “moderate”. As for the augmented session, nine participants answered, “not at all” and the other one answered “slightly”.

The third statement was “I thought about other things”, to this statement in the control session two participants responded, “not at all”, six “slightly”, one “moderate”, and another “fairly”. Comparatively, in the augmented session, seven participants answered, “not at all”, two “slightly” and one “moderate”.

To assess fatigue to the task, the following statement was asked: “I found it tiresome”. In the control session, six of the participants responded, “not at all”, one “slightly”, two “moderately”, and one “fairly”. In the augmented session eight of the participants responded, “not at all” and two of the participants responded “slightly”. The last question regarding possible negative emotions was “I felt bored”. In the control session, nine of the participants answered, “not at all” and one “moderate”. In the augmented session, all the participants answered, “not at all”.

To evaluate positive emotions, four statements were asked. The first statement was intended to assess the level of satisfaction: “I felt content”. In the control session, two of the participants responded “moderate”; six responded “fairly”, and two “extremely”. In the augmented session one responded “moderate”, five “fairly” and four “extremely”. The second statement was: “I felt happy”, for the control session; the responses obtained were one “slightly”, two “moderate”, four “fairly”, and three “extremely”. In the augmented session two responded “moderate”, five “fairly” and three “extremely”. The third statement asked was “I felt good” the responses in the control session show that one of the participants responded “slightly”, seven “fairly” and two “extremely”. In the augmented session, seven of the participants responded “fairly” and three “extremely”. The last statement was intended to assess their satisfaction; the following statement was placed “I enjoyed it”. In the control session, eight of the participants responded “fairly” and two “extremely”. In the augmented session, two of the participants responded “fairly” and eight “extremely”.

Table 4. In-Game Positive and Negative Emotions Results

Statement: “I felt annoyed.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	9	1	0	0	0
Augmented	6	4	0	0	0
Statement: “I felt irritable.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	9	1	0	0	0

Augmented	9	1	0	0	0
Statement: “I thought about other things.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	2	6	1	1	0
Augmented	7	2	1	0	0
Statement: “I found it tiresome.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	6	1	2	1	0
Augmented	8	2	0	0	0
Statement: “I felt bored.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	9	0	2	6	2
Augmented	10	0	0	0	0
Statement: “I felt content.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	2	6	2
Augmented	0	0	1	5	4
Statement: “I felt happy.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	1	2	4	3
Augmented	0	0	2	5	3
Statement: “I felt good.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	1	0	7	2
Augmented	0	0	0	7	3
Statement: “I enjoyed it.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	0	8	2
Augmented	0	0	0	2	8

6.5 Post-game

The analysis of the results after the game session is divided into two parts. The first part is about the emotional state of the players and the second part being the difficulty in returning to reality. Starting with the first part, the following statement was asked: “I felt energized”. In the control session, two of the participants responded, “not at all”; another two responded “slightly”, and six “moderate”. In the augmented session four of the participants responded “moderate”, another four responded “fairly”, and two “extremely”.

The second statement assessed the satisfaction level of the participants after the game. While in the control session, three of the participants responded “moderate”, five “fairly” and two “extremely”. In the augmented session, five of the responses were recorded “fairly” and the other five “extremely”.

To assess possible negative effects, two statements were asked. The first one: “I felt exhausted”, in which in the control session five of the participants answered, “not at all”, four “slightly”, and one “moderate”. In the augmented session eight of the participants responded, “not at all” and two “slightly”. The second statement was: “I felt weary”, to this statement in the control session. seven of the participants responded, “not at all”, two “slightly” and one “moderate”. In the augmented session eight responded “not at all” and two “slightly”.

For the second part, three statements were asked. In the first statement: “I found it hard to get back to reality”, in the control session, eight answered “not at all”, one “slightly” and one “moderate”. In the augmented session, seven answered “not at all”, two “moderately” and one “fairly”. For the second statement “I felt disoriented” in the control session eight of the participants responded, “not at all” and two “slightly”. In the augmented session eight answered “not at all”, one “slightly”, and one “moderately”. The last statement: “I had the sense that I had returned from a journey”, got the following responses in the control session. Three of the participants responded, “not at all”, six responded “slightly” and one responded “moderate”. Comparatively, the augmented session had three participants responding “slightly”, five responding “moderately”, and two “fairly”.

Table 5. Post-game Results

Statement: “I felt energized.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	2	2	6	0	0
Augmented	0	0	4	4	2
Statement: “I felt satisfied.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	0	0	3	5	2
Augmented	0	0	0	5	5
Statement: “I felt exhausted.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	5	4	1	0	0
Augmented	8	2	0	0	0
Statement: “I felt weary.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	7	2	1	0	0
Augmented	8	2	0	0	0
Statement: “I found it hard to get back to reality.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely

Control	8	1	1	0	0
Augmented	7	0	2	1	0

Statement: “I felt disoriented.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	8	2	0	0	0
Augmented	8	1	1	0	0

Statement: “I had the sense that I had returned from a journey.”					
	Not at all	Sligtly	Moderatly	Fairly	Extremely
Control	3	6	1	0	0
Augmented	0	3	5	2	0

6.6 System Usability

The last element that needed to be analyzed was system usability. Statements were placed that allowed us to understand the relationship of the participants with the augmented audio system. Regarding the answers, only the ones from the augmented session will be shown, since in the control session they only used the equipment without the system being active. In the first statement, “I think I would like to use this system often” three participants answered “neutral”, four answered “agree”, and the remaining three answered “strongly agree”.

In the second statement, “I found the various functions of the system well integrated”, one of the participants responded “disagree”, eight responded “agree”, and one “strongly agree”.

The next statement was intended to evaluate the consistency of the system “I found that there was too much inconsistency in the system” three participants “strongly disagreed”, six “disagreed”, and one responded “neutral”.

Regarding ease of use, two statements were asked being the first “I found the system very cumbersome to use”. To this statement, four of the participants responded “strongly disagree”, five responded “disagree”, and one responded “neutral”.

The last statement looked at whether the participants felt confident using the system “I felt very confident using the system”, to this statement two responded neutral, five responded “fairly”, and two responded “strongly agree”.

Table 6. System usability Results

Statement: “I think I would like to use this system often.”					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Control	0	0	10	0	0
Augmented	0	0	3	4	3

Statement: “I found the various functions of the system well integrated.”					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Control	0	0	10	0	0
Augmented	0	1	0	8	1

Statement: "I found that there was too much inconsistency in the system."

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Control	0	0	10	0	0
Augmented	3	6	1	0	0

Statement: "I found the system very cumbersome to use."

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Control	0	0	10	0	0
Augmented	4	5	1	0	0

Statement: "I felt very confident using the system."

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Control	0	0	10	0	0
Augmented	0	0	2	5	3

7. Discussion

Despite the results obtained being with a small number of participants, some possibilities can be drawn regarding the use of augmented audio to induce flow. As already mentioned in this section, the experiment was done with a smaller number of participants than desired, so the results must be analyzed as hypotheses and not conclusive. The analysis of the results comes from the comparison between the control session and the session with the augmented audio.

As discussed in the background section, the state of flow generates certain subjective sensations related to the activity being performed. When comparing the results between the two sessions, the level of concentration increased with the use of the augmented audio. Participants also described being more engaged in the activity, with the use of the augmented audio, also correlating with the merging of action and awareness and the completion of the task. Regarding complete abstraction from the environment, mixed results were observed and may be due to the social element required in the game. While some players may go for a more solitary path in the game, others may try alliances causing players to have to interact with each other. Nevertheless, the results obtained related to concentration and involvement in the game do not seem to be negatively affected by these external elements.

Through analysis of the sensory results, two points stood out. The first was that players felt more imaginative using the augmented audio, and the second was that the experience was more enriching with the use of the augmented audio. Both points can reinforce the idea that the use of augmented audio contributes as a layer of reinforcement to the game's theme and narrative, and thus can engage players in a more intense way. Regarding the positive reinforcement that the state of flow can create in

the experience, the statement “I enjoyed it” seems to demonstrate that the use of augmented audio makes the experience more enjoyable and is more likely that participants can experience flow. Regarding negative effects, some participants reported some discomfort regarding equalization not being adjusted to the acoustics of the room and a delay in the voices of colleagues due to the way Unity processes audio in real time. Despite this, only one participant wrote that he needed to remove his headphones once to communicate with the other participant. Looking at the results of the “I thought about other things” statement, it is possible that the augmented audio focused the players more on the task for longer periods of time and could thus relate to the increased concentration reported by the participants. As stated earlier in the section, most board games have an inherent social component and require communication between players either about the game or simply dialogs that may happen during the game.

The results show no significant differences between the two sessions, with the exception that participants were more influenced by the moods of others with the augmented audio. This could mean that participants are more involved in the game, and therefore may be more influenced by all elements of the game, including other participants.

As for the post-game effects, there was a small increase of 20% in the extremely positive responses in both questions, suggesting that some participants benefited from the experience of the augmented audio during the game, making their satisfaction level higher and increasing their willingness to repeat the experience, even leading to a small reduction in fatigue. No significant negative effects were detected after the experience. One of the common effects of the flow state is some difficulty in returning to reality after an intense experience. In the results obtained there was an increase in participants reporting greater difficulty in returning to reality and more prominently, a feeling of returning from a journey. Both are effects that can happen due to the emergence of the flow state in the participants. Through the results obtained, it can then be assumed that augmented audio positively affects concentration and engagement in the task, being these elements essential for the flow state.

It is also assumed that although it does not completely abstract participants from their surrounding environment, it does not negatively affect the experience, since board games require the social element, thus making the use of augmented audio possible. The post-game effects seem to show a slight increase in player satisfaction and a decreasing in some fatigue relative to the control session, a fact that may be due to the player being more immersed in the game and having an audio component to focus on while waiting for their turn. However, from the responses obtained after the game, the feeling that may reveal the emergence of the flow state was the difficulty to return to reality and the feeling of journey. With these results and adding the results obtained about the system usability, it is possible to assume that the system was well implemented, not creating difficulties and distractions to the players that could result in disruptions during the game.

Regarding some player comments, it was mentioned by six players that the augmented audio improved the game experience for them, and one player reported being more involved into the game theme and abstracting from the world outside and other thoughts. Some of the problems reported in the comments refer to the acoustics of the room; the delay introduced in the voice due to Unity that sometimes led to a little

difficulty in understanding the other participants. Through the results analyzed, it will be possible to assume that augmented audio can induce flow. However, further tests must be done to prove this and make some adjustments to the prototype in order to avoid acoustic and delay problems.

8. Conclusions

This paper presents the study done on the use of augmented audio in board games to induce flow. The study focused on the main characteristics of board games and how these characteristics can be leveraged to include the use of augmented reality and how it can benefit the gaming experience by inducing flow. To this end, an augmented audio prototype was developed for use with the board game Rising Sun. Special attention was placed on the need for players to communicate with each other. Despite the difficulties generated due to the Covid-19 pandemic and the tests being conducted with a smaller number of participants than desired, the results seem to point to a flow induction through the augmented audio.

The most significant results such as concentration, absorption and sense of journey demonstrated a possible flow state when compared to the control session. It was also possible to see that augmented audio does not degrade the social interaction necessary in many board games, and communication can happen most of the time without any problems. For future work, it will be important to continue to study the possible implications of augmented audio in board games and conduct further tests with a larger number of participants to have a more robust sample.

CRediT author statement. André Sousa: Methodology, Conceptualization, Prototyping, Experimental Protocol, Execution, Writing. **João Jacob:** Unity development support, supervision and review. **Eduardo Magalhães:** Audio consulting and development, Conceptualization, Supervision and review

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