AmbientSonic Map: Towards a new conceptualization of sound design for games

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Abstract

This paper presents an overview of the main features of sound design for games, and argues for a new conceptualization of it, beginning with a closer look at the role of sound as feedback for gameplay. The paper then proposes and details a new approach for sound feedback in games, which provides ambient, intensity-based sonic display that not only responds to, but also guides the player towards the solution of the game. A pilot study and leading outcomes from it are presented, in the hopes of laying a foundation for future investigations into this type of sonic feedback.

Introduction

Our soundscape is a vital part of our daily environment, and the act of listening is one of the primary modes of sensory experience in the world. While innovative interface design seeks to emulate the surrounding environment and create a realistic experience for the user, sound most often takes a secondary role to visual presentation. Background music, auditory icons and earcons (representational and abstract short signals, respectively) usually constitute the majority of sound feedback in traditional interfaces. Computer-based games, as a form of highly interactive interface, provide the user with advanced modes of multi-modal interaction. Yet, there is still a preoccupation with visual aspects of game production and development, while far less attention has been given to devising comprehensive and communication-rich systems of game sound.

There is growing literature on auditory displays designed for task-oriented, highly computerized environments; virtual audio environments through spatialization; and sonification of information datasets (Walker, 1996). The study of acoustic communication, on the other hand, attempts to combine cultural studies and models of acoustic ecology from the natural world, and bring it into design. Still few aspects of these approaches to sound design have found their way in the design of sound for games. This paper attempts to show that these informative and perceptual frameworks of sound could be harvested in game sound design practice. As a case study, *AmbientSonic Map* is a game prototype that uses sound intensity gradients to represent a

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player's level of success in completing a game goal. In contrast to most contemporary games, which would provide sonic feedback if the player does something "right," something "wrong" or when something shifts in the game, the auditory feedback provided in *AmbienSonic Map* is continuous, ambient, and provides incremental feedback to players so that they know "where to go next."

Game Sound: Where are we at?

From an acoustic communication and cultural studies perspective, there is a strong connection between sound design in modern commercial computer games and the standard cinematic sound model *speech – music – soundscape*, where speech/vocal information is the focal point of the listening experience, music provides the affective characteristic of the scene, and soundscape consists of carefully put together sound effects, which provide relevant contextual information (Fish, 2003; Truax, 2001). Music scores for games arrive from their counterparts in cinema, where sound serves a primarily aesthetic and affective purpose by providing mood, atmosphere and background. (Truax, 2001; Westerkamp, 1990). Sound effects in cinema provide sonic snippets to aurally enhance the representation of physical objects, events and actions (Metz, 1985). Metz terms them "aural objects," and points out how they solidify sometimes arbitrary associations in the audience's aural memory between film sounds and real sound situations (such as fist-fight sounds in movies, which have no counterpart in reality). Sound effects in games serve a derivative function of event-triggered audio icons that provide minimal contextual and/or environmental information about the imagined world. Sometimes aural objects from cinema directly transfer to game sound (again, fist-fight sounds are a good example). While information-rich, they still have a primarily supportive role, reinforcing visual representations and/or game shifts and events, rather than serving as a core game mechanic. The latter would entail designing sound in such a way that listening to and understanding the soundscape would be necessary for accomplishing the game goal.

It is the authors' belief that this could be accomplished by incorporating several key components into the practice of sound design for games. The first step would be investigating and applying psychoacoustic principles of listening and aural perception (see Figure 2) into the choice and approach taken to sound design. There are already existing guidelines about how people perceive sound, and what our physical limitations are. For example, humans can identify some relationships between differently pitched sounds and can identify different harmonies, but there is a limit to how many frequencies human hearing can "resolve" (Cook, 1999). Factors of sound amplitude, periodicity and spectral information, among others, have also been identified as important in relation to human perception of sound feedback (Neuhof, 2004). Another step to re-conceptualizing sonic feedback would be arranging sounds in a holistic and ecological way – where sound mediates the relationship between listener/player and sound environment/game environment (Schafer, 1977; Truax, 2001). This is already achieved in game sound design by providing layered contextual sonic information, (see Figure 1) which attempts to create a realistic 'sound and feel' of the game world. Environmental sounds, as well as material/object impact sounds must work together with the visual display to give the player a sense of "place" and control – for example, if their avatar is running on grass, they should hear the sound of footsteps on a soft grassy surface – a direct auditory feedback that confirms their actions within the game. Yet in order for sounds to be arranged in a truly holistic and ecological way, then issues of masking, timbral qualities and acoustic balance must be considered. For example, many contemporary commercial games contain loud music tracks that often overpower and mask other relevant sonic information about the environment, thus causing an imbalance in the soundscape of the game. An acoustically balanced approach to game sound design would strive to arrange sounds in such a way that they occupy their own spectral niche and are conceptually and informationally fitted within the context.

This would also entail radically changing users' learned listening habits. Games are part of popular culture and as such their audio-visual components are experienced in much the same way as their counterparts in cinema, TV, popular music, malls, shops, advertising, etc (Droumeva, 2005). The result of this blending of common perception is that listeners become accustomed to "backgrounding" most aural information they are bombarded with in daily life. We spend most of our lives trying to block out traffic noise, TV commercials, mall music, other people's conversations. When using interactive digital media applications we have to actively reverse engineer sound back into the foreground of our attention. Understandably, the task is hard. In the breakdown of *speech – music – soundscape* even well-designed sonic components are often experienced only half-attentively by the player. The alternative we propose is to draw attention and active listening to the sonic feedback in games by making it a requirement to gameplay and game solution.

Acoustic Space	The acoustic properties of a specific visual environment (e.g. a cave should sound different than a forest)
Object/Character Interaction	When visual game objects come in contact with other objects or characters this should be reflected aurally as well (banging on wood should sound different than banging on metal)
Localization	Systems that utilize multi-channel spatialization formats could emulate discreet sound source locations by distributing different sounds in different channels
Sound Effects	Standard sound effects (sounds that don't necessarily have a counterpart in reality, such as fist-fight sounds) are compiled in real-time

Figure 1. Common sonic components that provide contextual information in games

Novel research in interaction design and human-computer interaction gives a greater consideration to the role of sound in multi-modal systems, compared to more traditional domains such as cinema, or standard computer and video games (Anderson, 2004; Drewes, 2000; Rober & Masuch, 2005; Wakkary, 2005). One of the catalysts for such developments is a growing body of research in the development of special needs tools and applications for the visually impaired (McElligott & van Leeuwen, 2004; Parente & Bishop, 2003). This type of research takes into account perceptual qualities to maximize the scope of sound as a system element. For example, both Rober and Masuch's, and McElligott's games use spatialized sound as the only mode of denoting location, thereby allowing the users to explore a game space aurally and interact with virtual objects "placed" in discreet aural locations. Anderson's research, on the other hand, couples tangible interactions with a direct translation into sound parameter changes - allowing the player to compose an interactive musical soundscape via physical manipulation of objects in the environment. Parente and Bishop's geographic exploration interface is also notable, as it incorporates a more acoustically ecological framework of sound design – appropriate environmental sounds are used to denote discrete locations on a map and allow for smooth traversing of the virtual sonic world. Currently, commercial game sound contains contextual, aesthetic and confirmatory information, arranged in a variety of ways from music-based or MIDI tone-based to more sound effect-based. In his thesis on game sound design, Fish examines the interactive-adaptive qualities of modern commercial game sound (2003). This contemporary sound design model synthesizes dynamic soundscapes in real-time using large banks of sound samples, effects and filters in order to create soundscapes that are essentially unique to each player. Ultimately this approach renders vocal, musical and contextual elements of sound in real time resulting in a complex multi-layered informational soundscape (Fish, 2003). Yet, even this approach leaves sound outside the set of core mechanics of the game. The feedback, while rich, is still confirmatory and contextual in nature. A player can switch off the sound and still play the game.

Pitch Perception	The classical study of psychoacoustics, which examines common human perceptual patterns of tonal, pitched or musical sounds.
Association	The learned cultural associations we make with given sound objects regardless of their authentic meaning or source (e.g. sound effects)
Auditory Scene Analysis	Describes the way humans apply gestalt principles in grasping an entire soundscape
Conceptual Mapping	A research discipline investigating learned or innate conceptual mappings between sound and object or action, so that auditory displays function with better efficiency

Figure 2. Phsychoacoustic considerations in common practices of sound design

The Acoustic Communication Model

According to the acoustic communication model, the surrounding world is the best starting model for the design of complex soundscapes. In the physical world, sound is constant and ambient, and we have to dynamically negotiate our attention to it and our interpretation of it. Soundscapes are made up of many sounds in interplay with each other. These include ambient sounds that are present most of the time - *keynotes*, sound *signals* that attract attention, and *soundmarks*, which characterize acoustic spaces (Schafer, 1977; Truax, 2001). All of these elements working together contribute to an environment's acoustic and information ecology. Even though we "background" many sounds, we are still incredibly perceptive of often subtle sound differences in our everyday life (e.g. a car engine that sounds "funny" perhaps suggesting there is something wrong with the car). An ecological model would then suggest using sound in games not simply as an aesthetic backdrop to other system components or visual displays, but also as an active communicative medium that can provide information and guidance to users.

Intensity-Based Audio Feedback Model

Little work has been done to date in designing multi-layered informational auditory displays for responsive environments that actively *guide* human activity towards solving a problem or achieving a goal (Droumeva, 2006; Takahata, 2004). Our current research stems from a larger project named socio-ec(h)o, where interactive soundscapes provide confirmatory, anticipatory and directive sonic feedback to players of an ambient intelligent physical game. As discussed above, confirmatory feedback signals when a game goal (or sub-goal) is achieved, while anticipatory feedback confirms that players are very close to the solution, but not there yet. Directive feedback, the object of our investigations here, provides a constant, seamless ambient soundscape, which intensifies or de-intensifies to reflect the rate of success of players in a game (see Figure 3). This type of approach provides a consistent and reliable source of communication with users instead of just responding to actions with positive or negative feedback. If interpreted correctly, users would know not only *if* they are on a right track within a certain task, but also, *how far along* they are to completing it. We termed this feedback *intensity-based gradient approach* to sound, since it dynamically moves along a gradient of game progress mapped to sound parameter change.

Following this work, we developed a computer-based prototype, which uses the same approaches to sound and a similar game design, in order to separate and test out different approaches to intensity-based sound feedback. Particularly, we are interested in how different categories of sounds (environmental, musical, vocal or abstract) influence perception of the intensity gradient of sound. As well, we look into using different sound parameters, such as pitch, amplitude, phase (experienced as a pulsating rhythm) and spectrum, in order to find out if any of these approaches are more or less intuitive for interpretation. In its simplest form, the intensity-based approach to sound can be likened to the popular children's game of "hot and cold", where players use words along the continuum of hot to cold to signify the proximity of another player to a solution. Dynamic soundscapes that gradually change take the place of discreet verbal feedback in the *AmbientSonic Map* prototype. The design of *AmbientSonic Map* has also benefited from explorations in the perception of environmental sound (Ballas, 1993) and the acoustic communication theory developed by Truax (2001), where sound is seen as a ubiquitous communication channel between listener, soundscape and a physical (and cultural) environment.

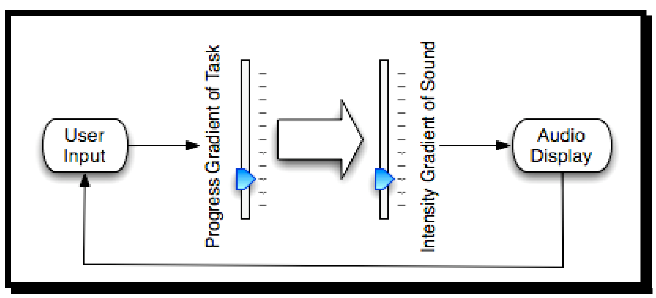

Figure 3. Illustration of the intensity-based auditory feedback model

The challenge of designing an auditory display that is ecological, ambient and provides rich guiding feedback through sound (alone or as a primary channel) is in its saliency as a perceptual system that users can reasonably interpret. Thus, auditory perception principles must be pushed beyond the limits of classical psychoacoustics (Neuhof, 2004) or data sonification design patterns (Kramer, 1994), and into interactive, task-based contextual activities, such as games. For this reason we developed a game prototype named *AmbientSonic Map.* This auditory computer interface presents an opportunity for exploring intensity-based sound, its perception qualities and application to gaming. As well, we offer a theoretical framework that both situates and informs the design of this game prototype within latest investigations into data sonification, acoustic communication and responsive audio-augmented environments.

In order to explore the utility of a tool such as *AmbientSonic Map* – one that puts sonic feedback at the core of gameplay and user-system interaction – we designed and ran a small pilot study. The pilot study asked four subjects to play *AmbientSonic Map* and perform geographic map identification tasks utilizing a loosely structured *Think Aloud* protocol. The purpose of this study is to validate the use of this tool for future investigations into contextual intensity-based sound perception, and its effective application in designing audio displays for game environments.

Intensity-Based Feedback

While in the physical world, intensity-based feedback is a natural and often unnoticed part of life, designed systems have yet to formally tap into its potential. Think of a runner whose heart beat increases in tempo the longer he or she runs. Whether consciously or not, the runner monitors their intensifying heartbeat and other body signals and is able to precisely determine their optimal exercise point. Similarly, when filling a bottle with water, most of us have a sense (aside from visual confirmation) when the bottle is nearly full – again, whether consciously or not, we can interpret the rising pitch of the glog-glog water sound to mean the bottle is getting filled up. These are just two of many everyday examples of our ability to interpret intensity-based feedback and relate it to accomplishing a task or activity. Such examples could also explain some of our seemingly "innate" associations between sounds and events. Most notable being our preference for positive polarity (Neuhoff, 2004; Walker, 1996) and our strong association for amplitude and pitch increases to mean an increase towards a desirable goal.

The one area of auditory displays research that has actively explored dynamically changing sound as an informative medium is data sonification. Research in this area focuses specifically on design patterns that optimize human auditory perception. Sonification research aims to discover intuitive mappings between sound changes and what they signify, and formalize these findings into guidelines for other designers. For this reason, it is useful to this current investigation to examine the history and main principles of sonification, so that they can best be employed in the design of an intensity-based auditory feedback model for game situations. However, it is important to note that sonification has so far been applied and investigated primarily for data monitoring, work-based environments, rather than in engaging, fun, problem-solving settings such as games. Therefore, our model must necessarily go beyond the lessons from sonification, and, using examples from other interactive systems (Anderson, 2004; Parente & Bishop, 2003), attempt to synthesize a new model for directive ambient sound feedback in games.

Lessons from Sonification

In sonification of data, parameters are mapped to sound characteristics, such as pitch, amplitude, timbre, granularity, tempo/phase, etc. It is important to note that these are all sound characteristics that lend themselves well to continuous, dynamic change driven by incoming data. Research in sonification has shown that using data-driven sonic parameters is a much more intuitive way of representing data and enables "quicker, more informed decisions through perception of higher level information in patterns across a wider range of data and over longer time periods" (Nesbitt & Barrass, 2002). Thus, the most critical design decisions in data sonifications are the saliency and effectiveness of mappings, scaling and polarity of data to sound (Walker, 1996). Effectiveness here is an umbrella term encompassing intuitive conceptual mapping, perceivability of auditory output, aesthetic considerations, ability to extract value estimation judgments and finally, the ability to make reasonable decisions based on the sonified data and advance in a given task. While many prominent experts in sonification have developed sets of design patterns and principles for mapping of data to sound, there still isn't a large-scale rigorous prescriptive system of design guidelines for all applications (Walker, 1996). Rather, context and complexity of activity is very important in making design choices of mappings and often significantly affects perceivability of sonification mappings and/or task performance.

Data mapping refers to the choice being made about which data parameter is to be mapped to which sound variable, i.e. should temperature be mapped to pitch, or tempo; is it better to represent volume with timbre or amplitude? These design decisions are aimed to strike a perfect balance between conceptual and perceptual associations of data and sound parameters. Scaling refers to the minimum and maximum value that a sound parameter will gradate between, driven by incoming data. This is also a significant decision, because even though humans can perceive fractal relationships between harmonic tones (this tone is higher than that), there isn't an inherent sense of a scale in a given sound. Polarity refers to the direction of gradient of change mapped between data variable and sound parameter. For example, if a rise in temperature results in a rise in pitch this would be a positive polarity mapping, yet if a rise in volume is mapped to a decrease in tempo, this would be a negative mapping. Choosing polarity is an important design decision, as likely, a "wrong" mapping would confuse and result in inaccurate comprehension of data. Most information auditory displays aim for a combination of usability principles that support not only template matching, but also value estimation judgments (determining fractal values in sound) and trend analysis. That is, they combine several types of displays, including audio icons, earcons, sonification and other contextual sonic data (Nesbitt & Barrass, 2002).

Using a Game Framework

The game approach is one frequently used in HCI research as a platform for studying various aspects of user experience, cognition, perception, system usability or interface design (Drews, 2000; McElliggot, 2004; Rober & Masuch, 2005; Wakkary 2005). One of the reasons is its tight structure and quantifiable outcome – that is, a game activity could be designed in such a way that the only way to "win" is to utilize particular system elements. For investigating the intensity-based auditory feedback model in particular, we require an activity that involves incremental progress towards a goal, which could be mapped to a sound intensity gradient. The game model seems a natural fit as our model is already based on the metaphor of the popular children's game of "hot and cold."

The sound feedback approach varies several sound parameters including amplitude, pitch, timbre and tempo, and uses several categories of sound – everyday/environmental sound, abstract musical sound and abstract non-musical sound. Each sound parameter within any type of sound can be varied relative to the progression of the task. For example, if a user is moving away from a solution to a problem then the sound intensity will decrease. If they move towards a solution or become close to completing the task, then a gradually rising intensity sound would be displayed (see Figure 4). When a player reaches the final goal or completes the task, a “reward” sound is displayed. This form of final confirmatory feedback was found to be very important in conjunction with ambient sound in the responsive environment of socio-ec(h)o (Wakkary, 2005). This model could be mapped to any task-based activity in which users make incremental progress.

Ambient Sonic Map: The Prototype

A geography trivia game meets the necessary constraints for examining intensity-based feedback in relation to a dynamically changing progress gradient. A map is a two dimensional object that has clear spatial boundaries and lends itself well to directional movement. Directional movement, in a location-finding task, represents the progress gradient. Its value could be calculated by using polar coordinates relative to a unique goal in every round of the game. This number can then be used to drive a dynamic change in one or more sound parameters in the given ambient sonic feedback. When coordinates match those of the desired destination, a reward sound can be triggered. The system has to be designed with care that a user does not simply “stumble” upon the solution, but has to rely on the directive auditory feedback to find it.

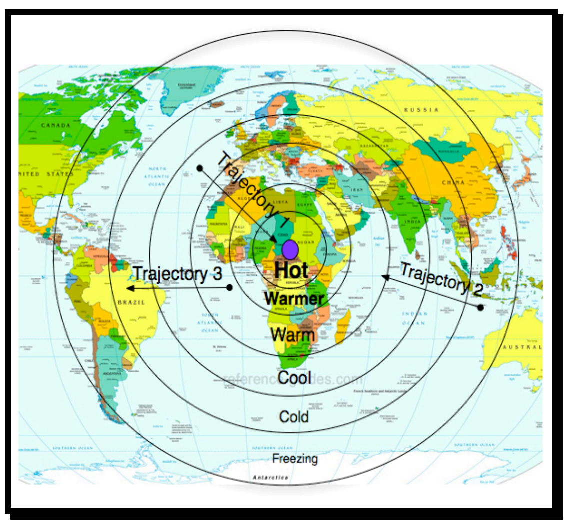

Figure 4. Schema of the intensity-based auditory feedback model in the Ambient Sonic Map.

The *AmbientSonic Map* game consists of five questions about world geography, and the task is to find a discreet location using only intensity-gradient feedback for direction. The questions and answers are fabricated to ensure that a user cannot find the correct location without directive sound feedback. Answers to the questions are physical locations on the map (e.g., countries, cities, specific ocean areas). The user has to read the question and explore the map to find the right location, tracing the map with the mouse curser at all times while hearing a dynamically changing soundscape. While it is possible that a user might find the right location by accident, it is unlikely since locations are small rather than large areas (e.g., London). In this way, users are very much dependent on the auditory feedback to find the correct location.

Each question has a unique single sound attached to it, which we tried to thematically relate to the geographic area where the answer is found. For example, one question calls for a specific part of the Atlantic Ocean, and the sound associated with it is of ocean water. The ocean sound is then modulated using a low-pass filter to create a perceivable change in the sound's timbre, as the mouse scrolls across the map image. When a player drags the cursor within a small perimeter of the goal area, a reward sound is triggered to indicate that solution is close at hand. Reward sounds were also thematically related to the questions and soundscape sound – for example, the reward for the "ocean area" question, juxtaposed over the ocean water sound was a short recording of a tall wave crashing at shore.

In the whole system there were three environmental sounds: ocean water, river water and fire; one abstract musical sound; and one abstract non-musical sound. All sounds could be considered "complex," as they have rich spectra, as opposed to MIDI or sine tone-based computer generated sounds that only contain one single tone or frequency. We were aware that this naturally increases the ambiguity of the sonic display and could potentially interfere with the pilot study results, but we felt it was important to contextualize the display with the activity and subject matter by presenting rich, relevant sound feedback, rather than controlled one-dimensional sounds.

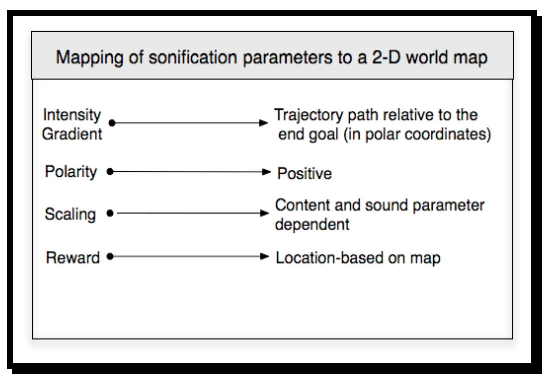

Figure 5. List of the core sonification elements mapped onto the 2-D spatial layout of a world map.

Figure 5 shows the mapping of sonification parameters to the particular activity of *Ambient Sonic Map*. This translation of sonification principles into game mechanics is done in order to further constrain game and system parameters so that user performance can be tracked and compared better. This kind of formalization also allows for using precisely the same scaling, mapping or polarity mechanism with different core sounds (see top row of Table 1.).

Pilot Study And Results

A pilot study was conducted in order to evaluate the effectiveness of our intensity-based gradient approach to sound feedback in *AmbientSonic Map* as a game-based interactive tool. Specifically, we wanted to begin to understand how directive auditory feedback may fit within a game design paradigm and how to design such feedback better. The pilot study consisted of four participants, two female and two male, with ages ranging from 27 to 64. They were asked to play the *Ambient Sonic Map* game, wearing headphones, and attempt to answer each of the five game questions by moving their mouse cursor over the map and listening to the auditory feedback. Since the game interface has no data collection capabilities as of yet, participants' general comments were solicited using a loose *Think Aloud* protocol. That is, they were asked to comment as they played the game so that spontaneous thoughts would not be lost. We felt that this approach to collecting data worked well within the context of the study in conjunction with a post-session interview, because auditory memory is quite short and participants would likely simply forget what they heard if not prompted on the spot. The post-session interview on the other hand allowed participants to express their overall impressions, final thoughts and suggestions (see Table 1 for details).

Table 1. *Participants' general comments on all levels of gameplay in Ambient Sonic Map.*

Player 1	Player 2	Player 3	Player 4
There isn't enough change to suggest where a player should go. Understands type of change, but there should be more degrees/levels to the gradient of change.	Sounds that are used should be very one-dimensional, drones or simply unchanging sounds. Only one approach to intensity should be used per sound. Also there should be more of a change leading the player towards the goal.	Sounds should be more related to the question – the place on the map. Movement should sonify relevant geographical areas through related sounds. There should be clearer change guiding the player.	Understood approaches to intensity, and can easily perceive low to medium intensity, but a large area around the goal seemed to have the same sound.

Table 2 contains the full breakdown of observations as they pertain to the system parameters – intensity mapping, scaling, polarity, sound content and reward sounds. Structuring results that way allowed for some comparisons to be made between participants' performance and helped organize the otherwise unstructured qualitative data. Some of the highlights of the pilot study results were the unanimous acceptance of positive polarity as mapped to a positive progress gradient. Another interesting result was the overall feeling reported by participants that dynamically changing sounds need to be "simpler" so that changes within the sound can be heard more easily. As well, all participants seemed to perceive and interpret very well the bottom and mid sections of the gradient of change, yet, they felt that a much more dramatic change in the sound should have occurred when they got within a certain closer range of the solution. As it is, they could not tell if they were 50% on the way to the goal, or 75%. This finding was interesting, as we did provide the confirmatory "reward" sound precisely for that purpose, yet players found it hard to even get within that range using the sound feedback alone.

Discussion And Future Work

Table 2. *Breakdown of participant comments and observations related to each sonification parameter in the game*

Sound Intensity Elements	Content: Water Intensity: Tempo Scaling: 0-8 Polarity: Positive	Content: Marbles Intensity: Pitch Scaling: 0.5-3.5 Polarity: Positive	Content: Water Intensity: Filter Scale: 250-17000 Polarity: Positive	Content: Fire Intensity: Filter Scale: 250-17000 Polarity: Positive	Content: Music Intensity: Tempo Scaling: 0-8 Polarity: Positive
Polarity	All players understood positive polarity	All players understood positive polarity	3 players understood positive polarity, 1 thought it was reversed	All players understood positive polarity	All players understood positive polarity
Scaling	3 Players thought it was the clearest degree of change,1 thought it was quite good, but not better than question five.	All players thought this was the most confusing type of feedback (unclear if because of scaling, polarity or content, or all)	All players perceived the scaling from low to medium, but couldn't perceive a meaningful change from medium to high.	All players perceived the scaling from low to medium, but couldn't perceive a meaningful change from medium to high.	1 player thought this feedback provided clearest change gradient, 3 thought it was better than most others, but not as good as question one.
Content	No one commented on the content other than it was uniform enough that it was easy to understand how it changed (1 player)	All players found that the sound was too complex which made it confusing. 2 players said they heard two separate sounds in it – one high and one low. 2 players said sound was changing on its own.	1 player liked that the sound was thematically related to the question. No other particular comment on the content.	No particular comment on the content. 1 player said sound was still too complex to provide clear change gradient.	Found feedback easier than other approaches but still not as clear as question one. 1 player mentioned there were still two separate pitches heard in the sound itself.
Reward	All players easily identified reward sound when they heard it. No comment on its content or appropriateness	All players easily identified reward sound when they heard it. No comment on its content or appropriateness	All players easily identified reward sound when they heard it. No comment on its content or appropriateness	All players easily identified reward sound when they heard it. No comment on its content or appropriateness	All players easily identified reward sound when they heard it. No comment on its content or appropriateness

Since this is a pilot study we did not expect to solidify or validate any study results (see Table 2), rather, we wanted to identify key issues of concern, problems, affordances and limitations to the presented approach to sound feedback. One finding, already suggested by the literature, which was confirmed in the study, was the strong association of rising intensity with a positive polarity of sound. A more interesting question – whether the gradient of change facilitated or influenced gameplay performance – revealed several interesting results. Participants' perception of the quality and ease-of-use of the sonic feedback had a lot to do with the inherent qualities of the core soundscape. Sounds such as water, fire and flat line musical tones – fairly familiar and one-dimensional sounds – had a much more perceivable gradation of change, then more complex, abstract, unfamiliar sounds. This was true regardless of approach to intensity change – pitch shift, tempo shift or spectrum filtering. Since participants did not comment much on the semantic relationship between soundscape and question topic, it is hard to establish whether this was a factor in the perception of audio feedback. Perhaps the most significant outcome of this study was that while players on the whole understood and were able to use gradient sound feedback, there was a sharp difference between their perception of low to mid intensity, and their perception of mid to high intensity. Specifically, most players were able to determine whether they were in an area of low intensity (i.e. far away from the correct location) in all instances of the game. At the same time, even when listening to the "easy" soundscapes, most players had a difficult time determining the transition between a mid and high intensity. Many commented that a more dramatic difference in the sound's intensity is needed to signify proximity to the goal. This finding illuminates the fact that a linear mapping between intensity/spatial location and rate of change of the soundscape is insufficient to truly guide players towards a game solution. A strategy that works to guide players from low to mid intensity may not necessarily guide them adequately from mid to high/goal intensity. Ultimately, even though this study is not conclusive, or specific enough to suggest guidelines, it is presented here as a proof of concept, and its findings are leading ideas towards more exploration of this model for the context of sound design for games.

This paper attempts to introduce a novel theoretical framework for designing complex sound feedback displays for games. We have provided a general overview of contemporary game sound design in both commercial games and novel human-computer interaction technologies. In both, sound feedback is primarily confirmatory and event-triggered, and is not generally designed with respect to perceptual or cognitive qualities of sound. In addition, contextual, environmental sound effects often take a backseat to an overpowering music soundtrack, thus causing an ecological imbalance in the sonic environment of games. Alternatively, we suggest bringing attention back to sound via the incorporation of game sound as a core mechanic within the designed experience of a game, rather than simply as a secondary modality supporting gameplay. We propose a rationalization for using intensity-based auditory feedback for games in that it provides directive feedback and actively leads players towards a solution, rather than affirming or negating their game actions. Such feedback also relates thematically to the context and subject matter of the game, and creates a seamless, conceptually relevant soundscape that is not obscured by crowding sonic elements.

This paper has presented a conceptual and practical alternative to the traditional model of confirmatory sound feedback for games. It is the authors' belief that a deeper understanding of people's experience of sound and music in the larger socio-cultural landscape is needed in order to enlighten sound design for games. Secondly, attention must be given to designing ecological systems of sound media, rather than combining disconnected elements of common sound design practice. Finally, tapping into the larger technical literature of auditory display design will help illuminate and enrich the design of sound for games. Hopefully the prototype described here helps bring these perspectives together in a meaningful way and advance the formative stages of a comprehensive conceptualization and re-invention of design practice for sound design in games. While the *AmbientSonic Map* pilot study provides only inspirational and leading ideas toward developing a more robust and rigorous model for directive sound design in games, it is the authors' hope that this is a step in the right direction towards areas of game sound research and auditory display research that are yet to be explored systematically.

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