2015

Designing Activity-Based and Context-Sensitive Ambient Sound Environments in Open-Plan Offices

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Abstract. This paper addresses the problem of sound disturbance in open office environments. We have in a design-based research study explored how digital, real time generated sound can be added to a work environment and how these sound environments are perceived by respondents when performing work tasks. In this first explorative study we have chosen to focus on designing a digital sound system for activity-based offices, where the physical environment is already designed for particular activities. Our approach is to explore if adding appropriate acoustic designs to the ambient environment can enhance workplaces. Our results show that test subjects perceived that acoustic design could enhance the ambient environments if the acoustic design is pertinent with the environment as a whole.

Keywords: Acoustic design · activity based · context-sensitive · ambient sound environments · open plan offices · design-based research · participatory design · sonic interactive design.

1 Introduction

The proportion of office workers in Northern Europe has increased in recent years and one of the problems that have emerged is how to achieve suitable acoustic environments in offices. It has been demonstrated that normal levels of low frequency noise affect our work capacity negatively when working with difficult problems or memory intensive tasks [1]. Low frequency noise originates from fan noise, ventilation, or various types of office machines. In that study, the low-frequency noise was generally perceived as disruptive, and for noise-sensitive people faced with high workloads, the noise caused physiological stress as well. Moreover, high-frequency noise affects human productivity negatively [2]. A poor acoustic environment creates stress, which, in turn, leads to an increased sensitivity to noise in general [3]. This means that even minor noise disturbance may become problematic over time.

The largest source of noise disturbance in office environments is considered to be co-workers talk [4][5]. Open environments can cause problems of noise disturbance on the one hand, but can also generate better knowledge sharing, and ease the communication between employees.

Sound perception is generally emotionally conditioned: a general positive attitude towards the work environment entails in a greater tolerance for the acoustic environment [6]; sounds derived from things we like are considered as less disturbing [6]; sounds that we understand the meaning of and which we find useful disturbs us less [7]; constant noise disturbs us less than occasional, sudden noises [2][7]; and finally what type of work to be performed also affects our sound sensitivity.

Earlier types of office work were process-oriented and consisted mainly of routine work, however, today office environments needs to support knowledge work and the "knowledge economy" [8]. Activities or tasks that require problem solving, reflection and concentration can make us more susceptible to noise disturbance. When designing open plan offices, two contrasting requirements must be fulfilled simultaneously; to support concentrated individual work as well as collaborative work in the same work environment. In [9], it is argued that customizable workspaces are needed to meet these contradictory requirements for supporting complex tasks, in order to maximize work effort and value. According to [8], interaction between people such as informal social networks has the most positive effect on office work productivity, and the latest trend is that office environments should support "the creative economy", where creativity, innovation, knowledge building and knowledge sharing activities are in focus. In recent years, flex-offices and activity-based offices have been gaining in popularity in comparison to individual offices. The basic idea behind flex-offices and activity-based offices is that there is not one fixed workplace for each individual as in traditional offices such as individual offices and open plan offices. Rather there are common workplaces accustomed to different purposes available to all employees to choose from based on current activity [10].

In [11], it is studied how different office types affect health and productivity. The study involved 1,241 employees from governmental and private companies and open-plan offices, flex offices and individual offices were compared. The open plan offices were considered worst in terms of health and productivity and individual offices were considered least problematic. However, the study showed that it is primarily our ability to stay focused that is affected, rather than our health. We chose to study activity-based offices since every place has distinct and specific function in such office type: there are quiet sections where talk should be avoided specifically designed for concentrated individual work as well as collaborative sections where talking is allowed and encouraged, i.e., the physical environment in these offices already have activity-based designs. Therefore, are such offices suitable to explore whether a physical workplace can be enhanced and support the designated activity better by means of activity-based ambient sound environments.

To summarize, we can conclude that the experience of a workplace acoustic environment is a complex phenomenon that depends on numerous interacting factors including; *type of office work*; *work-rate variability* (supporting both concentration and collaboration); *work task complexity*; a balance between *visual and sonic privacy*; a balance between *distraction risk and proximity to employees*; as well as *individual differences* such as distraction sensitivity and noise sensitivity. This leads us to our overall research question: *Can acoustic design enhance the ambient sound environments in open-plan offices?* We address this question, by exploring the

following 3 sub questions related to the design issue, the methodological issue, and the design effect in the workplace:

1. *What are the characteristics of ambient sound environments for open plan offices?*
2. *Which methods are suitable to explore and evaluate ambient sound environments?*
3. *How will such sound designs affect the workplace environment?*

The paper is organized as follows; first we explain the basic acoustic concepts informing the sound design. Then, we explain our research approach and methodological issues related to studying a sound environment, which is meant to become an almost imperceptible ambience. The design process is described, followed by results from the experiments we conducted using these digital, context-sensitive sound designs. Finally, there is a discussion, and concluding remarks.

2 Theoretical Concepts

This section describes basic acoustic concepts important for understanding how we perceive surrounding sounds and how these sounds affect the way we hear. The term acousmatics, our four listening modes (listening, hearing, present, understanding) and three sound categories (signal sounds, background sounds, ambience) are explained.

3 Acoustic Theory

Acousmatics [12] is a concept that addresses issues of sounds that we hear without seeing the original source of the sound, such as sounds distributed through speakers, which are more difficult for humans to interpret and understand. If one hears a sound without being able to associate the sound with a source, the spontaneous reaction is to try to interpret the sound by associating it to something previously experienced, which can vary considerably between individuals. Sounds that are perceived as intrusive or unnatural in that environment call for people's attention and interpretation. Hence, a generated acoustic environment needs to "fit" into the visual environment to not attract unnecessary attention or confusion. This leads us to the assumption that creating as authentic test environments as possible is important, e.g. by establishing congruency between visual and auditory stimuli in listening tests.

According to Pierre Schaffer's aesthetics Musique Concrłte theory [13], sound perception is categorized in four different "Listening Modes": listening, hearing, present and understanding. *Listening* involves the collection of information; where we direct our aural attention to someone or something in order to identify the event such as a scream, and its source, the screaming. *Hearing* is the most elementary perceptual level, which means that we passively take in sounds that we do not try to listen to or understand. *Present* however involves a processing and a 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. The interpretation is often culturally and experientially conditioned. In contrast to the theory of listening modes that have a

receiver perspective, Pascal Amphoux identified three sound categories [14] based on the transmitter perspective: sound signals, background sounds and ambience. *Sound signals* are sounds that appear suddenly and are sufficiently different from the existing acoustic environment to be perceived as an unusual or unexpected sound that makes us listen. The transmission category sound signals correspond to the receiver perspective listening. *Background sounds* are sounds that do not attract our attention to active listening, it is characterized by continuity and duration, and the sound is perceived as a continuous stream of similar sounds. The category background sounds corresponds to the listening mode hearing. The third category *ambience* is defined as a composition of the existing sounds in an acoustic environment, i.e., the composition of sounds that create a location distinctive character through its specific dynamics in terms of movement, rhythm and alteration of audio components. Ambience corresponds to present but can vary over time and also represent listening or hearing. Thus, the approach of adding sound components to an existing sound environment in order to enhance the acoustic environment falls into the category ambience sounds.

In a study [15] where listeners evaluated recordings of urban outdoor soundscapes it was shown that soundscapes dominated by synthetic sounds were experienced as unpleasant, those dominated by natural sounds were experienced as nice and those dominated by human sounds was perceived as eventful. However, perception of sound is situation-dependent. For example, in [16] and [17], the authors argue that lack of negative noise does not necessarily imply that the environment is perceived positively, whereas in [18] a noisy hospital environment was perceived as secure, due to the presence of technology and staff so in this case the noise was considered positive. This further shows the complexity related to sound environments perception, and thus the need to study such experiences in a holistic and multifaceted way.

4 Research Approach

The overall approach is grounded in design-based research [19], which is a systematic but flexible methodology aimed to improve practices through iterative design interventions. The method involves cycles of analysis, design, development, and implementation, which are iterated and successively refined in order to reach contextually sensitive design principles and theories. Our approach is further grounded in contextual design [20] a design methodology where the context is of great importance, and participatory design [21] where user's active participation in the design process is vital.

We also find support for the approach in Sonic Interaction Design (SID), an interdisciplinary field, which has emerged as a combined effort of researchers and practitioners working at the intersection of sound and music computing, interaction design, and human-computer interaction [22]. SID follow the trends in the so-called third wave of human-computer interaction, where culture, emotions and experiences, rather than just functionality and efficiency, is included in the interaction between man and machine [23]. SID also aims to identify novel roles that sound may play in the interaction between users and artefacts, services or environments [22]. The means

intervention by acoustic design [24], which deals with the change of sound sources in relation to the architectural design. Acoustic design implies that the function of sound is to support activities in a particular location, i.e. it must be contextualized. A certain place that "sounds good" is not necessarily quiet; the quality of the sounds is rather linked to the following: how sounds are articulated and understood, how sounds activate people and how sounds are related to the architecture as well as cultural and aesthetic connections.

5 Methodological Issues

A central issue for sound design (even more so than for visual design) is that the designer cannot be sure how others will perceive and interpret the designed sounds. An experiment was conducted to compare the sound designers' intent with the actual interpretation of designed sound environments [25]. In 19 of the 25 audio elements, responses were consistent between the designer and the listeners by over 80%, which suggests that at least on an analytical level, there is some form of consistency of how the sound elements are perceived. However, it tells us nothing about the subjective valuation of the acoustic environment as a whole.

In this study we applied an exploratory approach to the acoustic environment design, suggestive in nature, since there are no clear results or directions to base the design on. Previous research has shown that the methods for evaluating soundscapes differ and the need to consider a variety of methods for noise assessment was raised in [26]. Suggested methods included, but were not limited to, questionnaire assessments, interviews and group discussions. Likewise, in an experience-based design study [27], it was concluded that experiences are affected by individuals' feelings, values and experiences and that experiences are highly subjective, situated, and difficult to predict and talk about in general terms. Hence, the authors claim, experience-based design should be experimental and indicative and user testing needs to be based on simulated or real prototypes in real contexts to give reliable results.

6 Design Process

In our study, we have so far conducted and completed the following phases:

1) An *exploration phase* where the conceptual ideas and the first examples of the sound designs were innovated.

2) An *office simulation test phase*, in which the test scenario was developed and evaluated using experiments with sound experts in a laboratory setting simulating an office situation.

3) An *office simulation evaluation phase*, in which the designed sounds were evaluated using experiments with work-environment experts and open-office employees, also in the office-simulating laboratory setting.

Hence, we have completed one design-innovation phase, and two design-evaluation phases where the first is an expert evaluation and the second the first end-user evaluation. However, both evaluation phases are conducted in a simulated

context. The next step is to evaluate the sound environments in real offices by designing a technical sound environment prototype that can be used in these offices.

7 Exploration phase

The research question addressed in this phase is: *What are the characteristics of ambient sound environments for open plan offices?* The phase consisted of designing sound concepts based on problematizing open plan office work activities and applying acoustic theory in that context. These concepts were then transformed into concrete sound designs, used in three experiments focusing on: the sounds designs, the laboratory simulation test scenario, and the combination of the previous.

7.1.1 Exploration phase – Conceptual Sound Design

The conceptual designs proposed here are mainly based on acoustic theory, on previous research and experiences from soundscapes and sonic interactive design. As a first attempt, we decided to concentrate on two activities that are each other's opposites: individual, concentrated work and creative teamwork. Our aim is to explore i) if it is possible to design sound environments that are perceived as pleasant ambient environments at all, and ii) whether there are sounds "suitable for" a certain activity, i.e., whether there is general preference of a sound designed for a particular activity. The latter aim motivates choosing activities with different characteristics.

Based on acoustic theory and related work, the sound designs needs to respect the following general criteria: The sound designs should be perceived with the *hearing mode* only, which means they have to consist of background sounds and be ambient enough not to attract too much attention. However, one purpose is to camouflage over-hearing undesired talk, so the sound levels have to be strong enough to mask such unwanted listening and they need to be sensitive to contextual changes. Finally, the sound components should not be target of interpretation, so the sound composition needs to be unfamiliar enough so that most people do not recognize it as something familiar. Therefore, music is ruled out, both since preferences are too diverse and also because it can attract too much attention so people start listening.

Our idea is to digitally manipulate the environment's existing ambience sounds instead of adding sounds from other contexts, in order to make them appear more natural in that context. The sounds are designed to blend into the environment and we hope it will be perceived as a continuous stream of similar sounds and thereby trigger the *hearing* mode only. In *hearing* mode, the perception of sounds is not directly diverting attention away from other cognitive tasks.

7.1.2 Exploration phase – experiments

All tests and experiments took place in the sound studio at University College of arts crafts and design in Stockholm, Sweden. In order to create a test environment in a laboratory as authentic as possible, we tried to simulate an office environment. For this purpose, the ambient sound as well as the visual surrounding of an activity-based

office were recorded and played back in the laboratory during the tests as a way to simulate a real office environment. The recorded sound environments were adjusted to acoustically fit the location, and manipulated according to the two selected activities. Two modulations were created, one meant to stimulate concentration (1) and one meant to stimulate creativity (2).

Three experiments were conducted in the exploration phase. In *experiment 1* the conceptual sound designs were tested by two of the researchers. Both researchers are sound design experts and have vast sound experiences, one has expertise in test methods as well as.

To test our sound design and our experiment setup, *experiment 2* was conducted by having two test persons experience the simulated office environment. It consisted of a recording of the new sound designs mixed with the sound environment from the simulated office. A video from the office was displayed on one of the walls, in sync with the office sounds. The purpose of the video was to provide a visual background in order for the test person to image the office environment and get visual clues to interpret the office sounds. The video was taken from two fixed positions viewing the office space from a third person perspective. The two locations selected were a part of the silent section in a corner of the office and an open space in the middle of the office where a steady flow of people were passing. The silent section was chosen because it was adapted for concentration and focused thinking, the open space was appropriate and used for creative thinking and spontaneous meetings. From the recordings in the activity-based office the two modulations were generated. The recordings were changed rhythmically and temporally and through quenching certain frequencies, and amplifying other frequencies. The copy was then mixed with the original recording.

The test persons in experiment 2 were asked to perform a self-selected, for the person normal office activity during the listening tests, with the purpose of diverting the participants' focus from the acoustic environment and instead engage in office work. A researcher with experience and expertise in user test methods acted test person and tried out the scenario.

Experiment 3 was the last step in this phase. In this experiment two other sound researchers, unfamiliar with the particular designs, experienced the same test scenario as in experiment 2 in the laboratory. Both researchers are sound experts and have vast sound experiences. One is also expert in test methods and one expert in office design.

7.1.3 Exploration phase – results and insights

The exploration phase included analysis of reasonable acoustic variability parameters; the creation of aural concepts for different activity types and experimenting with different parameters and parameter settings to try to achieve the sound atmosphere we aimed for. Since previous studies [28] have shown that the sound needs to be consistent with the physical environment, our starting point was to use the sounds already present in the offices in question, instead of e.g. adding nature sounds that can be perceived as strange in this context. However, the idea was that these sounds would be modified, e.g., by changing the frequency range, by using

delay effects, by creating certain rhythms or trying to mask speech by adding sounds that absorb the experience of major changes in the original sound image. We opted to start from two typical but opposite activity types that are often singled out in previous research: individual concentrated work and creative collaboration.

Our first design concept was that for concentrated individual work to create a sound atmosphere that is perceived as spatially confining, soothing and directed attention inward. The sound should also be experienced as monotonous to be positioned cognitively in the background, activating the hearing mode. Here we figured we could use a subtle rhythm corresponding to quiet breathing, calm smooth rhythm, and sounds that are panned from one side to the other to direct focus towards the individual's centre.

The second sound design, for creative collaboration, we tried to create a sound that gave the experience of space, high ceilings, sound textures that arose from random locations in the sound image with some unexpected elements to simulate the idea of opening up the senses, be open to the unexpected, and thereby stimulate creativity.

The first experiment ensured that the envisioned concepts seemed reasonable in practice and that the two sound modulations were perceived as intended at least by the inventors of the concepts.

During experiment 2, the test scenario in the simulated office was evaluated. Our insights from experiment 2 were that the overall setup seemed to work but the 3rd person perspective on the background environment was not very realistic and too static. It was therefore decided that filming should be done with a Go-pro camera attached to the head in order to better simulate a work situation and try out a 1st person visual background.

Experiment 2 resulted in changing Modulation 1 by extracting a short segment from the original recording and creating a loop, by manually raise and lower the volume and record this, a more natural wave motion were created. It also emerged that an additional modulation (3) would be created. That modulation should act as a melodic complement to the concentration stimulating modulation, where the same effects and settings were used, except that a resonator simulating string vibrations were added. The resonator was used to make it easier to distinguish between the three modulations. Experiment 2 also resulted in a semi structured interview guide.

Insights from experiment 3 were that the sound design of the modulations seemed to work but the test needed a livelier environment for recording.

8 Office simulation test phase

The research question mainly addressed in this phase was*: Which methods are suitable to explore and evaluate ambient sound environments?*

8.1.1 Office simulation test phase – experiments

Since the first recording was performed in a relatively empty office, a livelier environment at University West was selected, and thereby new sound modulations had to be created from the new environment. The new work environment was

recorded and filmed to explore if the sound design were adaptable to different sound environments but also how suitable the principal sound design were with different visual environments. Ambience level (i.e., noise level) in the work environment was measured to make sure the noise levels were equivalent between the studio and the recording site.

Experiment 4 was conducted as a study design pilot with two students in order to test how the experiment-setup and the post-sound-experience inquiry worked out using the new sound designs and video recording. The *study design pilot* was divided into two parts; in the first part the students were asked to work with their own tasks at the same time as the acoustic environment was played. The three modulations were slowly faded in and out in the meantime. This was followed by a group discussion with the students to find out how they had experienced the working environment.

The next step of the phase was to perform experiment 5, *work environment study, in order to test the sound environment with participants from real user groups.* Three test subjects participated. All three had office work experience, two had expertise in office work design and one had sound experience. The study was conducted in the same manner as the pilot study with the difference that the sound modulations ended abruptly during this test in order to attract attention post intervention.

8.1.2 Office simulation test phase – results and insight

From experiment 4, *Pilot study,* it became evident that we needed to ensure that all test subjects had substantial previous experience of office work, preferably from different office types, in order to understand the situation of working in an office landscape. Previous experiences affect the test subjects' ability to relate to and thus ”play along” with the test scenario, in particular in a simulated environment as in these experiments. The test subjects of the pilot study, being art students, were used to working solely and with music in their headphones, which meant that they were not accustomed to reflect upon the general sound environment. The experiment design also needed modification by creating clear transitions between the modulations. One of the test subjects commented on modulation 1 as follows: *"It was very noisy, it felt like the noise increased at times and it was very distracting. It was sweltering, as if the walls came closer, the noise was really strong."* That the test subject did not like modulation 1 may partly be explained by that the amplitude was too strong in relation to the background noise and therefore became intrusive. The comment led to the conclusion that modulation 1 required adjustment. Modulation 2 was experienced as a bit distracting: *"It was pretty nice; but from a work point of view it was a bit distracting. Had it been continuous, it would not have been distracting. It became distracting because something happened."* The two test subjects only paid attention to one of the modulations each, which lead to the conclusion that the modulations at the next listening test should be faded into the original acoustic environment but be abruptly ended as an attempt to make people more aware that a change in the sound had occurred, retrospectively. This method has been used in other experiments with the desired effect. Altogether the setup seemed reasonable and to focus on own activities facilitated the listening experience.

Experiment 5, *Work environment* led to the insights that when test subjects arrived at the sound studio the recorded background sound should already be present in the background. The studio is extremely quiet which creates a great contrast when the listening test starts. That way, the only change in the test environment would be our sound designs, not the simulated background sounds. Moreover, the modulations should be longer in order to give the test participants time to get used to the sounds. The test sounds were much improved but needed some minor sound level adjustments: modification 2 needed to become more damped and we decided it should be faded in a bit subtler. The test subjects in experiment 5 really liked modification 1 (concentration) with noise waves in a breathing rhythm; they felt it was pleasant and soothing. However, we realised that modification 1 could be further clarified and refined by extracting white noise and used as "wind". No one seemed to notice modification 3. Perhaps they could not distinguish it from modification 2, or the test subjects could also have become accustomed to the test situation and were immersed in their job tasks instead.

Insights from experiment led to a modification of the inquiry method. A second part was added where the inquiry was enhanced with clips from the sound designs in order to expose the test subjects and stimulate their memories to reveal ambient awareness.

9 Office simulation evaluation phase

The last phase addressed the following research question: *How will the sound designs affect the workplace environment?*

9.1.1 Office simulation evaluation phase – experiments

The next step was to conduct experiment 6: *work environment study with a work environment expert.* The test subject has sound experience and office work experience and is also an expert in office design. The first two parts in this study was conducted in the same way as with the semi experts, however, a third and final part was added to further trigger a discussion. In the third part, the test subject would hear every modulation both with and without the original sound environment, and then describe their perception of the modulations as well as for which kind of work situation it seemed suitable for (if any). The last step, experiment 7: *work environment study with experienced activity-based offices workers,* was a repetition of experiment 6 in which three test subjects participated. All three participants had vast office work experiences and two participants had office design expertise as well.

9.1.2 Office simulation evaluation phase – results and insight

The test subject participating in experiment 6, the work environment study with work environment experts, belonged to an important but difficult target group with individuals suffering from high noise sensitivity. The participant strongly emphasised before and during the test: "*I'm really sound sensitive*".

The test subject experienced modulation 1 (concentration) as pleasant: *"The first, I could not tell if it was just a fan noise or whether it was noise from the ocean. I could listen to this when I'm writing, being totally alone."* The test subject liked modification 3 best (collaboration): *"I liked this a lot. It was easier to listen to and it was a little more distinct in some way. It suited me better. It would probably fit in number of situations. [I liked] that it [the sound] was clean and it was rhythmic in some way. It was that metallic sound, a little meditative. It reminded me of yoga."* The test person perceived modification 2 (creativity) as too intensive: *"When the two sounds were combined (original and modification), it was too much."* Experiment 6 indicated that the sound designs worked well also for individuals having a high hearing sensitivity.

The three test persons in Experiment 7: *work environment study with experienced activity-based workers*, all had relatively long experience with various office types. They estimated that they spent between 80-95% of their working time in their respective offices. They thought the test environment differed from their office environments in the following ways: Two of the respondents considered the sound environment in their office as too quiet: *"It has become so quiet so that you yourself know that you disturb others. There [in the quiet zone] it is so quiet that it almost feels like your eardrums get pulled in the wrong direction."* They evaluated the overall noise level during the test session as much stronger than in their office and less logical: "*It's the changes that cause disruption*", "*I reacted when it started*", *"When the music appears, who the hell comes up with the idea to play electronic music here? And it keeps on going, is it going to end soon?"*, *"It is neither positive or negative. It wasn't the sound but the illogical changes that was disturbing"*, *"In my case, when the fan noise starts. The professional in me wakes up and I wonder what's wrong with that fan. It should not sound like that"*.

Two respondents liked modification 1 (concentration): "*I had no problem with the fan noise itself, which I thought was a bit nice"*, *"Yes, the sound itself, I had no problem with it. I could work listening to that sound"*, *"If you are sitting by yourself, the fan sound is better. If I should choose a sound"*, and one did not: *"I did not like the sound of the fan. I did not like the feel of it"*.

It became clear during the group discussion that whether or not sounds fit depends very much on the culture at the office: In one of the offices both sounds were considered possible: the "fan noise" was considered viable for tasks performed alone and "the music" could be played in the lobby. In the second office on the other hand, it was considered as impossible: *"I would not be able to place them somewhere, someone would surely panic in the end. Possibly where you drink coffee and eat. There, it would be nice to have music. There is no space for any sound at all if you sit 20-25 people and have to concentrate. Sounds that are not a result of the work itself is probably totally out of the question. You may not deviate. You must respect everybody."*

To summarize, we conclude that it is necessary to test the sound designs in real office environments, as expected. It is very hard for test persons to imagine how one will experience these kinds of ambient, subtle environmental sound changes in a real office context.

9.1.3 Office simulation evaluation phase - Insights and Results.

The results of our iterative development process shows, as expected, that the perceptions and interpretations of the three sound designs vary between individuals, in accordance with previous research. However, one or more test subjects liked any of the three modifications. The majority perceived the first modification as soothing, better for concentrated work, when sitting alone. The second or third modification was perceived as suitable for collaboration, in meetings, in the lobby or dining areas, and test subjects associated the sounds with spa music or Yoga. These preferences were in accordance with the intended use.

10 Discussion

Since this work is novel and the area quite unexplored, our results are suggestive so far, and needs further investigations. Yet, we have identified tentative characteristics of ambient sound environments for open plan offices. The following *general characteristics* are based on acousmatics [12] and acoustic design [24], and describe a sound environment to be 1) an ambient, background sound, which will 2) camouflage (mask) undesired talk, 3) be sensitive to contextual changes, and 4) be an unfamiliar sound composition.

Such description, however, does not provide information of how to create the sound environment in any given situation. Acoustic design theory state that sounds must support activities, but not how this is accomplished when it comes to sound design. As a starting point, we have suggested two sound design concepts targeting different common office work activities. As a first attempt to characterize a *sound environment for individual concentration work* we suggest it to be spatially confining, soothing, rather monotonous, and to direct attention inward. A *sound environment for creative collaboration*, on the other hand, we suggest to provide a perception of space, sensation of high ceilings, and contain unexpected elements.

Our experiments so far show how sensitive the sound designs are to situational circumstances; individuals make different personal interpretations of sounds (e.g., sea waves, fan noise, yoga) regardless if this was intended or not. The sound must fit the surrounding environment, but it should preferably also be perceived as positive or beneficial in some way. For example, in order to immerse the listeners, the levels had to be precise; when sound was too strong the listeners went into listening and/or understanding mode and became disturbed. On the other hand, if the sound was too subtle, it was not recognized or may have no effect at all. The balance is fine-tuned, and must be explored further in longer studies in real office environments.

As anticipated, it is challenging to find reasonable ways to test and evaluate such ambient sound environments in an early stage. To setup a test situation of phenomena that should be peripheral to the participants' attention and consciousness is a real challenge. For example, we realised that any sudden change transferred the participants from hearing mode into the more conscious listening and understanding mode. This effect was deliberately used in the test scenario: when introducing new sound environments the sound modulations was smoothly added not to cause any

attention, whereas when removing a modulation it was abruptly stopped. This way we didn't interrupt the test subjects when introducing something new, but made them aware of that something was missing when it was stopped.

Using a video recording that is congruent with the enhanced ambient environment we believe helped immerse the test subjects and created a more realistic test-situation. This is a new approach that we have not seen elsewhere, but it is grounded in the theory of acousmatics. However, the visual feedback was more realistic if the video was recorded in 1st person view simulating being in the environment. The method described in this paper was suggestive as recommended in [25] for experience-based design; it was highly iterative with small alterations between tests, and truly explorative in nature. It gave insights on the conceptual level, basic understanding of the phenomena and was useful as a first feasibility test. However, it must be complemented with in situ longer experiments.

Addressing the question how these sound designs affected the workplace environment; we only have some early indications based on this office-simulating laboratory study. The test subjects started in the listening or the understanding mode, but after a while they got accustomed to the situation and went into hearing mode, due to the length of the test and the slow changes between the modulations. If the design of the added sound is based on the same rhythmic and temporal structures and the amplitude is similar to the original recording, the test subjects that were focused on their work were in hearing mode and had difficulties noticing changes in the ambient environment. Some of the test subjects said that the sounds were a bit annoying, but when we played the different modulation afterwards they had not noticed there were three modulations; which indicates that they changed modes. The test subjects stated that when the ambient environment embedded them and was pertinent with the environment as a whole they were most pleased with the sounds and stopped focusing on the ambient environment and started focusing on their work tasks. We conclude that acoustic design can enhance an ambient environment by adopting the environment to an activity in a way that enables users to maintain *hearing* mode.

11 Conclusions and Future Work

Our results suggest that ambient sound environments should be context-sensitive, support user activity by not being to eventful and not steal too much cognitive attention and at the same time they should be immersive to help the user mask out noise. Our suggested sound designs seem to accomplish this goal. The preliminary results are positive enough, that it is of interest to proceed with the concept.

Future work will focus on implementing sound in real contexts, starting with activity-based offices. Two prototypes will be developed based on the concepts in this paper: one small private sound environment for individual work and a larger collaborative sound environment for meetings. These prototypes will be tested and evaluated in an activity-based office for a longer period of time in order to iteratively modify the prototype and investigate whether cognitive, ergonomic, and experiential effects emerge over time.

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