SoundTrek: A Virtual Reality Audio Perspective-Switching Game

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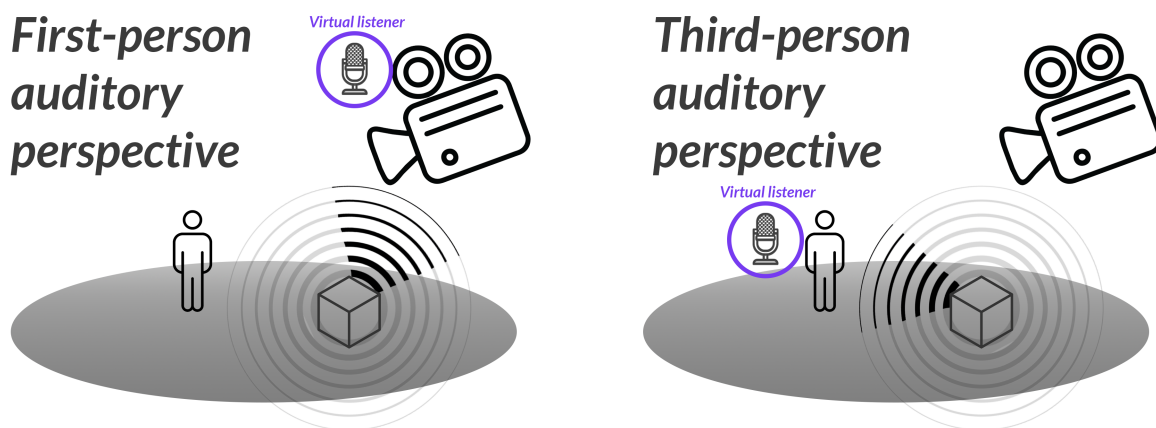University
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Figure 1: A diagram illustrating the auditory first-person perspective (left) and third-person perspective (right)

Abstract

Virtual reality technologies allow new ways of creating a sense of space not only through sight but also through sound. We present *SoundTrek*, a game about using listening perspective for navigating through environments in VR. In *SoundTrek*, the player needs to switch between listening to spatialized sounds from the first- and third-person perspectives to navigate through obstacles. *SoundTrek* also employs sound design strategies, such as spatialized sound-tracks and near-field audio to aid spatial navigation in the absence of visual cues and to create unique aesthetic experiences through sound. We present new ways of utilizing sound in virtual reality game design that highlights design considerations for audio-focused gameplay and diversifies the opportunities for creating rich, inter-active soundscapes.

CCS Concepts

• **Human-centered computing → Virtual reality**; **Sound-based input / output**.

Keywords

virtual reality, audio, perspective, game design

1 Introduction

Although sound has been acknowledged as a central concern since the inception of virtual reality [46], the current discourse on VR game design tends to focus on visual considerations, with audio often design being treated as an afterthought [34, 38]. This narrow conceptualization limits the design approaches for different perceptual attributes of VR games, such as the perspective from which the player hears sound from the environment. In fact, the very language used to describe perspective in everyday use and design terminology assumes the visual to be the default, e.g., "point-of-view" (PoV), "a narrow view/outlook", etc [28]. While the notion of a "point-of-audition" (PoA) is by no means new [7], it is rarely considered independently of the visual PoV [17, 33]. This approach deprives designers of a rich palette of audio-centric considerations that can diversify gameplay experiences and appeal to different audiences. For example, while there has been some exploration of first- and third-person perspectives (1PP and 3PP) in VR research and other applications, e.g., [12, 22], these have focused exclusively on visual perspective, with little exploration of audio feedback approaches. There are several reasons why audio is an appropriate modality for effectively conveying the notion of perspective in VR, such as the ability of audio to convey spatial qualities about the 3D position in an environment which can be perceived by means of head position and orientation [1, 23]. Sound can also provide information about the environment from all directions, unlike visual feedback which is limited to one's visual field-of-view [7].

Since the visual qualities of a 3D space in 3PP are perceived separately from the in-game camera, this allows players to perform actions that are not otherwise possible, such as using 3PP to peek around corners and gain awareness of the space surrounding the avatar [5]. Unlike the visual PoV which is by definition decoupled from the avatar in 3PP, the PoA can be flexibly located at either the in-game camera or avatar position. Sounds from the environment can thus be heard from the different perspectives and this perspective can be dynamically modified independent of the visual PoV. Previous work has discussed existing approaches and problems with implementing PoA in 3PP games [17, 33] although this is lacking for VR games. Furthermore, since auditory perspective in games is usually fixed to the visual perspective, the intentional use of such changes in PoA as a gameplay mechanic have not been considered before as part of gameplay design. The omni-directionality of audio feedback and the intuitive listening experience afforded by head- and body movement in VR warrant further investigation into the potential of PoA as a gameplay mechanic.

As an example of this avenue for VR game design, we created *SoundTrek*, a game about shifting between listening perspectives for navigating through environments in VR. Our game design draws inspiration from existing audio games that communicate gameplay information through directional sound cues, such as Papa Sangre [11]. Furthermore, we explore the sound design strategies of spatialized soundtracks [16] and near-field audio based on the proximity effect [19] which use the virtual soundscape itself to communicate gameplay information and create unique aesthetic experiences. *SoundTrek* thus leverages novel uses of aural perspective and perspective change that contributes to sound-centric game design practices by showing how playing with aural perspective can result in new game mechanics and puzzles in VR.

2 Background

2.1 Perspective and listening in VR

Similar to traditional gaming interfaces, VR allows the representation of avatars in third-person perspective (3PP), with examples such as Lucky's Tale [31] and Moss [32]. However, this is an uncommon approach as first-person perspective (1PP) has generally been the default choice for designing VR experiences [12, 22]. This is not without reason, as the general experience of VR can be said to imply a 1PP embodied presence within the virtual environment through which the player interacts, since a 1PP mimics our default mode of existence in physical reality and affords intuitive interactions with a virtual avatar [22, 44]. On the other hand, digital games have never been bound by this arbitrary limitation, as evidenced by the vast number of options pertaining to perspective, dimensions, and general representation and function of the gameworld [25]. Shifting perspective also allows varying options for the "focalization" of audio feedback, i.e., audio feedback being conveyed through and possibly modified by a virtual character/avatar's own perceptual faculties [24], which can be a powerful tool for conveying narrative information [9]. The overwhelming prevalence of 1PP in VR games is thus more likely attributable to current conventions and trends. These conventions, however, prevent designers from using the advantages of 3PP in VR, such as a reduced sense of motion sickness [30], and improved sense of the virtual space [18] and safety [14]. A 3PP also highlights the salience of avatars in VR as opposed to 1PP where a player cannot fully perceive their virtual representation without the use of other devices such as in-game mirrors.

The modification of perspective also has implications in terms of how sound from the virtual environment is heard, since the qualities of spatial audio implies a perspectival structure, i.e., the way information from the environment is received and decoded implies a point of reference from which perception is made [29]. For example, in a 3PP game the camera and avatar might be in different locations with different spatial characteristics in terms of how sound reverberates or is occluded, which raises questions about how these spatial characteristics should be processed and how that might affect the player's sense of their own position relatively to the 3D environment [33].

While the aforementioned properties apply equally well to "traditional" gaming platforms, such as PC and console, there are some properties that are uniquely enabled by VR and warrant specific considerations for audio. Perhaps most notable is the head-tracking provided by VR headsets, which allows an intuitive mechanism for exploring sonic environments and perceiving spatial affordances through head movements [35]. VR is thus especially suitable in enabling embodied listening whereby the hardware, e.g., headphones, and software, e.g., avatar, are incorporated into the player's sense of bodily self [37]. This can also lead to an enhanced sense of spatial involvement [5] as the player can use intuitive bodily movement to explore the implied spatial properties generated by the way VR audio is processed.

2.2 Audio games

Sound has long served supporting functions in games, such as providing feedback on events and helping the player orient themselves in the gamespace [26]. However, we focus on game design that relies primarily or exclusively on audio to provide feedback to the player, usually referred to as "audio-mostly" or "audio-only" games. The design of these game mechanics is most commonly associated with the area of accessible design for individuals with visual impairments, and much research has been done on design considerations to replace visual feedback with audio analogues with notable examples such as *AudioDoom* [41] and *Papa Sangre* [11]. These games present narratives and navigation through a virtual environment, but rely entirely on audio narration and other directional audio cues to guide the player. Since sound is the primary vehicle for gameplay information, they also place much emphasis on the design of sonic elements, such as narration, music, and sound effects. Similarly, research has been done on sound considerations in designing VR for visually-impaired individuals, such as for a boxing game [20] or locomotion in general [34].

However, audio-focused game design does not need to be limited to this specific area of interest and there are examples of well-known games that have included sound-focused design. For example, the puzzle game Myst (1993) - the best-selling PC game for nearly a decade - required players to recognise note sequences, and within VR games, the rhythm game Beat Saber is still one of the most popular VR games currently on the market [2]. Furthermore, the relegation of audio-focused games as a niche is also not necessarily beneficial for the design of games for visually-impaired individuals. An unfortunate result of the design of many such games is that they are often simplified versions of "non-accessible" games that deliver diminished user experiences [4]. Accessible games also generally do not enjoy the same attention as "mainstream games" due to a much smaller market share [39]. Thus, while our aim is not to design an audio-only game, we do aim to explore new avenues for audio games that capitalize on the affordances of VR technology and how these lend themselves to new sound design practices. By expanding the range of audio-focused design practices, we expect that this endeavour could provide new functional or aesthetic approaches in "mainstream" games which would also serve as a point of reference for the design of accessible games.

2.3 Spatialized soundtracks

The agency provided in digital environments creates unique challenges but also enables vast potential for interactive soundtracks and soundscapes in games [42]. One possibility for this that aligns itself well with the properties of spatial audio in VR is that of spatialized soundtracks, i.e., the delivery of the overall soundtrack of the game through spatially-located objects [16]. While this can refer to overtly musical soundtracks, our approach involves a more holistic experience of the overall soundscape, in this case music and sound effects[1], and how this is enabled through gameplay. Different considerations are thus required for the design of various sound components, since the player can move and interact with the sound

sources in any number of ways, so the final audio "mix" delivered to the player at any given moment needs to be constructed with this fluidity in mind [40].

In addition to aesthetic considerations, the soundtrack should also assist the player in the construction of their internal model of the environment for navigation and orientation [6, 45]. Furthermore, since most games do not spatialize musical soundtracks [6, 40], the possibilities of doing so in VR are under-explored. One design discipline where this has been explored is sound installation art, which has long utilized the agency of the audience in space and considered the movement of the audience between sound sources, thereby altering the composition of heard sound sources toward creating the intended experience [21]. Another example is 3D environments for music composition where the placement of individual sound sources and the design of layouts and/or interactive elements become musical composition devices, as they provide approximations that guide the audience[2] through the soundscape [8]. Thus, we consider similar sound design implications in terms of how the placement of sound sources as well as the general level design might affect the overall listening experience.

3 Game design

3.1 Design goals and process

SoundTrek follows on previous research exploring the concept of aural perspective in VR where different aural perspectives were not found to significantly affect investigated outcomes [3]. We theorize that this is partially because an aural perspective was unfamiliar to participants and, as such, they were likely not paying attention to the aural details enough to notice. *SoundTrek* is thus a more directed approach in drawing attention to the aural perspective and exploring ways in which it can be used as a design dimension for audio-driven level and puzzle design. The way we approached the design of sonic elements was also motivated by the dual goal of utilitarian and aesthetic functions for sound. While the utilitarian purpose of sound in interactive media such as games has received increasing attention in research [10], the affordances for navigation and other actions also allow new ways of designing sonic experiences, e.g., interactive music [8]. Since audio-focused games rely primarily or exclusively on audio to deliver aesthetic and evocative experiences, we aim to explore opportunities for doing so that align with utilitarian functions and utilize the unique affordances of VR. In doing so, we aim to highlight the artistic and playful potential of this medium and diminish the boundary between games and immersive spatial music/soundscapes [8]. We do this by exploring different approaches for spatialized soundtracks as a way of enriching agency-driven sound design that uses the virtual space.

The game was conceived of by the first, fourth, fifth, and sixth authors as part of the first author's PhD project. The second and third authors implemented the game as part of their Honours degree. *SoundTrek* was developed using Unity using OpenXR for VR headset integration and Oculus Spatializer for spatial audio. The use of OpenXR allows the game to run on different headsets, such as

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[1]For our purposes, we distinguish between musical and non-musical sounds in terms of clear tonality or rhythmic qualities, although we do not suggest that this distinction should always apply.

[2]Both of the aforementioned examples have interesting implications for digital games regarding the role of the player in the musical experience, as they can be considered both the "performer" and the "audience".

the Meta Quest[3], HTC Vive, and Valve Index. The design process followed an agile approach whereby regular feedback meetings and informal testing sessions were used to discuss design concepts and give feedback on the development as it progressed.

3.2 Sound design

All sounds were created, recorded, and edited by the first author and were rendered in mono to work with the spatializer plugin. The musical elements were created in an ambient style that drew inspiration from the seminal ambient album *Ambient 1: Music For Airports* by Brian Eno. This was motivated by the free exploration allowed within the application, hence the decision was made not to incorporate musical elements that imply a predetermined structure or require specific synchronization between the different musical layers. Eno's description of his ambient music as creating a "sense of place" [36] also aligns well with the functions of the audio for navigation and orientation. The musical elements themselves were created with the digital audio workstation (DAW) Reason 12 [4]. Instrument and synthesizer sounds were selected and edited to cover a wide frequency spectrum to allow for effective spatialization [23]. To contrast with the musical elements, obstacles in the game were aurally represented by abstract sound effects. This included recordings, such as shaking keys, rubbing plastic, and gently moving a tambourine, as well as atonal synthesized sounds. Using sounds that were unlikely to be perceived by players as musical in nature allowed a clear distinction between the two main categories of aural objects in the environment, i.e., orienting objects and obstacles. These were recorded using Adobe Audition [5] and edited to loop seamlessly.

As a general orientation tool, we modified an approach by [43] by adding audio beacons that emit different simple musical chords (root + fifth up). Their volume roll-off functions, i.e., how far the sounds are audible, are defined in such a way that there is overlap between where each can be heard on the map to allow a dual utilitarian and aesthetic purpose. The utilitarian purpose is to allow players to use the spatial properties of each sound to orient themselves within the gamespace while moving around. Aesthetically, the different chords harmonize in different ways depending on the position of the player creating an interactive soundscape that changes as the player moves around. This allows for an interactive soundtrack that emerges as a result of the level design, since the layout of not only the sound emitters but also the trajectories afforded by different level designs ultimately create the soundscape the player hears [8].

To assist players in more detailed localization of goal points, different versions of each were created: a far- and near-field version. The far-field version refers to the base sound without modifications, which is audible across a larger area, while the near-field version is only audible from very close to the object. It was also modified to be more "juicy" [38] by applying a granular pitch-shifting delay that shifts the pitch up with an octave and creates an audio effect that can be compared to visual particles. This was also approached from a dual utilitarian and aesthetic purpose, as depth estimation

is known to be inaccurate using audio- compared to visual information [15] and using a layered far- and near-field audio approach can add more depth and "juiciness" to the overall soundscape. For obstacles, a similar but inverse approach was used by boosting the low-frequency content (around 100Hz) when the 3PP avatar was very close to the obstacle to make use of the "proximity effect" to enhance the sense of closeness and aid the localizability of the sound source [19]. The size of the block was also communicated using the frequency of the sound cue, with smaller blocks emitting higher-frequency sounds and inverse for larger blocks.
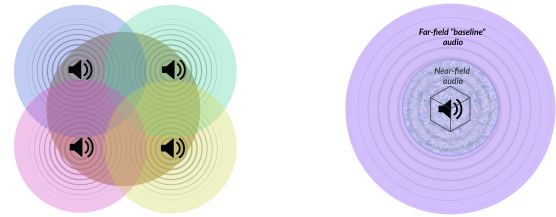

Figure 2: Diagrams illustrating the two audio design strategies described above: the overlapping audio beacons (left) and near-field audio (right)

3.3 Game design

The general game concept takes inspiration from existing audio games, especially *Papa Sangre* [11] which presents a virtual environment to the player through rich and detailed sound objects. The main structure of the game takes the form of a 3PP puzzle game where the player navigates to a goal point while avoiding obstacles. The goal point emits constant ambient music while obstacles emit a constant "abstract" noise. The avatar moves around on a platform resembling a table in an empty space and the player controls the 3PP avatar using the left joystick/touchpad on the VR controllers and using the left trigger to switch audio perspective.

For the 3PP avatar, the virtual listener is tied to the head-tracking from the VR headset, i.e., the player hears the audio relative to the avatar but can still move their head around, which has the same listening effect as if the avatar were moving its head. The player thus perceptually embodies the avatar [13] in 3PP by listening to the environment from its perceptual capabilities. For the independent controller-based movement, however, this was limited to only using the position of the avatar as the virtual listener and not the rotation. For example, if the avatar is located to the right of a sound emitter and the player is looking ahead in physical reality, the player would perceive the sound as coming from their left, regardless of the rotation of the avatar. The decision to limit the listener properties to position only was made based on experimentation and previous convention [33].

The player is also able to switch to a 1PP listening perspective, i.e., where all audio is heard from the perspective of the virtual camera. This allows a different mode of listening to the environment through physical movement in the virtual environment, similar to that found in most VR experiences. Each listening perspective serves different purposes in the context of *SoundTrek*: 3PP allows

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[3]While the Meta Quest headsets have built-in speakers, we used and recommend the use of headphones for the spatial audio to be delivered as effectively as possible [27]
[4]https://www.reasonstudios.com/shop/product/reason-12
[5]https://www.adobe.com/products/audition.html

inferring the locations of the obstacles and a detailed listening experience of the overall soundscape from a position within the level itself, but levels were designed so that the end goal is hard to discern through listening if there are many obstacles between it and the player. 1PP is needed to overcome this limitation, as the player can physically move around the space and use their head movement to listen for the position of the end goal. The player thus needs to toggle between these modes to progress through the levels. To make the distinction between the 1PP and 3PP modes clearer, all sounds except the end goal were muffled using a low-pass filter when in 1PP and a visual analogy of a glass globe covering the gamespace was used to communicate this boundary to the player.

The game contains 8 levels that progress in complexity and difficulty. A scaffolding approach is used to first introduce the player to the mechanics using sound and visuals before the visuals are removed and they must rely on sound alone. The levels are as follows: first, only a goal point is shown/heard. The next level introduces visible, sound-producing obstacles that block the player's path. In levels 3 and 4 the player must navigate past increasingly more obstacles to reach the goal, all of which are now invisible. Level 5 visually introduces obstacles that now "kill"/reset the player. Level 6 allows the player to practise avoiding a small number of these obstacles, now invisible. Finally, levels 7 and 8 have the player navigate a minefield of invisible "kill" obstacles to reach a hidden goal.

The level design process pointed toward several unique considerations: firstly, a primary design parameter was that of the volume and roll-off function of the sound sources since this, combined with the spatial location of the sound sources, replaces visual layout considerations, such as depth cues, contrast, etc. In terms of the distance by which sound is audible, this introduces a trade-off between a larger area of effect, which is easier to locate within the larger level but harder to pinpoint exactly, and a smaller one, which is harder to discern against other sound sources but easier to find once located roughly. The choice of sounds was also an important factor to consider. The goal and obstacle objects need to constantly communicate their location using sound. A looping "pinging" sound was initially used to signpost the goal, but this was found to become annoying quickly, hence a more atmospheric musical sound was used instead. The obstacle sounds used were more abstract and noisy-sounding to make them seem more abrasive and hence something that the player would want to avoid, again without making the sound repetitive/annoying.

4 Gameplay innovations

Through the design of the game and audio strategies, *SoundTrek* introduces novel directions regarding the incorporation of audio-focused puzzle design in VR. We introduce auditory perspective-switching as a gameplay mechanic and highlight how it enables unique level designs that utilize the embodied nature of listening in VR. By creating levels that afford different navigational capabilities depending on the auditory perspective, the player needs to be attuned to their own listening experience and how this is affected by the perceptual properties of the avatar. We also introduce ways of implementing spatialized soundtracks as sound design strategies that lend themselves to the interactive nature of games
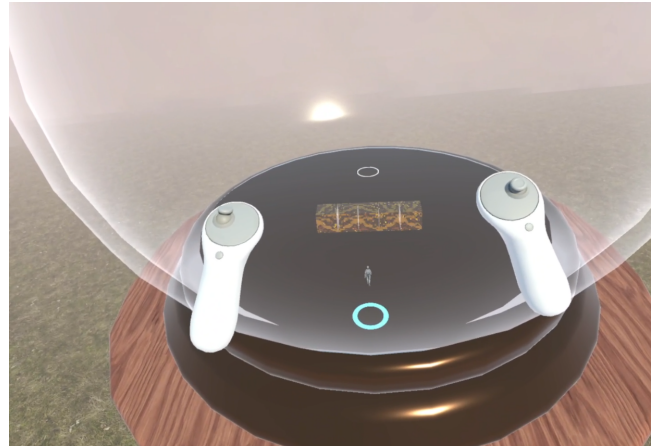

Figure 3: A level in *SoundTrek* with some visible obstacles to avoid

through requiring the player's agency. Musical and abstract soundscapes are created in terms of the organization of sonic elements in virtual space that are affected by the rules and layout of each level. This also includes a level of depth for each gameplay object through the creation of near-field audio cues that aid accurate navigation through the environment. This approach also emphasizes perspective-switching and intuitive movement capabilities of VR through the changing soundscape as a result of the VR gameplay. Approaching the design of the overall soundscape with spatial considerations can lead to new strategies for the incorporation of sound effects and music in VR games.

5 Conclusion and Future Directions

We present *SoundTrek*, an audio-focused VR game that takes inspiration from audio-games and underutilized strategies for interactive audio in virtual spaces. The game introduces the notion of auditory perspective-switching as a mechanic that enables new design opportunities for VR. The design considerations in terms of novel use of sound and the implications for level design can be applied toward audio-only or audio-mostly VR games. More broadly, we aim to expand on the limited utilization of sound as not only an aesthetic consideration, but a core gameplay mechanic in VR games as well as on the use of the combined use of the first- and third-person perspective in VR games.

Our continued exploration of listening perspective will involve user testing with *SoundTrek* to understand how different listening perspectives affect relevant aspects of VR gameplay experience. The different listening modes implemented in *SoundTrek* will thus serve as different conditions in an empirical investigation and user feedback can inform future developments for listener-focused gameplay opportunities. Future work could also explore the relationship between the physical movement required to navigate the sonic environment and the design of visual components.

Acknowledgments

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