THE ROLE OF PARTICIPATORY WORKSHOPS IN INVESTIGATING NARRATIVE AND SOUND ECOLOGIES IN THE DESIGN OF AN AMBIENT INTELLIGENCE AUDIO DISPLAY

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ABSTRACT

We describe two participatory workshops conducted to support design decisions in the making of the audio display for an ambient intelligent game platform. The workshops discussed here explore specific issues of players' interactions with sound and auditory display design. The workshops helped move our design process forward by specifying the role of narrative and sound ecologies in our design. They clarified the role of sound in creating narrative coherence, guiding player actions, and supporting group interaction. We describe the workshops, the auditory display issues we addressed, discuss how the workshops helped inform our subsequent design, and extend recommendations on how participatory workshops can be used by other designers of auditory displays.

1. INTRODUCTION

Ambient intelligent (AmI) environments rely on ambient interfaces in which sound plays a critical role. Our current research involves the design of an AmI environment for a physical multi-user game known as socio-ec(h)o. socio-ec(h)o delivers a responsive environment through sound and light display. In this paper we describe our use of participatory workshops as a method to support design decisions in the making of our audio display.

Ambient intelligence is the embedding of computer technologies and sensors in physical environments that combined with artificial intelligence, respond to and reason about human actions and behaviours within the environment. In our final prototype, the socio-ec(h)o game is played by a team of four players and features six levels of increasingly difficult word puzzles solved by coordinated body positions and movements. The environment is responsive to players' actions through abstract light and sound. Players' movements are tracked using a motion capture system. A custom reasoning engine was developed to track the game state and infer players' actions. An audio engine was developed to create real-time and responsive sonification. The audio display creates the aesthetic feel, represents current game state, and guides future player actions through abstract and ambient real-time sonification. For more technical details of our prototype see [1].

Our overall research goal is to develop approaches for group communication, collaboration and skill acquisition in AmI environments. A game platform like socio-ec(h)o provides both a prototype and test environment.

In this paper we describe two participatory workshops that enabled us to develop an approach for the audio display, which in the end provides a continuous, ambient response along a gradient. Yet the path to this outcome was not a straight line. We explored related ideas of group interaction, players as game avatars, physical movement in responsive environments, perceptions of immersion, game mechanics, and play through an emergent and participatory design approach. This primarily involved an extensive series of participatory workshops and iterative prototyping. Given the systemic and experiential nature of AmI environments, we would argue that few other design approaches would be as effective. In fact, we offer participatory workshops as an alternative to more controlled experiments and usability approaches currently used in employing and testing the audio design techniques we investigated, within similar contexts. The goal of this paper is to describe how we approached designing audio displays for our participatory workshops and to inform readers of the lessons we learned. We hope to encourage the use of participatory workshops in future audio display designs.

The workshops helped move our design process forward by specifying the roles of narrative, game identities and sound ecologies to our design. As a result, the experience of a sound avatar was a significant emergent game element. Sound characters, or unique sound characteristics, enabled players to assume a story world identity that fostered communication, exploration, skill acquisition, and a sense of progression. Ultimately we drew on this experience of unique sound characters and mapped it to game levels in the final prototype, thus providing a narrative coherence to each game level and overall sense of progression that guided participants' actions.

In this paper we provide theoretical background on the role of auditory display in games and participatory workshops. We follow by providing the context for our participatory workshops and an overview of the audio design concepts we investigated. We describe each workshop by detailing the issue addressed, the structure of the workshop, our technical set-up, and lessons learned. We end the paper with a discussion, reporting on future work and conclusions.

2. BACKGROUND

Sound is an important channel through which humans perceive their natural or designed environments. There is a proliferation of literature on auditory perception and design for task-oriented, highly computerized environments [2, 3. 4, 5], virtual audio and spatialization [3] and sonification of information clusters [2, 6, 7], yet relatively few of these approaches to sound design have found their way in the design of sound for games [8, 9]. While our conceptual sound design included a variety of existing research in psychoacoustics [2, 10] and the ecological approaches developed by Schafer and Truax [11], creating participatory workshops was a crucial step in addressing the issue of interactive audio display for an AmI environment.

Due to the complexity of the design concept – to create a game that is played by a team, has structure and rules, offers challenges and affordances, is physical and spatial, and responds to user actions only through its environment, we needed a design methodology that would allow us to explore the richness of the situation. Traditional formative evaluation and usability methods for auditory display simply do not provide a setting that is ecological and holistic enough to allow for actual participation and involvement. As Gibson points out, quoted by Neuhoff [10], "awareness is rooted in meaningful experience of the environment: thus ecological validity results from studying subjects/people in their own natural environment, in motion, in active exploration. For people this environment is social, cultural, systemic, economic, political, etc." Since we were interested in examining social contexts, group interactions, and embodied experiences, we adopted the approach of participatory workshops.

Participatory workshops can be viewed as a design method based on Participatory Design (PD). PD emerged to address social, technical and power relation issues in designing within organizations [12]. Traditionally, the method involves lengthy involvement with stakeholders within the users' settings that result in an empowered stakeholder and informed designer co-designing solutions [13]. Participatory workshops adopt the principles of genuine user participation, design within end-user settings, and enabling participants to co-design, however in a severely shortened time period and without the goals of in-depth contextual design, transformation of users into designers, or systemic sustainability. Rather, the workshops are a quick, flexible and powerful tool that allows designers to investigate specific activities, situations and environments. The aim of such workshops is typically to move beyond traditional user-centered design to harness participants' creativity in understanding what they *make* as well as *say* and *do* [14], or to utilize expertise for hands-on concept development [15], as well as model and manipulate simulated environments through role playing [16]. This last approach is closest to our use of participatory workshops in socio-ec(h)o. Within our research, we have previously employed participatory workshops to investigate multiple approaches to situated activities [17].

3. DESIGN PROCESS AND WORKSHOPS

The two workshops that we describe came midway through the design process. We had previously hosted several other participatory workshops and conducted concept development meetings where we developed the conceptual foundations of socio-ec(h)o, which included core game mechanics, game progression and structure, and narrative development. We had yet to build a working prototype. Our main concern at this stage was the design of a compelling environment based on user engagement, movements in physical space, immersion, and narrative or game progression. We knew at this point that we needed to investigate specifics in the role that the audio display would have. We had determined that the technical preconditions included location tracking, and an ambient interface that might involve body and object movement, location, and gestures. Given the AmI nature of the project we ruled out a graphical user interface of any kind.

Both workshops were set within the physical game space: a black box environment with controlled light and sound displays, delivered via *Wizard of Oz* techniques. A *Wizard of Oz* experiment is one that simulates the functionality of a technological system without actually building an automated prototype. While participants interact with the "system" as if it were autonomous, human researchers provide behind-the-scenes functionality in response to user actions (i.e. bringing up light or sounds, triggering events). This method allows for exploratory testing of user interactions and experience patterns. It focuses on the effectiveness and possible uses of the simulated prototype, rather than on the usability of an entire system.

Our conceptual starting point for the audio was the use of sound avatars that would allow game characters to be used in the game mechanics and would provide a vehicle for narrative progression. Both workshops were organized around this conceptual starting point. The underlying focus was on the interaction patterns between players and system, and the role of the ambient response in audio and light. We subsequently invited participants to suggest changes in the environment and interaction rules based on their experience of the environment and their avatars.

4. SOUND DESIGN CONCEPTS

Here we discuss design concepts of auditory display that we incorporated into our participatory workshops in order to examine their effectiveness. These concepts were selected on the belief that they might be useful in communicating game information between players and system, signaling progress and changes in the game, and creating an immersive atmosphere. As mentioned above, these concepts are based in applied psychoacoustics, as well as the acoustic communication framework of soundscape design [11], where sound mediates the relationship between listener, environment and soundscape. Below we present the general ideas for audio display, and their relevance to socio-ec(h)o.

4.1. Keynote sound as "Ground"

Sound is an extremely powerful tool in creating a sense of ambience in a space, as well as fostering an evocative cultural experience for the users. This is exemplified in various media, especially cinema. In both our workshops, we felt it was important to create an atmospheric keynote [11] sound that would serve as a 'ground' for localization of the game's acoustic space, and situate the rest of the auditory display within its context.

4.2. Musical Expression as Avatar

A core mechanic in our game was player identity. Through previous design sessions we had come to the idea of using unique sounds within a system of display to represent game characters. One way to do that through sound is by using

musical sound. This "musical expression avatar" approach would utilize a discrete musical (MIDI) phrase to sonify players' identities, their actions and spatial location. This model rests on a long lineage of recognition of a sequence of periodic sounds, and template matching [10]. We used this approach in participatory workshop one, in the form of four individual parts of a counterpoint MIDI composition. Given that the phrases could combine in a number of different ways, we wanted to know how well this approach could work in terms of recognition and identification, and in the formation of sound ecologies, narrative and play.

4.3. Environmental Metaphor as Avatar

This approach, like the previous one (section 4.2), relies on pattern recognition and template matching of a discrete sound, unique to each player. Yet we felt that the richness of environmental sound alone deserves exploration as a vehicle for facilitating recognition, identification with character, and narrative possibilities. In this concept we were inspired both by Schafer and Truax's work in acoustic ecology [11], and their classification of the natural sound environment. We also were inspired by Ballas' work in recognition and perception of environmental sound [18].

4.4. Timbre-Based Sonification of Game Events

Besides using avatars to sonify player identities, we wanted the auditory display system to represent subtleties in the play and game shifts that reflected players' groupings, their level of activity, their proximity to one another and to the sound sources. We felt that this could be achieved by using timbre changes as a model for qualitative sound coloration in the real world. Timbre could be affected by applying simple reverberation to a given sound source. Players will have to listen for complexity, colour and quality of the sound. In simple perception terms, this technique could be categorized as a gradient of "muffled" to "bright" or "distant" to "close-up" sound. This approach is based on holistic everyday listening, in which we detect small changes in sound quality when we are required to extract information from sound [10]. Since this approach is the most intuitive and qualitative, we anticipated that it would be hard to gauge its effectiveness.

4.5. Spatialization of Sound

This approach comes from existing literature on sonification of information and attention management [2, 7, 4, 6], which suggest that separating sound in different spatial locations helps in recognition and interpretation of its significance within a rich system of information. In the context of socio-ec(h)o, we hypothesized that this approach would work well with our attempt to introduce sound avatars as a game mechanic. We thought that spatializing sound and mapping its virtual location to the physical location of participants would reinforce the connection with individual sound avatars. We used this approach specifically in participatory workshop one.

4.6. Hierarchy of Auditory Display

While using a single sound avatar proved promising, there was a need to provide more coherency and richness of the sonic characters. As research in auditory icons design suggests [2, 10], a hierarchy of internally and semantically consistent audio icons create better recognition and facilitate navigation and utilization of a system. Thus this approach uses a set of three semantically related sounds that

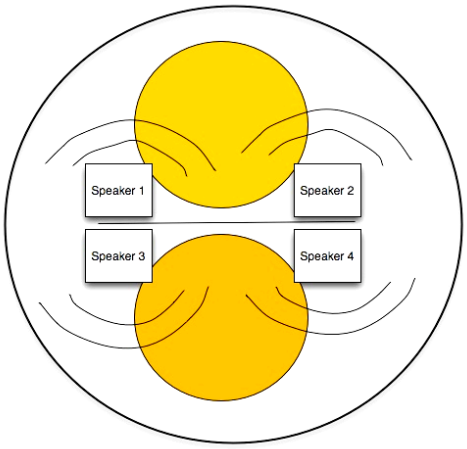

Figure 1. Illustration of the speaker arrangement and acoustic space ranges in Workshop One. The two yellow circles represent circles of projected light

increase in perceived intensity in order to represent each game avatar. Essentially, we constructed a hierarchy of sound signals related to gameplay, movement and character (see Table 2). This approach was introduced in participatory workshop two.

4.7. Delayed Feedback as Core Game Mechanic

This approach developed in response to participatory workshop one, where the feedback was continuous and constant. Instead, utilizing this concept in participatory workshop two, we provided no auditory feedback unless players achieved a specific configuration of spatial positions. Further, the feedback was delayed in that players had to *hold* their position for at least 3 seconds before they were rewarded with an auditory response from the environment. This model specifically explored the idea of subverting sound's traditional role as auditory reward in computer games by delaying the sonic gratification in order to establish clearer yet subtler gameplay.

5. PARTICIPATORY WORKSHOP ONE

We describe the first participatory workshop by discussing the sound issues we addressed, the structure of the workshop, and design investigations. We provide technical discussion of the sound set-ups and *wizard of oz* techniques. We conclude this section by detailing what did and did not work, and the lessons we learned. Participants were students at the university and included both males and females aged between 22 to 34 years old.

5.1. Sound Issues

In this first workshop, the specific sound issues that were explored included: the introduction of personalized sound avatars (including their spatialization patterns); the effectiveness of using different sound categories – music, voice, abstract, or environmental sound, with regard to observed recognition, interaction and play; and the use of audio process [reverberation] and amplitude in sonifying player location and team activity.

Figure 2. Participant on individual exploration in participatory workshop one

5.2. Structure of Workshop

Within the black box space, a circular area was designated as the interaction/play space. Four speakers were placed on the floor back to back, forming four semi-distinct acoustic spaces, or zones (see figure 1). The zones were dynamically created by players' interactions and groupings.

The four participants were first engaged in a pre-discussion during which they were given basic information about the workshop. The participants were told that they would have an individual "sound avatar" but were not told what it would be; and that the avatar would "follow" them in space.

The four participants acted as a team. The workshop consisted of three parts. The first stage was an exploration in which each player individually explored their "sound avatar" and its behavior in the physical game space based on their actions (see figure 2). In the second stage, all four players explore the space together and discover relationships and audio combinations that they can create with their sound avatar and other participants' sound avatars. The third stage included discussions, suggestion for changes, and real-time implementation of some of the suggested changes.

5.3. Design Investigations

While we had spent most of our conceptual design work on developing game and narrative progression, this workshop was open-ended in terms of narrative and game mechanics. We looked to the workshop to explore possible options. The workshop investigated the following game event and narrative components:

- *Discovery* of sound avatar (who you are in the game);
- *Discovery* of audio combinations with other participants (exploration and manipulation of collective identity);
- *Sound Ecologies Challenge*, this challenge addresses players' ability to affect the environment by forming new ecologies (their movement stimulates the dynamic soundscape – in periods of inactivity the environment decays);
- *Ecology As Metaphor*, discovering the right configuration of players and/or activity that will result in a prominent sound ecology. Conversely, the "wrong" combination of players and/or activity could result in a negative ecology or complete decay.

5.4. Sound Settings One

In the first stage of the workshop, we used the *Musical Expression as Avatar* approach to audio display. A Bach counterpoint piece (in MIDI) was deconstructed into four parts and each was assigned to each of the four participants. The sound avatar (a subset of the Goldberg variations) physically followed each participant, thus reinforcing a sense of association with a sound-based avatar.

The sound ecologies that players constructed by movement formed different musical orchestrations. Here we also tested the use of reverberation to affect timbre of sound and mapped this to distance (proximity to sound source). Amplitude levels were mapped to intensity/level of group activities and movements in the play space.

Our objectives were to observe the perception of musical parts, on their own and in different combinations, as well as the perception of distance through timbre in the form of reverberation, and amplitude levels (volume) as a response to levels of activity. Since we were manually driving the system's response, we were able to adjust those elements fluidly throughout the session. In an exploratory way, we also wanted to test notions of emergent play, free-form play, movement, gesture, and social interactions.

Processes	Activities	Issues
Amplitude	Proximity/Level of activity	Easy to perceive for individuals, harder for groups
Panning	Player position in space	Easy to perceive for individuals, harder for groups
Reverberation	Proximity to sound source (speaker)	Harder to perceive for individuals, requires fine timbre recognition and conceptual mapping
Sound ecologies mix	Player groupings	Easy to perceive for groups. Masking an important issue. Dependent on the above components

Table 1. A schematic of the audio processes used in conjunction with the sound avatars. Here the processes are mapped to activities

5.5. Sound Settings Two

In the second stage of the workshop we used the *Environmental Metaphor* approach to sonic display. Four environmental sounds signifying *earth, fire, water* and *wind* were created. We again used the idea of creating combinations and ecologies with the sound metaphors. Also, amplitude levels and reverberation were used to make subtle changes in the sound, as a response to activity, movement, proximity to sound source, and types of participant groupings. Two known issues we were aware of in working with environmental sound, were the semiotic mappings between avatar and its sound representation, and masking. Naturally, water and fire are concepts that could be translated in direct representations, while earth and wind are more metaphoric representations. For example we used footsteps and a processed windy sound, respectively.

The workshop objectives here were in large part similar to those of stage one. The idea was to explore how environmental sound, as a different sound category from

music/MIDI, would influence participants' experience of exploration, discovery, interaction and play. We also wanted to see whether having environmental rather than musical sound would encourage formation of sound ecologies or game narrative in any specific ways. The display was once again restricted to only one sound for each category. We used amplitude, panning (moving sound around to different speakers), and reverberation to respond to patterns of game events and/or player actions. For mappings of the *Timbre-Based Sonification of Game Events* in both stages of the workshop see Table 1.

5.6. Wizard of Oz Techniques

For this workshop we created a custom *Wizard of Oz* sound

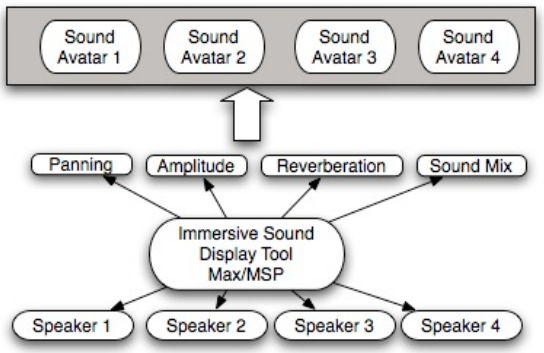

Figure 3. Schema of the audio display tool used in participatory workshop one

display tool in Max/MSP (www.cycling74.com) (see figure 3). The *Wizard of Oz* method is the manual simulation of unimplemented technology. Besides playing the four parts of the Goldberg Variations (stage one) and the four environmental sounds (stage two), the audio tool allowed us to spatialize sound, add reverberation, vary sound levels, and apply granulation. The tool was operated via a UC-33 MIDI controller for faster response time, and operated by two people at once.

We had an audio station set to the side of the interaction space enabling a clear view of the participants' location, actions and group configurations (see figure 2). In stage one, we only played the sound avatar of the individual who was in the space. We attempted to localize the sound wherever the player was, as well as increased or decreased the sound's amplitude depending on how close the player was to a speaker. In the second stage, we monitored and responded to the formation of particular ecologies, by mixing in the different musical parts, or different environmental sounds. As well, we introduced reverberation as an indication of distance of player(s) from sound source (a speaker). Amplitude, on the other hand was increased when lots of activity and play occurred, and decayed over time if there was little or no movement.

5.7. What Worked

For the most part we were able to respond instantly to relevant participant interactions, and reward behaviours that we wanted to encourage. The value of using a *Wizard of Oz* approach, is that in a workshop, which is highly exploratory and quite loosely structured, it allows us the freedom to examine what kind of activities and interactions we want to support, encourage and reward. It also allowed us to spontaneously and dynamically adjust the sound display to match the players' ease-of-use of the system, thus facilitating their engagement and playfulness. The technique also allowed us the ability to improvise and bring in a special sound reward (a granulated vocal composition) if we felt the players achieved a particularly creative configuration.

5.8. What Didn't Work

In stage one, we could not make the personalized sound parts follow the individual as we had intended (due to a programming flaw), thus everyone had difficulty identifying with their sound in a spatial sense, and they felt as if the ecologies they formed as a group were random and arbitrary.

In stage two, we were able to make the sound follow the participants across two directions, which dramatically improved the reported individual experience of avatar discovery. However, the sound couldn't follow participants everywhere, which limited the directionality of the ecologies created. Also the sounds of water and wind proved to be too broadband and partially masked the other two sounds in the ecologies. This resulted in players' inability to identify their sound, and to develop strong affinities with it.

5.9. Lessons Learned

After the first workshop, our formulation of the core game states were distilled into the following conceptual aspects:

- Evolution (interactions and game state shifts)
- Relationship between play and mastery (skill acquisition)
- Discovery and exploration (as core game mechanics)
- Game types (how different players affect the game)
- Characters and identity (sound avatars/characters)
- Narrative represented by environment (sound, light)
- Sustainability (engagement and generative play)

The ideas of ecology related more to testing the development of narrative and story world. Ecology was understood to encompass both environmental ecology – the internal consistency of the ambient immersive world, and social ecology – the sustainability and engagement in social group models that were formed. Again, even though the structure of the workshop was not formalized, the design had a built-in internal consistency of representation through sound – sound avatars did not mutate or change during the play session, rather they created multiple 'sound mixes' based on groupings and activity.

Even though players were not able to identify their sound part within the group musical composition, their movement across space indicated that they didn't feel constrained by this. Their actions showed that they kept trying to affect the system in some way and get a response or a clear idea of their sound part – what it is and where in the acoustic space it is. We are unable to say whether participants consciously registered the changes in timbre/reverberation and how it may have affected their interactions or movements. It was clear from the discussion that changes in amplitude levels have a much stronger perceptual connection to the sense of responsiveness of the system. We believe that spatialization of the sound was beneficial, especially in the individual sessions, however, since we could not fully simulate it again, it is unclear how this would have affected the game.

While players seemed much more playful with the music components in the workshop they reported a high

satisfaction with having environmental sound characters. Participants felt they were able to identify with them. The players with *fire* and *water* avatars reported feeling particularly attached to their "character" and feeling a strong sense of projected identity.

In the second stage's group experience, all participants expressed a desire for sound to better support the "narrative" formations that they were trying to construct. For instance, the *fire* avatar employed gesture and composition-like movements, and acted "threatening" to other sound avatars (except water, since a participant declared that water quenches fire). All participants seemed frustrated with not having strong enough feedback and requested a more "clear feedback" system response. In terms of sound narrative with environmental sounds, participants suggested that a greater array of sounds should be used to represent each character, rather than have only one sound.

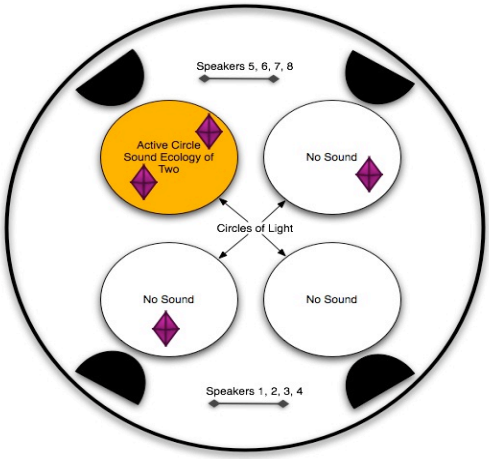

Figure 4. Illustration of the speaker arrangement and acoustic space ranges in participatory workshop two

6. PARTICIPATORY WORKSHOP TWO

Similar to our description of the first workshop (Section 5), we describe the second participatory workshop by discussing the sound issues we addressed, the structure of the workshop, and design investigations. We provide technical discussion of the sound set-ups and *wizard of oz* techniques. We conclude this section by detailing what did and did not work, and the lessons we learned. Participants were students at the university and included both one male and three females aged between 22 to 36 years old. Two of the participants took part in participatory workshop one as well.

6.1. Sound Issues

After having established, from participatory workshop one that participants found environmental sounds more meaningful and rich in narrative potential, we focused on utilizing only the four environmental sounds signifying wind, earth, water and fire. In this workshop, however, we attempted to create a narrative based on the sound characters by creating three accents for each sound with increasing levels of intensity (see table 2).

In the previous workshop we learned that participants wanted more "direct" feedback: a clearer connection between their actions and the perceived system response. As a result, we developed a response pattern that had a delayed, yet clearly defined response (our *Delayed Feedback as Core Game Mechanic* approach). The objective for this workshop was to better understand 1) the effectiveness and recognition of richer sound avatars through consistent, yet varied content; and 2) the response to a delayed feedback.

6.2. Structure of Workshop

Participatory workshop two was also set in a black box space. A circular play space was marked out on the floor and a white curtain tied in the middle, hung from the ceiling. Overhead lighting kits were used to create 4 circles of light within the darkened space. A 4-channel sound system was implemented in the space (see figure 4).

Similar to workshop one, participants were assigned sound avatars and the first stage allowed for individual exploration of the avatar. As well, participatory workshop two consisted of two stages, each containing two parts: individual and group exploration.

6.3. Design Investigations

In participatory workshop two we decided to employ restraints in order to encourage specific types of interactions related to game mechanics, namely, exploration, discovery and achievement. We aimed to build on the free play of the previous workshop and see if a more explicit audio and visual display could shape the play and ultimately encourage skill acquisition in the game and conscious exploration of the game rules.

We focused on clearly describing different aspects of gameplay by explicitly directing what players can and cannot do. In the individual and group sessions, the four circles of light were the only places where players would get auditory feedback, which might be their sound avatar or combinations of sound ecologies. Other areas of the space were non-interactive. The group play was more restrictive, since we had decided to only encourage even groupings of 2 and 4 participants in the lit zones but not of configurations of 1 or 3 in lit zones (see purple diamonds in figure 4). Thus whenever only one participant occupied the spotlights, or two participants were joined by a third, the system decayed and stopped auditory feedback (see figure 5).

An additional nuance to workshop two was time as a variable. We designed the sound and light feedback to be delayed, requiring a player or group of players to linger inside a circle of light for a fixed amount of time (between 2 and 4 sec) before the system responded. Again, this was an

Figure 5. Participants creating ecologies in workshop two

Sound Avatar	Representations
Wind	1- Processed wind sound – soft 2- Stronger wind sound 3- Musical sound - marimba
Earth	1- Footsteps in forest 2- Eagle call – mountain ambience 3- Wolf sound
Fire	1- Light crackle 2- Heavier flame 3- Blowtorch gust
Water	1- Rumbling of small stream 2- Outdoor waterwheel 3- Splash of an ocean wave

Table 2. Sound avatars and their representations, which include three levels of increasing intensity

attempt to shift attention to actions and system response. The workshop followed this sequence:

1. Skill acquisition of game rules (delayed feedback rule – player have to be in a circle for at least 3 secs)
2. Discovery and exploration of individual avatar (players discover their sound avatar and its three levels of intensity, see table 2)
3. Forming ecologies – skill acquisition (players learn that combinations of 2 and 4 participants create an auditory and visual response)
4. Forming ecologies of sound (players explore sound ecologies and learn other players' sound avatar by entering into combinations with them)

6.4. Sound Settings One

In workshop two we based our auditory design approach entirely in the *Environmental Metaphor as Avatar* concept. We used environmental sounds to create a system of auditory icons using the four different avatars. We enriched the complexity of the sound characters by adding increasing intensity to the base sound (see table 2). This approach aimed to support participants' request from the first workshop for more narrative dimensions to the sounds and stronger and richer qualities in the sound avatars.

6.5. Sound Settings Two

This setting was identical to the first sound setting (section 6.4), with the exception of a constant and light ambient sound of frogs' chorus. We also introduced a wildcard auditory event triggered when a single player spent more than 3 seconds in a circle of light. In this case, a composed musical sound (light marimba musical phrase) was played.

6.6. Wizard of Oz Techniques

Our *Wizard of Oz* set up was virtually identical to that of participatory workshop one (section 5.6). Only in this workshop we included four sets of three environmental sounds and several "wildcard" pre-composed auditory rewards.

In terms of system response, the environment was "silent" unless one of the four circles of light was "activated" by participants. Only one circle of light could be active at a time, and the first player or group to achieve a desirable configuration and hold it, would determine the audio and visual response. As mentioned above, participants had to stay inside the circle for at least 3 seconds in order to hear a sound. The longer they stayed in the circle, the more "intense" the sound would become; the sound would cross-fade through its three intensity levels (see table 2) and would increase in amplitude over time.

6.7. What Worked

This time our sound set up was relatively easy and we managed to respond through audio display precisely. In addition, we were able to reward a few moments of play/exploration with a pre-composed vocal/musical sequence. For example, one player started interacting with the scrim in the middle of the dark space (a white transparent curtain) and we were able to respond to her touching gesture with great precision. Soon other players joined too and explored this newly discovered system feature.

6.8. What Didn't Work

Because this iteration of the participatory workshop had a tight structure and system rules, the only form of feedback we provided were sound avatars in various combinations, and two accent sounds for each avatar. While we still varied amplitude depending on duration of player actions and movement, this session resulted in a rather dull soundscape. Players later reported being quickly bored with it, after they discovered their avatar in all its dimensions.

6.9. Lessons Learned

Individual explorations with sound avatars went quite well in this workshop. Players typically spent an average of five minutes getting to know their avatar and learning how to elicit system responses. Participants reported being frustrated at having to restrict their movement to the lit circular areas and felt disappointed at the absence of sound triggers. They were also disappointed at having to discover the system's behaviours, rather than the opposite of the system responding to their free flow of behaviours. However, as participants reported, the response patterns of the system were very clear and the learning/exploration and discovery were greatly facilitated by introducing clear restrictions and feedback. Players did a lot of lingering within a light circle and listening (or what appeared to be listening) to the sounds in great attentiveness.

Some players exhibited more compositional objectives, and others more exploratory activity; it became clear that both should be supported by our system. It was also clear that people were thinking about narrative and different groupings of sound avatars and expected more of a reward to different groupings. They expected the system to respond with something more than just the mix of the present sound characters. The challenge is how to give them more, yet not confuse them by creating conceptual incoherence in the sound content choices. Gesture mapping to sound could afford for action and effect, and measure effort/speed, thus appearing that players are "making something happen." Yet since gesture is a compositional tool, it provides a challenge for motion tracking, sound mapping and recognition of cause and effect.

7. DISCUSSION AND FUTURE WORK

The participatory workshops allowed us to make preliminary conclusions about auditory display in our AmI environment

related to narrative, identity and sound ecologies. What was most valuable to us was that the workshops helped move our design process forward in a structured and meaningful way. As a result, the availability, manipulation and experience of a sound avatar were a major emergent game element. Sound characters or unique sound characteristics for individual players enabled players' to assume a story world identity that fostered communication, exploration, skill acquisition, and a sense of progression. This approach encouraged specific exploration of the system response based on one's character, making participants more aware of the subtleties and narrative aspects of their experience. This enabled participants to form internal representations, associations and expectations about how a sound could or should act in the game. Ultimately, we drew on this experience of unique sound characteristics and mapped it to game levels in the final prototype, thus providing a narrative coherence to the level and overall sense of progression that guided participants' actions.

To summarize our key observation, the relationship between narrative elements and sound ecologies repeated itself throughout the two workshops. We were later able to draw on the distinct aspects of the sound avatars and game narrative in creating an internal narrative coherence, thus supporting skill acquisitions (learning behaviours) and communication resulting from awareness of manipulation and creation of sound ecologies.

Specifically, at the points of ecology creation, narrative associations were especially evident with environmental sound. In discussion, a participant commented that the "fire" avatar seemed to keep running away from the "water" avatar because water would put out their fire.

We had not anticipated these narrative developments, and therefore had no way of supporting them through the system's auditory display response. Yet these results became extremely useful in future explorations of the use of sound in fostering and developing narrative constructs and an immersive story world. Both these workshops are an example of using representational sound (whether music or environmental) in tapping into evocative individual memory, from where narrative structures are bound to emerge.

Some issues to think about when attempting to explore sound's narrative qualities in gameplay situations, are improving on the internal consistency of sound character 'databases' (as exemplified in table 2) and their clear delivery in the game; improving on the mappings between player interactions and system response; working on play/game/event time and state shifts; and supporting different ecological activities inside the play space.

8. CONCLUSION

In this paper we have described two participatory design workshops that were a platform for exploring auditory display issues for AmI environments. We have described our use of participatory workshops, lessons we learned, key observations we identified in sound perception and their impact on the design of our game environment. We hope that we have shown that using participatory workshops as a formative design tool is useful in exploring the multiple dimensions of auditory displays in AmI environments, and situate explorations in sound design in a more ecological, contextual and holistic setting.

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