Sound Bubbles: the aesthetic additive design approach to actively enhance acoustic office environments

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ABSTRACT

Moving towards more open and collaborative workplaces has been an emerging trend in the last decades. This change has led to workers sharing a common open space, with seating's based on current activity, so called activity-based offices. Consequently, it becomes difficult to design sonic environments that cater to different needs in the same space. In this study we explored the possibility of adding site-specific but location-adaptive sound environments to enhance the experience of an activity-based office workplace. For this purpose, we developed the concept of the "sound bubble," a micro-space in which the user is embedded by a semi-transparent sound environment. The purpose of the bubble is to help the user ignore irrelevant and disturbing noise while working in an open landscape. The sound bubble supports the user to stay in "everyday listening" mode, i.e., not focusing on anything particular in the surrounding environment while being able to keep a link with it. The sound bubble was evaluated by a total of 43 test subjects participating in an experience-based test, conducting their usual work tasks in an office landscape. Our results show that the sound bubble can enhance auditory work conditions for individual work requiring concentration.

Author Keywords: acoustic design; sound design; sonic interactive design; sonic micro-milieu; sound bubble; site-specific designed ambience.

1. INTRODUCTION

In recent years, the research and practice field of sound design to improve every-day environments such as work places has experienced a substantial evolution. In an area traditionally dominated by physical acoustics, a wide range of new concepts and methods have emerged allowing site-specific solutions beyond the limited noise reduction approaches, e.g., insulation, absorption, noise cancelling, and energy masking. Also in the fields of sound studies and ambiences research, new tools and methods have been provided and explored for dealing with everyday complex public or private shared environments. This approach, like ours, takes on a constructive, creative approach and develops methods to manage sounds as mediators of qualitative information, as opposed to the traditional, defensive approach to only protect people from sounds. See for example the work by Laboratory CRESSON since the 90's and its application into different case studies [2] [13]. Getting a space as silent as possible is far from enough: every sonic diagnose and treatment needs to take into account the complexity of a whole physical, social and sensorial environment. Such holistic approach methodologies are based on fields such as psychoacoustics [20] and ambience theory [12]. For example, in psychoacoustics the concept of information or attention masking was introduced, which is an action not physically masking the environing sounds but redirecting or abstracting the user's attention from the environing context. In ambience theory, new methods such as the interdisciplinary sonic effects have emerged [2].

Our approach to deal with these complex environments is a constructive method where digitally constructed, subtle sound textures are added to the local ambience. Such textures are meant to consciously or unconsciously transform the perception and experience of the current sound environment. A similar approach was used to enhance the sound environment in trains [3], [5]. Here, the method is further developed, the context is indoor office landscapes, and the sound bubble solution is localized to individual usage as opposed to sound environments for whole train coaches.

In recent years, activity-based and flex-offices have been gaining in popularity. What characterizes these types of offices is that there is not a fixed workplace for each individual as in traditional offices, rather there are workplaces accustomed to different purposes common to all employees to choose from based on current activity [8]. Beyond an economic motivation, such organization acknowledges that many types of jobs require flexible spaces due to the variation of tasks required by office workers. To minimize noise interference is a complex challenge for acoustic design in such offices. The main source of noise interference is considered to be co-workers talking [16]. However, talk is not only a problem in open office landscapes; it can also lead to improved knowledge sharing and ease of communication between employees.

Research has proved that sound perception is emotionally conditioned: a general positive attitude towards the work environment results in greater tolerance for the acoustic environment [23]; sounds derived from things we like are considered less disturbing [23]; sounds that we understand the meaning of and which we find useful disturb us less [17]. In addition, it has also been proved that constant noise disturbs us less than occasional, sudden noises [17] [19]. And of course the type of work to be performed will also affect our sensitivity.

The focus of previous research has primarily been on noise reduction and understanding the effect of such noise on working conditions while very little has been done in terms of how to actively improve such complex environments. According to [10] there is a need for more knowledge about how to integrate creative practices with contextual influences (users, environments, or activities) that are seen as key elements of situated design practices.

In this study we explore the possibility of improving the sound environment through inserting context-dependent, adaptive sonic textures in an activity-based office environment. We argue that an active (as opposed to passive traditional acoustic methods such as noise reduction, absorption and insulation) and a constructive design approach is required to significantly improve the sound environments in complex contexts such as open office landscapes.

2. APPROACH

Our aim is to improve the quality of office workspaces and our means is to design site-specific and location-adaptive sound environments. We have promising results from testing the concept in a laboratory setting where we found that the designed sound environment immersed the listener and generated a sensation of an encapsulating sound bubble [9]. In this study we take the research and design process one step further and evaluate a location-adaptive prototype in a real office context.

2.1 Research approach

Our overall approach is grounded in design-based research [24], which is a systematic but flexible methodology aimed to improve practices through iterative design interventions. Our approach is further grounded in acoustic design [14], which focuses on the treatment of sound environments in relation to their architectural design and acoustics. This implies treating sound as a positive design element to create environments that interact with all senses. Acoustic design suggests that the function of sound is to support the ongoing activity, i.e., it must be contextualized. Therefore, the field of contextual design [6] will also be relevant in our research process, a design methodology where user and context of use are essential components. Last but not least, and at the core of our methods and practices, sonic interaction design (SID), which is an emerging field that interweaves auditory display, interaction design, ubiquitous computing and interactive arts [18]. SID research is dependent on knowledge of everyday sound perception, ecological acoustics, and sound and music computing [18]. SID also aims to identify unconventional ways to use sound in the interaction between users and artefacts, services or environments [15].

3. RESEARCH QUESTIONS

We pose the following research questions; all devoted to the aim of exploring if and by which sounds a working environment could be improved by sound design:

1. *How do users perceive the acoustic environment with the sound bubble compared to without it?*
2. *How do users perceive and describe the sound bubble and their experiences with the different sounds in the bubble?*
3. *Which sound environments are preferred and used?*

4. THE SOUND BUBBLE CONCEPT

When using the concept of "bubble", it's important to clarify that we do not intend to isolate the worker by physically masking the environing sounds; far from that, our aim is to provide a porous semi transparent sound bubble able to help people focus on their work while maintaining a link with their working context and colleagues.

As a first theoretical frame, we initiated our research process and design concept in Pierre Schaeffer's aesthetics in Musique Concrète theory [7], in which sound perception is categorized into four different "Listening Modes": hearing, listening, comprehending and understanding. Hearing is the most elementary perceptual level where we passively take in sounds that we do not try to listen to or understand. Listening involves the collection of information, where we direct our aural attention to someone or something in order to identify the event. Comprehending however involves processing and selection of sounds, to choose what interests us, to qualify and react to the inherent properties of the sound. Understanding involves semantics where the sound is interpreted as a sign or code that represents something meaningful to us. Gaver [11] describes the concept of everyday listening where each person hears the environing sounds as surrounding events in a larger context and not as sounds to pay attention to per se. Another similar idea is suggested by [1] when describing our common sonic attention mode as "floating listening", i.e., perceiving without focusing our attention, keeping some kind of potential listening and finally reacting when unexpected, uncommon events emerge. In everyday listening mode or floating attention, we are aware on a more subconscious level of the origin of a sound. Where sounds get a function and can be related to e.g. an activity, everyday listening is then more of a response to hearing. We often unconsciously shift between these listening modes.

4.1 Design concept

Our design concept is intended to help users of the prototype to get into hearing mode or everyday listening mode in order to help them focus better on their job tasks. A way to attain that is to camouflage undesired talk by creating what [1] describes as a "sonic micro-milieu" that takes precedence over a distant or secondary perceptive field. The resulting dominant effect is that of perceptually placing the inserted environment in front of the background sound.

For obtaining a non disrupting micro-milieu, a subtle modification on the existing environments was required. In order to achieve that, different techniques were tested and evaluated such as space and time manipulation of the existing sounds, as well as insertion of other sonic contexts and materials; the goal being to generate a micro-milieu not invoking any specific sonic attention, but providing a somehow “natural” environment for such context and tasks to accomplish. The sound components should be abstract enough –e.g., non musical– so that most people do not recognize them as being familiar or analyse them in terms of musical taste for example. [22] investigated in a study the ease of learning different sound types and found that abstract sounds were learned and retained with far greater difficulty than both speech and representational sounds. A contradictory condition defines thus the nature of the sounds we are to design: on one hand they should be “obvious” enough not to attract prolonged attention; on the other hand they should not be recognizable as that may also lead to focused attention. An interesting paradox we are trying to solve.

The sounds are therefore designed to blend into the environment in order to be perceived as a continuous stream of similar sounds. The aim is to create a sonic micro-milieu triggering the hearing mode and ultimately everyday listening only. The design concept aims to facilitate interaction with the local sound environment by adding a semi-transparent sound environment. In the sound bubble the user is embedded by sounds that should not require sonic attention. This makes it possible for the user to select what to focus on, the sound in the prototype or the surrounding sound environment.

4.2 Individual and collaborative models

Two basic sound models have been developed and explored in this research, one for individual concentrated work and one for creative, collaborative work:

i) Based on acoustic theory and related work, our first design concept for concentrated individual work aimed at creating sound atmospheres that could be perceived as spatially confining, soothing and enhancing an inward attention.

ii) The second sound design concept, for creative collaboration, aimed at creating sound environments that could induce the experience of space and motion, sound textures that arise from random locations in the environing space bringing unexpected elements to metaphorically simulate –and stimulate– the idea of opening up the senses, being open to the unexpected, and thereby stimulate creativity.

5. THE SOUND BUBBLE SOUNDS

The sound bubble sounds were designed, tested and refined iteratively in two phases: First two sound concepts where iteratively designed, tested and refined in a laboratory setting. Then, these two concepts were implemented into 2 variants of sound environments from each concept. Also, a “neutral” sound was developed to be used as comparison in the study. The five sounds were then evaluated in an in-situ study with office workers.

5.1 Two Sound Concepts developed in laboratory

Our original idea was to generate sound sequences consistent with the physical environment, using for example sounds already present in the offices or subtly inserting filtered noise molded to the particular needs of the space and activities in question. However, the sounds needed to be modified in order to answer to the problems detected in these spaces: disturbing speech from other colleagues, background sounds from cooling systems, etc. For that, original sounds would be modified, e.g. by changing the frequency range, applying different perceptual effects (like inserting delay lines), creating certain rhythms or masking the speech by adding sounds able to absorb or flatten major variations in the original sound image. Three sounds were developed based on the two concepts and tested in the first laboratory phase. These sounds were refined into 5 final sounds evaluated in the main phase of the study.

5.2 Five Sounds Environments tested in-situ

The two design concepts were orchestrated into five sound environments developed for the in-situ test. Their purposes were twofold: 1) to have attention masking effects on surrounding talk and background noise as opposed to traditional energy masking, e.g., water sounds of a fountain for treating the sounds of traffic, and 2) to support intended activities in the office landscape.

To evaluate if there were any preferences of sound environments related to the intended activities in the office landscape we designed two sound environments for supporting focused work (A and B), and two for facilitating creative work (C and D). The fifth sound environment (E) was a recording of the background noise of an empty office. Sound E served as a static ambient background sound related to the room rather than to the activity. It was the closest we could get to a “placebo” in medical experimental settings, since no sound at all was too different to serve as a neutral, control condition.

The sound environments were based on results from previous research conducted by one of the authors concerning sound design of high-speed trains [3][5]. Those studies focused on different situations but deployed similar methods and aims as they were also exploring potential improvement of complex environments through the insertion of designed, site-specific sound environments. In the train context, sounds based on cycles and repetition proved to be the most pleasant ones compared to designs based on the notions of variation or improvisation. In that case, the idea of cycle was connected with rhythms of the human body (breathing) as well as sea rhythms.

Our expectation is that this type of sound environments would only be perceived in *hearing mode*, which means they needed to establish some kind of new background atmosphere not attracting too much attention. This could be achieved by composing as legato as possible, in the terms of Schlittmeier and Hellbrück [21]; their work showed that legato –i.e., a sonic continuous stream characterized by few dynamic and spectral variations–, affected cognitive ability less than music with distinct temporal and spectral variations.

Grounded in our theoretical frame and derived from findings and insights from the train studies and the foregoing laboratory test; five site-specific and location-adapted sound environments were developed. The overall idea was as follows: The first 2, sounds, A and B, was intended to support focused work through the exploration of static sequences in terms of emerging sound events, dynamic progressions and timbre variations. Conversely, sounds C and D intended to promote creative work through more dynamic (even if still humble) characteristics; in order to reach that, these sequences were given a subtle discursive line, slowly evolving in register and timbre.

The sound bubble concept involves connecting the sounds with the particular location and making the sound bubble adaptive to the surrounding environment. This was achieved in this first prototype system by modifying recordings of the office ambiance and having changes in the amplitude of the surrounding environment trigger alterations in playback speed and panning of all the sounds, except in the placebo sound E that was static. The detailed design of each sound environment is described below.

Sound A: the purpose of sound A is to simulate the sound of sea waves and wind. It was generated by dynamically filtering pink noise. The filter was used to restrict the frequency range to attenuate certain frequencies of sound and alter the sound image. The filter allowed a softer and more appealing pink noise. To achieve a corporeal rhythm the pink noise was faded in and out following a breathing tempo, following similar ideas as in the train case. Finally, the modulation was panned, which meant that the sound slowly moved between the speakers to give the impression of a slow wave movement. Soft pink and white noise have traditionally been considered as a way to mask unwanted background noise; with this example, we wanted thus to test the validity of such protocol.

Sound B is based on the same concept and material as sound A, but here we aimed for a tone-based example instead of the noise character of sound A. For that, a resonator and a delay have been added. The resonator was used to reinforce a number of frequencies, affecting the timbre and at the same time changing the key signature in order to colour the pink noise and transform its perception into a chord-based resonance. The sound was split into two layers, the second layer pitched an octave above the first and delayed to maintain the sensation of a wave motion.

Sound C is derived from the other concept, that targeting collaborative, creative work. Sound C is based on an iterative 5^{th} interval, in search of ever-changing tonal relations. Different chains of ascending 5^{th}'s, starting in non-related tones (not belonging to the same traditional scale in hz), generate a cyclical structure without clear reference points for the listener. The aim with a non-referential structure is bring about the sensation of an open, unpredictable space, and thereby induce a suspended floating listening mode.

Sound D is derived from the same concept as sound C. Sound D is based on a drone-based, static and coloured sound texture, which spectral envelope slowly evolves within a cyclical structure. It is created by applying different sound effects –equalizer, reverb, delay and resonator– on the recording of a walk on a pebble beach, obtaining thus a static sound texture where the corporeal rhythm of walking is still present as a background print.

Sound E is a recording of an empty office; our "placebo". This recording, belonging to an office space, was equalized and amplified for it to be noticeable as a distinct sound material within the local surrounding environment. In this case we insert a space within a space, both of similar character, exploring the masking potential of such confrontation.

The five sound environments had a length of 15 minutes each and seamlessly looped when played.

6. THE SOUND BUBBLE PROTOTYPE

In order to evaluate the sound environments, one prototype for the individual and one for the collaborative setting were developed. The individual prototype (Fig.1) consisted of an office chair on which speakers were attached, about 5-8 cm from each ear depending on how the user moved his/her head, at the headrest on two rods directed forward. A user could to some extent alter the preferred listening position because the speakers could be moved horizontally. Placing the speakers that close to the head resulted in an effect best described as the sensation of an encapsulating sound bubble.

Figure 1. The prototype: detailed view on the speakers.

A laptop was connected to the speakers. The laptop controlled audio playback and logged which sounds were played and for how long.

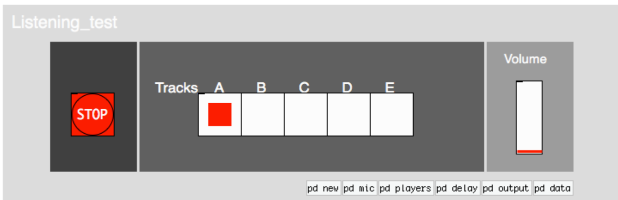

Figure 2. Interface.

The interface (Fig. 2) designed for the test was developed in the graphic programming environment PureData. The users were confronted to a very simple window reduced to five boxes labelled A-E where it was possible to select the different sound environments (random distribution different for every user) and a slider to adjust amplitude level. Since the purpose was to investigate how added sound in an office landscape is perceived we chose not to enable the users to mute the sounds completely.

The prototype setup also contained a microphone that registered amplitude changes, which affected how sounds were processed in the laptop. We assumed that an increased amplitude level registered by the microphone would originate from activities, e.g. people moving in the immediate environment or conversations. Amplitude changes in the immediate environment affected the tempo and panning of the sound environments in the speakers. When the measured amplitude increased that led to a narrower stereo sonic space, and the sound bubble was then perceived as more compact and encapsulating. In parallel, an increase of the amplitude also generated a temporal acceleration in terms of playback speed.

A normal sound pressure level in offices is approximately 50 dB [20]. The Swedish Work Environment Authority, which is an administrative authority for occupational health and labour issues, has published a white paper about noise, AFS 2005: 16. According to that document a workplace with a sound pressure level of 50 dB (A) has satisfactory speech intelligibility. Therefore, we decided to set the limit for when the interface should react and alter tempo and panning at 50 dB (A).

The prototype for collaborative setting consisted of four speakers, one in each corner of a meeting room. A laptop with an external soundcard managed the four speakers. The interface was identical for both prototypes.

7. THE SOUND BUBBLE EVALUATION

The sound bubble was evaluated first in a laboratory setting with experts, then in-situ in an office landscape with office employees. The study design was piloted prior to the full-scale office test.

7.1 Laboratory test

A first trial run was performed in a lab environment to investigate the possibility to enhance the room ambience by actively adding sound, thereby creating a barely noticeable sound environment influencing the user. The trial run was conducted through three iterative phases:

- An *exploration phase* where the conceptual ideas and the first examples of the sound designs were developed.
- A first *office simulation test phase*, in which an in vitro test scenario was developed and presented with the visual support of video recordings from working spaces. Immersed in this virtual environment, two sound experts helped to evaluate our first sonic sketches.
- A second office *simulation experiment*, in which the sounds were slightly improved and incorporated different video stimuli; the experiment was conducted with the help of 4 work-environment experts and 3 open-office employees.

7.2 In-situ test location

The chosen location for the in-situ test was a table with seating for 10 people in an activity-based office at the IT department in a large manufacturing industry in West Sweden. Table occupants worked both individually and in groups. The table was characterized by spontaneity as several group meetings could take place simultaneously and sometimes meetings would end up in new meetings among team members. The table was located in front of three conference rooms that generated a stream of passing people. The immediate environment thus became a natural gathering place for spontaneous meetings and conversations. The location of the collaborative prototype was inside a frequently used meeting room with one large table for 10-15 people behind the abovementioned table.

7.3 In-situ Pilot study

Prior to the main field test, we conducted a pilot test during 8 days, to determine if the study design was suitable. 16 test persons performed self-selected work tasks while using the individual prototype. Which sonic environments the participants played, how long they were played as well as what amplitude level the user chose was logged. After the test, the participants answered a questionnaire, with background questions about gender, age and perceived hearing sensitivity, work-related questions and overall questions about the sounds and their experience of using the prototype.

7.4 In-situ Study

Forty-three test subjects were recruited to the experiment, which had undergone a relevant change: random assignment of sounds to interface buttons. Participants were asked to answer a questionnaire, which was slightly improved relative the pilot test. All participants were observed and they also had the opportunity to read through the observation protocol to comment and clarify any misunderstandings. The observer took notes on visual and auditory events and how the test subjects seemed to react to the events. Two test participants were recruited to use the prototype for an entire working day, and these test sessions were followed up with supplementary semi structured interviews. Questions included if they perceived the sounds differently during the day and why they choose the sounds.

The recruitment of test subjects for the collaborative setting was more difficult, since all meeting delegates had to accept having the sound environment running during the meeting. Also, observation in the meeting room was not allowed due to meeting confidentialities.

8. RESULTS

8.1 In-situ study

Of the 43 participants in the individual experiment, 12 were female and 31 were male, which reflects the employee ratio in the office. The participants ranged in age from 24-58 with a mean of 38,7. One person reported impaired hearing. The collaborative experiment failed in getting enough participants to complete the test due to the abovementioned difficulties, and therefore are the results below derived from the individual experiment only. The research questions are answered as follows:

8.1.1 How do users perceive the acoustic environment with the sound bubble compared to without it?

In a direct question enquiry with the categories (better, same or worse), participants were asked how the sound bubble changed their sound environment. 74.4% answered better, 16.3% answered the same and 9.3% responded worse.

8.1.2 How do users perceive and describe the sound bubble and their experiences with the different sounds in the bubble?

To evaluate how the users perceived our designed sound environments we applied Axelsson's model from 2010 [29]. The model is based on several previous works since the 80's and provides pertinent criteria for the assessment of an environment. The participants were asked to evaluate the added sound environment they preferred in terms of 4 criteria-pairs, presented as 8 separated criteria: pleasant-unpleasant, eventful-uneventful, peaceful-chaotic, exciting-monotonous. The results below show the qualities characterizing the sound of each participant's preferred sound. The analysis shows which characterizing criteria the participants preferred.

Two criteria present a well-defined dominance, pleasantness and peacefulness, where participants clearly state a preference for their positive dimension *pleasant* and *peaceful* (see Figure 3, right). A participant described the experience in this way: "*The sound I chose was pleasant and I could ignore the [sonic] details, it did not change too much. The sound was very constant. [...], it was in the background all the time. It was easier not to focus on it. The wind sound (A) was a bit too significant, I was thinking too much about the sound and too little on the job.*" The qualities pleasant and peaceful seem to be globally reinforced for the preferred sounds and in particular for sound 5 (in black). One participant described her experience as: "*A sonic wallpaper that gave a faint pleasant sound*", "*Silence in a wave noise*", and "*The sound felt both calm and gave focus.*" A high correlation can be observed between pleasantness and peacefulness (see figure 3, rightmost graph).

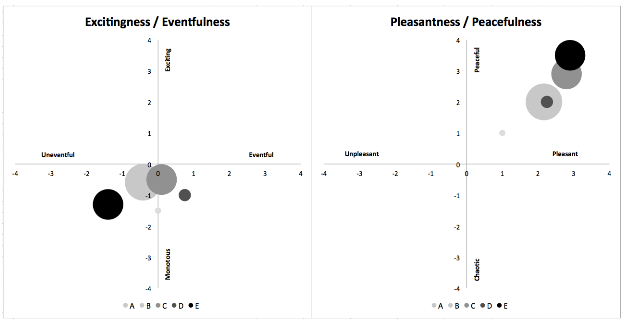

Figure 3: Two graphs showing the results of the evaluation of preferred sounds by the participants. The graphs analyse correlation between excitingness and eventfulness (left) and pleasantness with peacefulness (right), with a high correlation degree for this second case. The physical dimension of the spheres corresponds to the number of people having chosen each sound (preference).

For the criterion excitingness, the preference is less clear but is always presenting a tendency in favour of monotonous sound environments (relative exciting ones).

Finally, regarding the criterion eventfulness, it's even more difficult to describe a clear tendency towards one of the poles; two of the three preferred sounds (E and B) seem to present a narrow tendency towards the uneventful, while C and D are on an average value.

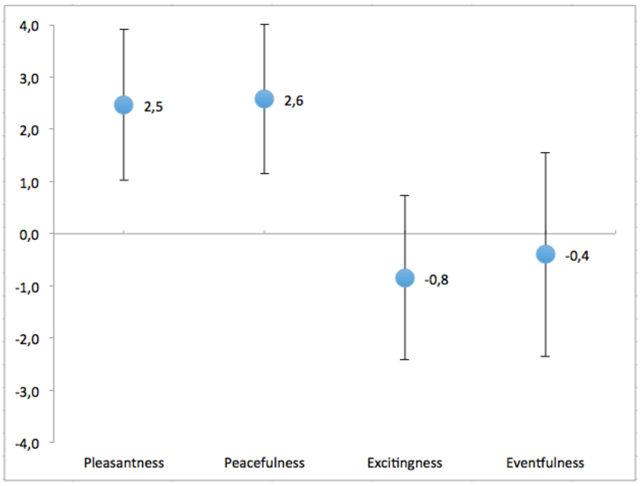

Figure 4: A graph representing tendencies for each one of the four criteria analysed. The graph shows the average value for each criteria as well as the total deviation range.

In general, all criteria are characterized by a low deviation degree of the results for the different sounds, even narrower when just considering the preferred ones (B, C and E). This low deviation degree indicates that the preferred sounds present, for the participants, a quite well-defined character (limited variation in range) regarding the criteria evaluated. Summarising, this character corresponds in general to pleasant and peaceful sounds, with a less marked tendency towards monotony, and a medium degree of eventfulness (not eventful, nor uneventful either).

A participant declared that: "*The sound I listened to most was relaxing, one might say that it brought me back [to focus mode] when my thoughts drifted away. It was just kind of present all the time. Some were disturbing because I thought that they maybe had a too fast tempo or if there was too much happening.*"

A male participant who was critical to his experience stated that the sounds became disturbing/distracting after some time. He described the experience as: *"The sound was too monotonous. After a while it became annoying.*"

The majority of the test subjects gave descriptions of their experiences showing that a sound environment should provide both functional and aesthetic values, as illustrated by: "*I prefer the sounds that sounded more musical. I usually listen to music while I work. Other sounds than talking people were pleasant.*" One test subject who described the preferred sound as restful stated that: "*I felt less disturbed by noise from the office.*"

The participants were asked in open question which was later categorizes, how they chose the sounds. 52.2% answered that they chose the sound because it was the most pleasant, 17.5% felt that the sound they chose was least disturbing, 12.5% answered that the sound helped them to concentrate, 10% answered that the sound blocked out surrounding sounds and 7.5% answered that they didn't know the reason of their choice.

8.1.3 Which sound environments are preferred and used?

Sound B, the most popular sound, was preferred by 31,6% of the participants, 26,3% preferred sound C and just as many preferred sound E, the placebo (26,3% too), 10,5% preferred sound D. The least popular sound was A (dynamically filtered pink noise), which was preferred by only 5,3 % of the participants.

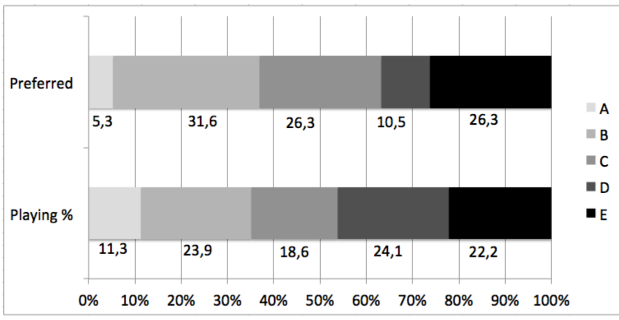

Figure 5. Preferred sounds and playing time percentage.

9. DISCUSSION AND FUTURE WORK

The results provide evidence that the sound bubble presented advantages over the usual acoustic environment in the activity-based office. The large majority of the participants responded that the sound bubble improved the auditory conditions and facilitated focus and concentration. Regarding which of five sound environments that was more attractive and worked better, still remains unclear and needs further investigations. Our results show that the character of the sound should be pleasant and peaceful, but the participants have different opinions of which sound that bring such sensation. One reasonable explanation is that the preference is based on different subjective and individual interpretations of the added sound material; this would point to the problem of sonic/musical taste conditioned by diverse cultural and education backgrounds. In this research project, careful attention was employed on avoiding as far as possible such musical prejudgements by exploring a sonic material as non-musical and abstract as possible, but we cannot discard such tastes operating at different levels other than just as a direct matter of musical language.

We argue that those who experienced the sound environment with the sound bubble as better than without it, actually helped the participants to end up in hearing mode or everyday listening mode. If so, the sound bubble succeeded in establishing a sonic micro-milieu which provided masking, in attention terms, from disturbing background sounds. These results are based on participants' perception of attention and productivity by self-assessment of their experiences only, and should be complemented by studies of actual gain in attention and productivity. That is planned in our future work.

Regarding preferred sounds, the three most popular sequences were one designed for concentration, one for collaboration, and the "placebo" sound. Our findings show that the most popular sounds predominant characteristics were pleasant and peaceful, with a less marked tendency towards monotony and a medium degree of eventfulness; revealing the importance of both aesthetical and functional values.

The least popular sound was the pink noise. These findings correlate with Schlittmeier and Hellbrücks study [21] in which participant ratings spoke in favour of legato music instead of continuous noise as an added acoustic background. They propose that inserted sonic environments must be specially designed with respect to both objective performance effects and subjective ratings. The majority of the participants considered the sound environment in the bubble as positive in comparison to the usual acoustic environment. The reasons given by the participants were that the sound bubble provided aesthetic qualities to the sound environment and supported focused attention by masking out unwanted sounds while still letting the users pick up information from the environment. We can therefore conclude that an active acoustic approach has clear potential for generating place-specific sound environments that better satisfy individual auditory needs in today's office environments.

In terms of future developments of this project, a main concern will guide the next coming phases: enhancing the adaptive nature of the inserted sound environments, developing the system's capacity to "listen to" and analyse the surrounding sounds in order to provide a more accurate sonic response to each situation and context. Further developments should also provide means for the sound bubble to adjust not only to environmental conditions, but also to personal biometric data such as pulse or stress.

It is still not possible to deny the presence of external compositional minds in the development of such inserted environments; however, the final aim of this research project is to evolve this role of a designer/composer more into the one of a sound programmer able to model the patterns of a basic intelligent dialogue with a given context.

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