Zwischenräume - A Case Study in the Evaluation of Interactive Sound Installations

Georgios Marentakis, David Pirrò, Raphael Kapeller
Institute of Electronic Music and Acoustics
University of Music and Performing Arts Graz, Austria
marentakis,pirro@iem.at
raphael.kapeller@student.kug.ac.at

ABSTRACT

This paper presents a collaborative project revolving around the conception, the realisation, and the qualitative evaluation of the interactive sound installation *zwischenräume*. In the installation interaction is considered in a particular way, in that both the installation and the visitor are regarded as being part of an evolving dynamical system.

First, we will frame the addressed question in the relevant research context. Then the installation and the ideas guiding its realisation will be described. Next, the evaluation methods used in this case study will be presented as well as the first results arising from their application. We finally point out how evaluation results could inform the subsequent refinement of the sound installation and directions for future research. The aspects investigated here are part of broader research project that looks into how evaluation strategies could be integrated in the development lifecycle of interactive sound installations.

1. INTRODUCTION

The development of interactive art installations is a complex process. Notwithstanding aesthetic aspects, the component of interactivity requires that the artist is actively concerned with how visitors interact with the artwork, and possibly with each other, through the artwork [1]. Given the accentuated importance of user involvement in interactive art, one normally questions whether and to what extent the methodologies used in the development of interactive systems as they appear in HCI research can be integrated in the development lifecycle of interactive art. An increasing body of work investigates therefore, whether, how, and when evaluation can be involved in the interactive art development process.

The ways in which interactive artworks can be evaluated are many, as are the actors involved in setting up an interactive artwork. Edmonds et al. [2] distinguishes between three main recipients of evaluation results, namely the artist, the curator and the evaluator. According to the authors, artists are mostly concerned with the making of the artwork and with defining the system within which the artwork operates. Curators are primarily concerned with facilitating the encounter between the artwork and the audience. Evaluators often seek knowledge and target both how artists develop their work as well as how audience experiences the artwork in its context in order to understand important aspects of human behaviour. In this sense, the evaluators contribution in understanding audience experience is central as it forms the feedback loop within which evaluation results are related to the artist and curator goals.

Audience experience in relation to an interactive artwork is multidimensional, both in the way it is conceived by the artist, but also in the way it emerges through participation in the installation. Interactive artworks quite commonly do not aim to create something that offers a specific functionality, style, and mood, nor a common user experience as interactive systems do [2]. Instead, the aim is to create an experience that is open to multiple interpretations through the exhibition of a certain behaviour. Within the context of interactive art there is value in such interpretations being incompatible with design expectations and inconsistent within and across groups. This complicates the evaluation process in the sense that the typical approach in which a system is adapted until a common user experience emerges. Therefore typical quantitative approaches to evaluation addressing efficiency, effectiveness, and user satisfaction are not directly relevant here.

The process of designing and evaluating for multiple interpretations which appears to be particularly relevant in the evaluation of artistic works, has been addressed by Sengers and Gaver [3]. As the authors put it *Systems that can be interpreted in many ways allow individuals to define their own meanings for them, rather than merely accepting those imposed by designers*. Evaluation of such systems should integrate user interpretation into the process which can be achieved using ethnographic methods. Further input can be obtained by 1. using dynamic feedback, a process in which whatever information obtained from the users is given back to the users to interpret, 2. conducting longitudinal studies, as user interpretations shift over time, and 3. gathering and presenting a variety of assessments from a diverse population of interpreters, including outsiders. Designers then should weigh the results to justify their conclusions and make sure that they do not abdicate the responsibility for the eventual success of the system [3].

2. RELATED WORK

A considerable body of work in the evaluation of interactive art has emerged in the Beta _ Space [4], a space in which interactive artworks at different development stages are exhibited and audience experience is evaluated [2]. The evaluations use a variety of methods, combining direct user observation or video recordings, with either contextual interviewing, video-cued recall, structured interviews, or questionnaires [5, 6]. The video-cued recall method is an especially interesting dynamic feedback evaluation method [3], as participants are shown a video of themselves and asked to recall what they experienced, while watching their actions. The group has developed a coding scheme that can be used to support data analysis based on the analysis of evaluation material from a number of installations. Two major coding classes are used. The first relates to the behaviour of the individuals as it emerges through their observed actions and the content analysis of the texts. The second represents the cognitive activity, being divided into hypothetical levels of how information is processed.

Höök et al. [7] have used a variation of the co-discovery method, in which groups of users visited the installation while their interactions were recorded, followed up using open-end interviews. Since visitors spoke to each other naturally while visiting the installation, such a method enabled the researchers to follow their theory-forming process and obtain insight into how different personalities interacted with the installation. The authors also argue that although such a group method would not yield typical average user data, it provides access to group reactions and dynamics and is closer to how art is often experienced.

Morrison et al. [8] have used more open techniques which they tried to bring together using the grounded theory method [9]. The evaluators used shadowing, interviewing and informal discussion, and questionnaires. The authors used the concept of *lucid engagement and design* [10] in their evaluations as it helped emphasising the playfulness aspect of artistic works.

2.1 Evaluating Sonic Interaction Design

Despite the amount of work directed in the evaluation of Interactive Art, the application of evaluation methods in Sonic Interaction Design (SID) installations has been limited. As a first step in investigating evaluation in SID installations, we evaluated the interactive sound installation *zwischenräume*. As this was our first attempt in evaluating a SID installation, we used the open and flexible approach of grounded theory, which poses no particular constraints in the evaluation process and allows the evaluator to proceed without assuming any previous knowledge on the research domain [9]. Stemming from sociology, such an approach is inherently ethnographic, thus being appropriate for the evaluation of systems designed to yield different interpretations [3]. Although we considered using the video-cued recall method for the evaluation, this did not prove feasible to apply, as video and audio obtained with conventional recording means did not appear to provide something the visitor could relate to given the auditory spatial complexity of this installation. Instead, data from in-situ user observation, video recordings, and open interviews were collected and analyzed.

3. THE INSTALLATION *ZWISCHENÄUME*

3.1 Conception

The idea behind *zwischenräume* was to create an interactive sound environment which would be experienced as an organic entity continuously sensing the space, reacting to sonic events, and providing dynamic sonic spatial perspectives depending on the visitors' actions or their mere presence. Interaction with the installation is made possible only through sound which functions both as input and output.

Displaying the inner rules and workings of the installation to the public was less relevant. Instead, the aim was to capture visitors' interest and convey an impression of openness and playfulness by offering graspable and playful affordances that trigger the action perception loop.

Di Scipio's approach to interactive systems as ecosystemic systems[11] was central to the conception of the installation. The visitors and the installation are regarded as equal partners or agents that share the same space and interact with each other much like an evolving dynamical system. Interactivity was conceived as a continuous exchange between these actors that affects the state of both of them through an adaptation process that eventually "resonates" in one or more particular behaviour i.e. *the sense of any change in time or space of an entity with respect to its surrounding* (Rosenblueth [12]). On this basis, three specific scenarios or separable *eigenbehaviours*[13] (see section 3.2) were developed. These *eigenbehavours* were then recomposed using a dynamical system that orchestrated their temporal and spatial evolution depending on the way the visitor would interact.

The aforementioned concepts were framed by conceiving the installation as a feedback system, in which sound picked up by microphones is projected back into the room with a specific delay. Feedback systems exhibit dynamically evolving behaviour which served as the basis for the *eigenbehaviours* developed.

In particular, by varying the time delay a rich palette of distinct sonic experiences emerges ranging from feedback tones, to the perception of spaciousness and eventually to echo effects. The need to stimulate the whole room emerges naturally when aiming at such impressions as it provides a spatial layer for the system behaviour and an embodied agent to interact with.

Consequently, the development revolved around the spatial, temporal and energy relationships between the location of microphones picking up sound and the loudspeakers projecting it back. Necessary tools were a simple location detection algorithm, implemented by determining which microphone received the maximum input at any time, and a fast ring buffer system that allows the efficient control of the delay and the gain of the output of each loudspeaker. Implementation has been done in the *rattle* [1] an

[1] Rattle is being developed and maintained by David Pirrò

(a) (b) (c) (d)

Figure 1: Photos from the final installation setup in the Forum Stadtpark exhibition space.

real-time DSP programming environment written in C. *rattle* can also be used as a mass-based physical modelling server, a feature we used in the final realisation of the installation. This programming environment is based on an interpreter written using CLANG and LLVM [2] that is used to define and JIT-compile new functions in real-time thus allowing for rapid prototyping and audio synthesis[14].

3.2 Development and Scenarios

The installation was developed during a period of experimentation and exploration that took place in the CUBE [3] studio in the Institute of Electronic Music and Acoustics in Graz. The principal aim was to develop a repertoire of clearly separable *scenarios* or *eigenbehaviours* that yield interesting and perceptually distinct sonic outcomes. Scenarios were defined as parametrisations of the system that expose a special behaviour with respect to its interaction with the visitor and the environment. Finally, a physical model was conceived that would bring these scenarios together in a single installation that could expose either one or mix together according to the visitors' activity in the room. The three scenarios and the physical model that were eventually chosen for the installation are presented in the next paragraphs.

3.2.1 Feedback

This scenario is exploiting the feedback phenomenon that occurs when no or very little delay exists between input and output. In the most simplest case, feedback manifests as tones, whose frequency depends on the main resonant frequencies of the room and its acoustic characteristics. However, when many loudspeakers with quasi-random orientations and locations are used as output and many microphones as input, more resonant frequencies can be excited simultaneously producing complex spectra. To allow for spectral variability however the main resonant frequencies need to be suppressed as they would otherwise dominate and lead the system into similar states. This can be achieved using a limiter and a peaking filter bank to control the overall amplitude of the feedback tones and the time needed for these tones to appear. Adapting the filter bank allows direct control over the "inertia" of the system, that is the system sensitivity to changes in the environment and the ease with which a transition between different feedback states occurs.

Calibrating gain factors, filters and limiters was challenging as the feedback system strongly depends on the par-

[2] http://clang.llvm.org/ accessed 2014-04-12
[3] http://iem.kug.ac.at/, accessed 2014-04-12

ticular space and the loudspeaker and microphone spatial positioning. It was however possible to find configurations in which complex feedback tones were produced whose spectra depended on the listening location and the mere visitors' presence. In particular, the nearer the visitor was to a loudspeaker (or even holding a hand directly in front of a membrane), the more dramatic and fast were the reactions of the system. It has to be noted that this is the only scenario in which the installation was producing sound apparently on its own.

3.2.2 Hall and Echo

In this scenario we increased the delay between input and output creating a spatially distributed hall effect and effectively increasing the perceived acoustic size of the room. With even longer delays echoes would appear, that would propagate onto the loudspeaker leading to an impression of spatial spreading of the sound. Moreover, the feedback of the echoes into the system through the microphones, yielded further softer echoes that eventually smeared uniformly over the whole array and slowly disappeared.

By adjusting the spatial distribution of the loudspeakers, the effect of echoes from specific loudspeakers on specific microphones can be changed leading to the appearance of prominent spatial inhomogeneities. It could happen that echoes would "hang" between some loudspeakers and microphones never disappearing or even continuously growing louder. To avoid this we introduced a calibration step by which loudspeaker gains were recomputed so that the maximum RMS value from each loudspeaker measured on the microphone array was equalised. This operation allowed more control and more stability in the overall system.

Refining this scenario, gain and delay times were chosen such that the delayed signal was just on the threshold of being perceived as an echo. In this way a hall effect would emerge for continuous sounds (e.g. whistling), due to the temporal overlap of the sound with the echo onsets. In contrast, for impulsive sounds, the perception of echoes would be accentuated given the temporal distinction between sound offset and echo onset.

3.2.3 Paths

This scenario is derived from the previous and restructures it in order to provide the impression of auditory movement; echoes that slowly "crawl" in space, departing from the location the sound was produced and moving along clearly perceivable, dynamic and changing paths through the loudspeaker array. To reinforce echo perception, delays here operate past the echo threshold.

Sound captured by the microphone closest to the sound producing action is recorded and played back delayed from the nearest speakers. Using an adjustable delay the same sound is projected to the one or two loudspeakers closest to the previous with a slightly attenuated amplitude. As this process is repeated, a path of echoes is created, propagating from one loudspeaker to the other and eventually, after a period that depends on an attenuation factor, disappears. We intentionally avoided propagation paths in fixed directions in space (e.g. all paths moving towards one side of the room) and paths that would recirculate between a small number of loudspeakers. In order to minimize the effect of propagating echoes on further stimulating the system, the signal from the one microphone receiving maximum energy was used as source and the input gain for all other microphones was strongly diminished. Only sound exceeding a specific threshold would be used as sources for this scenario. The scenario was fine tuned in order to minimise recapturing subsequent repetitions that would obscure the development of the paths in space.

Particular to this scenario is that it explicitly advocates interaction between the visitor and the installation. In contrast to the previous scenarios, the effect of the acoustic environment is limited, making the behaviour of the installation's response completely dependent on the actions and sonic events produced by the audience.

3.2.4 Physical model

The goal of the physical model was to operate on the parameter space defined by the previous scenarios and synthesize their behaviour. In the model, both loudspeakers and microphones were defined as masses placed in locations that resembled their actual positions in the exhibition space, with microphones above the loudspeakers plane. All these objects were connected by forces. The masses representing the microphones exerted gravitational forces on the neighbouring loudspeakers masses. These, in turn, exerted and were affected by fixed spring-like forces exerted by their nearest neighbours. When a microphone received a signal above a certain threshold, it "pulled" the loudspeakers it was connected with, with a force proportional to the signal's energy, thus exiting the whole system. This threshold was high enough to allow the whole system to relax when sound in the room was soft. The result was a mesh that, when excited, would behave much like a plate. An excitation would be transmitted to all loudspeaker masses in the model and the whole mesh would slowly wobble back to a resting state within a time frame determined by the inertia of the masses and the attrition we used. Using *rattle*, the simulation of this model was run in real-time at sample rate.

The displacement of the loudspeakers along the z-axis (towards the microphones) was used to control the delay with which captured sound would be reproduced by the connected loudspeakers (ranging from zero when in rest position to values appropriate for the hall and echo scenario). Velocity along the z-axis was used to control the gain of the loudspeakers (ranging from a lower threshold suitable to the feedback scenario (mass at rest) to a value appropriate for the echo scenario). Speed along the direction connecting one loudspeaker mass to its neighbours (paths scenario see 3.2.3) was used to control the amplitude with which the signal was reproduced by the next mass. The displacement of the loudspeaker masses was mapped to the delay factor with which the repetitions were reproduced along the paths.

The effect of these choices was that when the masses were at rest i.e. when there was little or no activity in the room, the installation would fall into the feedback scenario. As soon as a sound or a feedback tone appeared, the microphone masses would start to pull the loudspeakers. Feedback tones would slowly disappear as the excitation would spread over the whole mesh and the hall and echos scenario would appear. Louder sounds and much activity in the room, would result in greater displacements and speeds of the loudspeaker masses and the path scenario would eventually appear.

Connecting the real-time physical model's state with the parameters of the scenarios, allowed us to recompose and merge the three single eigenbehaviours into one. Fine tuning these mappings was a process that took a long time, but eventually converged into the realisation of one system that would be perceived as coherent, exhibiting a global behaviour that exposed the three scenarios in dependence of the overall activity in the space.

3.3 Setup and Staging

The installation was realized using 48 (ca. 5x5x5 cm) loudspeakers and 24 microphones. The first staging decisions related to the placement of the loudspeakers and the microphones. With respect to the loudspeakers, a positioning that would structure the space less rigidly was sought, in order to allow the visitor more freedom in choosing which paths to take through the installation. Loudspeakers were thus distributed quasi-randomly (see Figure 1d), forming small clusters in the exhibition space. Various kinds of objects were used to mount the loudspeakers (music stands, microphone stands, table, wooden blocks) to underline the playful character of the installation. As a consequence and in contrast to a more regular kind of distribution, this configuration led to the appearance of spatial inhomogeneities and local behaviour as the different loudspeakers clusters projected sound slightly differently. Finally, to emphasize the fact that the installation reacts to the sonic activity in the room, some sound producing objects (a snare drum, some squeaky ducks and a trampoline with some bells attached under it) were distributed in the space.

In the context of this exhibition, we worked together with artist Johanna Reiner [4] who helped to shape the installation visually. She further contributed by placing one of her works in the space which was a sizeable hollow heap made out of shredded paper, providing an entrance and enough space for 2-3 persons to lie down (see Figure 1c). As a reaction to her idea, inside the heap we fixed four loudspeakers which reproduced the sound picked up by two microphones placed outside the exhibition venue. In this way, sounds from the exterior could be heard in the heap while the installation provided the background and vice versa.

In contrast to the loudspeakers the microphones were hung from the ceiling in a very regular fashion. The exhibition area was covered with a regular lattice, in which microphones were placed with a fixed distance between them (see figure 1b). The desktop computer running the installation, the necessary audio interfaces, the necessary AD/DA converters, amplifiers and pre-amplifiers were stacked vertically within a box standing roughly opposite to the paper heap. As a consequence, all signal cables formed a star shaped stem as they connected to the sound system. Although hiding the cabling was appealing to us, for practical as well as aesthetic reasons, it was decided to use it as a visual element of the installation and to shape it consciously.

4. EVALUATION

There were three goals targeted by the evaluation: 1. to assess the success with which the perceptual and cognitive phenomena the artist wished to create were communicated to the audience, 2. to understand the audience experience and how this emerged through interaction with the installation and 3. to make a first step towards understanding visitors behaviour in installations involving Sonic Interaction Design .

4.1 Evaluation Process

The evaluator observed different visitors to the installation and made some general remarks with respect to the way they behaved in the space. In addition to this, seven participants were invited to visit the sound installation, four of which were filmed while in the installation space. One had neither musical nor sound related training, two had musical training, and four had both musical and sound engineering training. All participants were between twenty and thirty years of age. They did not receive any explicit information about the installation, although some participants have read flyers, or visited the homepage of *Forum Stadtpark* to gather information in advance. They spent as long as they wished in the installation space while being videotaped. Subsequently, they were immediately interviewed. The interviews were open ended and held as informal as possible to give the participants the possibility to talk freely about their impressions. The interviewer interfered when participants when the conversation got stuck or went off topic and made sure the following aspects were addressed: the first impressions upon entering the room, the sound producing actions the visitors used and their perception of interaction with the installation, the way the sound from the installation and its interaction with the room was interpreted, the impressions in the paper heap and comments concerning the temporal evolution of the visitors' impressions with respect to the installation. Interviews and video recordings were subsequently transcribed and analyzed using the method of constant comparisons and a combination of open and selective coding within the grounded theory framework [15, 16].

4.2 Overview of the material

In the interviews, participants talked about their sensations, their emotions, their actions, and their thoughts and they described the behaviour of the system, the ways they interacted with it, as well as their theories about how it works. Statements relating to the people's perceptions were classified under the sensation category. Within this category subcategories relating to visual and auditory sensations were created. Auditory sensations were further subdivided in

[4] http://johannareiner.at/jr/about/, accessed 2014-04-12

Figure 2: An overview of the tags used in the evaluation

sensations relating to timbre, pitch, loudness, and the temporal and spatial dynamics of the installation sound on one hand, and sensations relating to the room acoustics on the other. This was because visitors differentiated explicitly between the sound of the installation and the perceived room acoustics, and because they related the first to the way the installation responded to their actions, while no direct relationship between the latter and their actions was established. Statements relating to the visitor's emotions were classified under the emotion category. Statements relating to the visitors' thoughts, theories, and hypotheses with respect to how the installation works were classified under the theory category. Finally, statements relating to the way people interacted and perceived interaction with the installation were classified under the interaction category. An overview of the coding scheme, mixed together with the attributes that were assigned to the different aforementioned categories appears in Figure 2. The coding scheme emerged by balancing between the way the artist described the installation and the way the installation was described by the visitors.

Statements under the visual sensation category were mostly collected when people described their first impressions. Very few comments relating to visual aspects appeared in other parts of the interviews. Importantly however, the visual appearance of the installation dominated the first impressions of the visitors and shaped their expectations. Only two visitors referred to an auditory impression as their first impression, while the rest referred to the visual appearance of the installation when describing their first impressions; the paper heap, the loudspeakers, the cables hanging from the ceiling, and the microphones. All visitors entered the space in a cautionary mode and expected to receive some immediate auditory sensation. It was not until accidental sound producing actions, as footsteps, laying down a jacket etc., occurred or the sound producing objects were used that the interactive aspect of the installation became obvious. This required however some time and it was often the case that people did not notice it; some visitors (not participating in the evaluation) would sometimes leave without interacting, or producing sound at all.

Participants used attributes relating to the pitch and the timbral, temporal, and spatial dimensions of the sound, as well as metaphors to describe the auditory impressions classified under the auditory sensation subcategory. They often mentioned that the sound from the installation was a pitch shifted version of the sound of their actions. Terms such as noises, rumbling, sound from mice or cats, crackling, thundering were used to describe the response to their sound producing actions. Other preferred technical terms such as echoes, sometimes called delays, or explicitly feedback. Attributes such as circular movement of sound, sound from all directions and sound from different locations were used to describe spatial auditory perception. Perception of auditory movement was however not clearly established, and only one person mentioned perceiving paths in the way sound was moving, while there was a general agreement that the location of the sound from the installation was spatially diffuse.

Most of statements under the emotion subcategory appeared when people described the sound of the installation. Some people, in particular people with no sound engineering training, did not use audio terminology and referred to the sound from the installation using explicitly affective terms, such as aggressive, relaxed, chaotic, cool, dark and so on. Few statements relating to emotion were collected in response to a visual sensation. One notable statement related to the contrast between the visual and the auditory room impression of the room, resulting from the fact that the first was classified as dry and empty and the second as rich and full, which was described as strange by the visitor.

When examining statements under the room subcategory all participants agreed that the perception of the room acoustics was influenced by the installation and that they felt that they were in an acoustically larger room. Only one person however, mentioned perceiving dynamic changes in the acoustic size of the room, albeit without establishing any connection to his actions.

The paper heap was perceived as a separate environment. The auditory scene inside the heap was recognized as a public location soundscape; but not a live one. The lack of a way to influence the sound was however evident to all.

A large number of statements were classified under the behaviour subcategory. In order to refer to the sound from the installation visitors used the term soundscape quite often, but also terms such as the room, the delays, the echoes etc. Expressions like it (i.e. the sound from the installation) spreads, moves, changes depending on the timbre, the location, the pitch and the intensity of my actions, changes depending on my location were often used to describe the installation behaviour. The contrast between local and global behaviour was prominent in the visitors's remarks. Most of the people made remarks concerning how the sound was different depending on where they were in the space and their proximity to the loudspeakers. One person even listened directly on the loudspeakers and compared to the sound when standing away from them.

In the statements under the interaction category, the installation was described as interactive by all visitors, who justified their judgement based on the immediate auditory feedback they received in response to their sound producing actions and the resemblance of the sound from the installation to the sound of their actions. The different sound producing instruments in the room were used extensively and quite often other sound producing actions were employed, such as singing, shouting, dropping things, clapping and so on. Visitors enacted with the installation in a primarily playful and explorative way, in which the system was stimulated for fun and not directly to test a hypothesis. The installation was thus interpreted as a rich medium where variable perceptions could be created and observed, a pattern that was also quite evident in the video recordings.

Quite often statements classified under the behavior category overlapped with statements under the interaction category. This is not surprising as the installation behaviour was meant to manifest as a result of the interaction with the visitors. In addition to establishing that the installation responds to their actions, visitors noticed that they could shape the installation behaviour using the timbre and the location of the sound of their actions and to a lesser extent the loudness and the pitch of the sounds they were creating. There was however difficulty in establishing exact patterns in the way the installation responded. Visitors related these difficulties to the irregularity of the spatial and timbral mapping between the sound producing action and the feedback from the installation. This led to some inconclusive experiments in which visitors tried to establish ways to control the sound of the installation and compose it. For example, one person focused with limited success on controlling the pitch trajectory of the sound of the installation by the pitch of the sounds he was creating. Another person tried to form a chord by consecutively playing single notes on the whistle, albeit to limited success. A relatively successful experiment emerged when one person noticed that silent or calm behaviour on her side resulted in an inviting atmosphere, whereas loud signals resulted in aggressive and scary noises and stimulated the system accordingly. Irrespective of the success of their experiments, people mentioned that they provided them with insight on the internal workings of the installation. Interaction with the installation often stopped upon reaching a satisfactory conclusion with respect to how the installation works or a feeling that the possible scenarios have been explored. Three visitors predicted that the (only) partial resemblance between the sound produced by the installation and the sound of their actions would lead to difficulties in relating them in cases in which more than one person produced sound. This was also evident in the opening ceremony, when many people stimulated the installation simultaneously: although they were playfully interacting they had difficulties establishing a causal connection between feedback and action.

5. DISCUSSION AND CONCLUSIONS

The results of the evaluation show that the major goal of the artist to create an agent that exhibits behaviour, in the sense of changes in time or space of an entity in relation to its surroundings, was successful. At the same time, it appears that certain aspects of the implementation as well as the calibration of the scenarios could be further tuned. For example the implementation of the auditory movement paths was not as successful as visitors did not experience the intended sensation. In addition, people mentioned a stable impression of an acoustically bigger room, rather than a room whose dimensions change as was the original intention.

Despite the small amount of participants, the evaluation provided us with a wealth of material and some interesting findings that could be generalised in future work. These relate to the weight of the visual appearance on the initial perception of sound installations and the difficulty in identifying how to interact with the installation that puzzled the listeners. The difficulty to “find where to start”, as a visitor put it, may be attributed to the *invisibility* of the interface as well as the “unfamiliar” interaction technique. As in order to interact with the installation one has to produce sound, no evidence of the interaction potential appears until such an action is undertaken. Although accidental sound producing actions as well as the sound producing objects provided hints to the interactive component of the installation these were not clear enough for some of the visitors. Thus, it might be relevant to consider how to make the existing affordances “audible”.

Another finding to consider in the future relates to the inquisitive nature of the visitors, manifested as the tendency to find ways to explicitly control the installation and synthesize its soundscape. Although the original intention to stimulate playful interaction was successful, some visitors sought a more structured way to interact with installation. The artistic decision here was not to provide a soundscape composition tool but an agent that contributes on equal terms as the visitor to the sound of the installation. It is therefore not surprising that such experiments were not successful. This finding would be important to consider when revisiting the installation as it would be interesting to investigate how it may relate to the creative engagement of the public[17].

Based on our experience with this project, we mention that introducing evaluation in the installation development cycle resulted in an exchange that provided both the evaluators and the artists with insight. Specifically it sharpened the questions addressed by the evaluation and helped the artists in clarifying ideas that could otherwise have remained implicit.

We mention two aspects that we consider worth discussing concerning evaluation strategies. First, that the video-recall method commonly used in such evaluations might need to be revised so that it can be applied to interactive audio installations. This is because video even when supplemented with audio recorded with conventional means, does not appear to provide material the visitor can relate to when spatial sound is used in the installation. The more open methodology of videotaping and interviewing participants worked well in our case and avoided the aforementioned problem. Second, having experienced this realisation/evaluation cycle, it appears that this process is difficult to perform by a single person. This is primarily related to the workload and the costs involved in performing a qualitative evaluation. Introducing evaluation into the creative development process could be important, as apart from providing an explicit validation stage, it could also provide the artists with alternative ways to look at and reflect on their work and eventually contribute in sharpening their "tools". As a trained evaluator is not always available, research of time and cost effective evaluation methods that could be handled by the artists themselves, is important.

The work we presented here is part of the *Klangraüme* project we have just started, which will deal with methodological issues concerning the application of an iterative design process on the interactive sound installation design and the possible repercussions on artistic praxis and try to to enrich applied Sonic Interaction Design using ideas from artistic works. Within this project we will publicly stage evaluate and refine three more interactive sound installation. Interactive sound artworks have a long history, but the field of Sonic Interaction Design with Human Computer Interaction Research has only been recently formulated explicitly [18]. This project represents the optimal context to further clarify issues, questions and research methodologies.

Acknowledgments

We thank the Institute of Electronic Music and Acoustics, Graz, Johanna Reiner and especially Andreas Heller for promoting and assisting this project. The work was supported by the Klangräume project, Zukunftsfonds Steiermark, AT.

6. REFERENCES

[1] E. Edmonds, "The Art of Interaction," 2007.

[2] E. Edmonds, Z. Bilda, and L. Muller, "Artist, evaluator and curator: three viewpoints on interactive art, evaluation and audience experience," *Digital Creativity*, vol. 20, no. 3, pp. 141–151, Sep. 2009.

[3] P. Sengers and B. Gaver, "Staying Open to Interpretation: Engaging Multiple Meanings in Design and Evaluation," *Proceedings of the 6th conference on Designing Interactive Systems (DIS'06)*, pp. 99–108, 2006.

[4] L. Muller, E. Edmonds, and M. Connell, "Living laboratories for interactive art," *CoDesign*, vol. 2, no. 4, pp. 195–207, Dec. 2006. [Online]. Available: http://www.tandfonline.com/doi/abs/10.1080/15710880601008109

[5] L. Candy, S. Amitani, and Z. Bilda, "Practice-led strategies for interactive art research," *CoDesign*, vol. 2, no. 4, pp. 209–223, Dec. 2006.

[6] Z. Bilda, B. Costello, and S. Amitani, "Collaborative analysis framework for evaluating interactive art experience," *CoDesign*, vol. 2, no. 4, pp. 225–238, Dec. 2006.

[7] K. Höök, P. Sengers, and G. Andersson, "Sense and sensibility: evaluation and interactive art," *. . . of the SIGCHI conference on Human . . .* , vol. 5, no. 1, pp. 241–248, 2003. [Online]. Available: http://dl.acm.org/citation.cfm?id=642654

[8] A. Morrison, P. Mitchell, and M. Brereton, "The Lens of Ludic Engagement : Evaluating Participation in Interactive Art Installations," *MultiMedia 2007*, pp. 509–512, 2007.

[9] B. G. Glaser and A. L. Strauss, *The discovery of grounded The discovery of grounded theory: Strategies for qualitative research*. Hawthorne, NY: Aldine de Gruyter, 1967.

[10] B. Gaver, "Designing for homo ludens," *I3 Magazine*, 2002.

[11] A. D. Scipio, "'sound is the interface': from interactive to ecosystemic signal processing," *Organised Sound*, vol. 8, no. 3, pp. 269–277, 2003.

[12] N. W. Arturo Rosenblueth and J. Bigelow, "Behavior, purpose and teleology," *Philosophy of Science*, vol. 10, no. 1, pp. 18–24, January 1943.

[13] H. von Foerster, "Objects: Tokens for (eigen)-behaviors," *Cybernetics Forum, PROCEEDINGS OF THE SYMPOSIUM, "RELEVANCE AND PERSPECTIVE OF CYBERNETICS IN PSYCHOLOGY"*, vol. 8, no. 3&4, pp. 91–97, 1976.

[14] G. Marentakis and D. Pirrò, "Exploring sound and spatialization design on speaker arrays using physical modelling," in *Proceedings of the 9th Sound and Music Computing Conference, Copenhagen, Denmark*, 2012, pp. 55–60.

[15] Corbin and A. Strauss, "Grounded theory research: Procedures, canons, and evaluative criteria," *Qualitative Sociology*, no. 13, pp. 3–21, 1990.

[16] B. G. Glaser and A. L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New York, NY: Aldine de Gruyter, 1967.

[17] Z. Bilda, E. Edmonds, and L. Candy, "Designing for creative engangement," *Design Studies*, vol. 29, pp. 525–540, 2008.

[18] K. Franinovic and S. Serafin, Eds., *Sonic Interaction Design*. MIT Press: Cambridge, 2013.