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CHARACTERIZING NEW MODALITIES OF SHARED OFFICES: A DIARY-INTERVIEW METHODOLOGY TO INFORM AUDIO AUGMENTED REALITY APPROACHES

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ABSTRACT

Noise is a persistent issue in indoor environments such as shared offices, where acoustic treatments may not provide sufficient auditory comfort. Sound masking systems, which reduce speech intelligibility by adding background noise, can be effective but typically increase overall sound levels, leading to very mixed results in the literature. This paper first presents an exploratory experiment that examines sound masking to enhance shared indoor soundscapes. The sound mixtures created using two ventilation noises and five water sounds are evaluated for their pleasantness. While variations in pleasantness are related to the type of water sound, the results raise some questions about what is perceived as annoying, what is considered pleasant, and what practical elements should be considered to improve sound comfort. To conduct more in-depth research about contextual elements, a forthcoming diary study is initiated to investigate people's sound-related experiences, behaviors, and needs in shared offices. The methodology used to design this study is presented, as well as the expected results and perspectives, offering insights into auditory experiences at work and informing the development of audio augmented reality approaches.

Keywords: *indoor soundscapes, augmented reality, sound design, generative design research, diary-interview methodology*

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1. INTRODUCTION

With the development and popularity of open-plan offices, many people today work in shared offices, including open spaces and coworking areas. Although these open spaces have created a sense of conviviality and sharing, some comfort issues have emerged quickly. In particular, noise exposure during the work period can create stress that leads to reduced performance, unpleasantness or annoyance, and changes in social behavior [1]. Furthermore, people seem to be more and more aware of the quality of their sound environments, which turns out to be a complex problem based on multiple factors.

Over the past few years, research on open-plan offices helped gathering some important information about employees satisfaction (see Pierrette et al. [2] for example). Therefore, some improvement approaches have been proposed, mainly considering acoustic treatments that help reducing the overall level and intelligibility of speech. Although such treatments provide better privacy for employees [3], they may not be sufficient to ensure sound comfort, as annoyance and distraction can come with specific sound sources even if their level is satisfactory. In fact, various factors must be considered, such as the temporal and spectral properties of the sound [4] and its informational content, which brings together anything meaningful in the sound and obviously depends on the listener [5, 6]. On top of that, quiet environments can reinforce the problem as it may make way for emergences that are unpredictable and very annoying to workers.

Recently, sound masking systems have been developed and applied to reduce speech intelligibility and improve privacy by adding background noise. The idea of adding sounds to make soundscapes more pleasant may appear counterintuitive but is very consistent when the

context is well studied. Valérian Fraisse notably demonstrated in his thesis that outdoor sound installations can improve the perception of urban soundscapes. For example, three installations on the Fleurs-de-Macadam square in Montreal had an effect on perceived loudness (people evaluated that it decreased after applying sound installations) [7]. However, many studies were conducted in open-plan offices and obtained mixed results. For example, Hongisto and Haapakangas [8] explained their positive results by the fact that the background noise level was low in the office they studied, while Vassie and Richardson [9] and Bergefurt et al. [10] later observed both positive and negative effects for their level-adaptive sound masking. In fact, mental health aspects such as well-being, productivity, and job performance were rated more positively after the application of the system, but employees felt more disengaged as masking sounds were presented through earphones. These results question the conditions under which such masking systems are really possible. Patrick Chevret especially highlighted the importance of different types of work activities in the process of assessing annoyance in open-plan offices by proposing a typology of open-plan offices in his recommendations [3]. Most of the studies we reviewed here also concluded that context elements such as activities and layout must be carefully studied, as the perception of sound is different between individuals but also between environments.

On that basis, this paper presents the development of a forthcoming study that aims to investigate people's sound-related experiences, behaviors and needs in shared offices. Section 2 exposes the results of an exploratory experiment that raises some important contextual questions about sound masking. Section 3 introduces the principles of generative design thinking used for conducting qualitative and context research. Section 4 presents a diary study that is designed following these methodological elements. The expected results are finally depicted and some perspectives are provided for further research in audio augmented reality in Section 5.

2. AN EXPLORATORY EXPERIMENT ON AUDIO AUGMENTED REALITY APPROACHES

2.1 Objectives and procedure

An exploratory experiment is conducted to assess the pleasantness of sound mixtures generated with sound masking approaches. The first is inspired by the methodology used by Cai et al. in their study to investigate the effect of sound masking by adding water sounds to an electric welding noise [11]. We call it the *masker approach*, that consists in adding two sounds: a noise source and a masker that is actually a positive sound, which means a sound considered commonly accepted. The second is the *concealer approach*, that is based on a minimal added loudness paradigm and consists of complementing the noise source rather than just masking it. By complementing, we mean that the added sound, named the concealer, could add "what is missing" to the noise source to sound like the positive sound. To do this, the concealer is constructed from the same positive sound as in the masker approach, but also from the noise source itself [12]. Following both approaches, 140 sound mixtures are generated between two ventilation noises (noise sources) and five water sounds (positive sounds). They are then presented at levels between 50 and 53dBA and are evaluated in terms of pleasantness by 30 participants using a Best-Worst Scaling paradigm [13, 14]. We hypothesize that water sounds are commonly accepted [11, 15, 16], so that the use of sound masking approaches may improve the pleasantness.

2.2 Results

The masking effect of water sounds on ventilation noise is obvious, as the mixtures are perceived more or less well depending on the water sound used. From the full lines in Figure 1, the masking effect sequence of the five water sounds to pleasantness scores is: stream $>$ waves $>$ rain $>$ fountain $>$ waterfall. The reason might be that the masking effect strongly depends on the subjective feeling of water sounds. However, while previous studies showed that water sounds could improve the quality of acoustic environments [11, 15, 16], we cannot draw such conclusions, as no reference was considered in our study. In fact, the participants were not exposed to both ventilation noises alone. We can still assume that the water sounds had no positive effect on the overall quality of the acoustic environment presented in the context of the experiment because the less the water sounds are perceived, the more pleasant the mixtures are (see Figure 1).

Furthermore, due to the important role of loudness in the assessment of pleasantness [17], ΔL_{Aeq} is created as an indicator of the level added to the sound environment ($\Delta L_{Aeq} = 0$dBA means the mixture has the same level as the initial scene with only the noise source). The sound mixtures were then generated with ΔL_{Aeq} from 0 to 3 in step 0.5dBA. Figure 1 shows the relationship between the

masking effect and ΔL_{Aeq} of the sound mixtures used as stimuli, which appears to be almost linear. With an increase in ΔL_{Aeq}, the pleasantness scores of the mixtures decrease. The level added causes the subjective feeling to get worse, regardless the type of water sound used in the mixtures. The reason of this result could be that the selected ventilation noises are not really annoying, so the added level is not appreciated. The water sounds themselves may not be as pleasant as we hypothesized, considering a work context, as suggested previously.

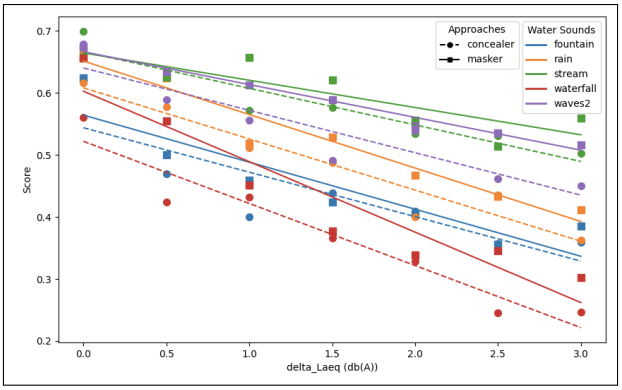

Figure 1. Mixture scores as a function of ΔL_{Aeq}, approach (circles and squares) and water sound used (colors) for both ventilation noises.

2.3 Discussion

The results obtained are not expected and question our initial hypotheses. In fact, the pleasantness scores of the mixtures decrease with the perception of water sounds added to the ventilation noise. The latter, which was assumed to be annoying, might not actually be so in the context of the experiment. The stationary behavior of the ventilation noise may also make the sound more accepted than other sounds with irregular spectral content. On the other hand, these results do not confirm those presented in the literature on the positive effects of masking by adding water sounds to the environment. If some studies show the relevance of water sounds in improving noisy environments [11, 15, 16], research in an open-plan office context draws controversial conclusions about their use as masking sounds [18]. In our case, water sounds may not be as pleasant as we hypothesized, as some participants expressed their discomfort at the end of the experiment. In fact, the participants explained that they actually evaluated the sound mixtures according to unpleasantness instead of pleasantness, as no stimuli seemed pleasant to them. Finally, the results do not show any improvement in the perceived sound environment presented by the different mixtures. One limitation of our experiment might be that we are not working at the right level. In fact, in an open-plan office where people have to focus on mentally demanding tasks, an additional level might be automatically perceived negatively whether the overall level is already too high, making masking operations pointless, even counterproductive. Therefore, lower levels should be considered to prevent people from being annoyed by the salient events in quiet environments. Another limitation is that the study was conducted under laboratory conditions. Contextual elements should then be provided in further experiments so participants can immerse themselves in a real office sound environment.

3. CONTEXT RESEARCH

As we want to have access to contextual elements that impact the sound perception of users of shared offices, we must consider specific contexts in which people can be annoyed while working [6]. This section presents some theoretical aspects of context research that will help us design a field study.

3.1 Ask about future sound experiences

To obtain relevant information from the field and provide relevant content that will improve sound comfort in shared offices, we want to better understand how people experience sound and what people need whether sound is actually a problem. However, needs are difficult to express because it requires talking about future experiences. In fact, people often talk about their current experiences and problems without identifying what they actually need. To ask people about their future sound experiences, we choose to adopt a generative design thinking, and to be inspired by user experiences to develop our methodology.

3.2 Generative design thinking

The main principle of generative design research is to put the participant in a creative mindset [19]. Questions in context are often asked to subjects in user experiences, such as ”How could it be otherwise?”, “What would you expect?” and ”How might we. . . ?”. As the researcher/designer is interested in finding out what people

need in the future, they consider a human-centered co-design process where the user is considered an expert in their own experiences [19] [20]. Several ways can be used to convey ideas: design workshops, interviews, diary, stories (persona, storyboard, etc.), and the use of some simple materials such as shapes, colors, or drawings helps to bring out what subjects cannot express with words [19].

3.3 The path of expression

Since it is difficult for most people to talk about their imagined futures, the researcher/designer has to give some help by providing them a path of expression that leads the time course of the creative process [20].

The path of expression depicted in Figure 2 shows how a person's awareness can be guided in steps by thinking first of the present, then of the past, then looking for underlying layers, in order to move toward the future. We can browse the different temporalities with four steps:

1) Observing and documenting current activities
2) Recall memories from earlier experiences
3) Reflect on memories and possibilities for the future
4) Express to create artifacts for future experiences

Using the path of expression framework allows people to connect to what is meaningful in their past and present experiences, using this as a springboard for ideation about the future.

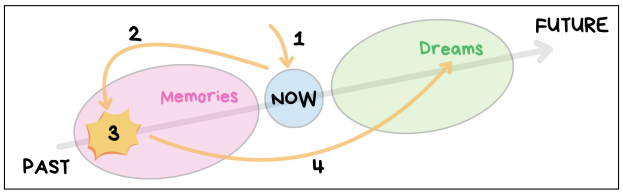

Figure 2. The four steps of the path of expression, as presented in [20] and slightly re-edited. The current experience (now) is connected to the past and future through memories and dreams.

3.4 Tools and techniques

To gain rich information about people's experiences, the researcher/designer gives people tools and techniques to explore their current experiences, as well as past and future experiences. Three categories of research tools/techniques are identified: what people do, what people say, and what people make [20].

Do techniques consist of observing people, their activities, the objects they use, and the places they carry out these activities. It is about behavioral data. *Say* techniques are used to collect attitudinal data and are usually based on questionnaires and interviews to get answers from people to specific questions. *Make* techniques allow people to make things to express their thoughts and feelings, usually through a toolkit developed by the researcher/designer.

It is important to use techniques from all three categories during the generative design process that address different parts of the experience timeline. Through this timeline, a link is made between the path of expression and the different tools/techniques. Each step of the path of expression can be associated with a technique, *Do* techniques being used for current experiences, and *Say* and *Make* techniques for the past and future in the timeline.

4. GENERATIVE RESEARCH THROUGH A DIARY

In order to inform audio augmented reality approaches to improve sound comfort in shared offices, we will conduct a generative design research protocol where people's experiences will be collected through a diary distributed to users of various work environments. In this section, we present the design of the future diary study with respect to the principles and methods provided by the generative design research exposed in Section 3.

4.1 Research questions

The main objective is to better understand people needs and sound-related behaviors in their workspace. The principal problem is to consider each environment as a specific context we have to study. For each environment, we wonder to what extent noise is a problem and, if so, why it is a problem and how we could deal with it. We formulate this general problem along three axes: (1) What do people hear? (2) What do people do to cope with noise? (3) What do people dream about? More precisely, we want to gain insight into (1) what are unpleasant and pleasant sounds in shared offices, (2) what are people's behaviors toward noise disturbance, and (3) what sounds emerge in a work environment ideation.

4.2 Diary-interview methodology

4.2.1 Study design

The study is designed to last for a mean duration (between 3 and 5 weeks) during which the participants will

go through an immersion period and a reactivation period, interspersed with incubation periods (where the problem is internalized into the unconscious mind and nothing appears externally to be happening) [20], as presented in Figure 3. The idea with these different periods is to engage the participants' thinking and creativity, which is a process that happens over time.

A diary format is chosen as a sensitizing material during the immersion period, which corresponds to the first step of the path of expression (observing and documenting current activities). Participants will be asked to provide self-reports on their workspace by completing some tasks in the diary that gather *Do* and *Make* techniques. It is a good way to prepare people for interviews or group sessions and involve them in the noise issue, while proposing a study that is as less intrusive as possible by fitting participants' schedule and workload.

After this first part of the study, one-on-one interviews will be conducted to (1) return to the responses given by each participant in the diary and to ask for some precision and clarifications (*Say* technique) and (2) come up with identified needs about sound in the work context (*Make* technique). This period of reactivation will encourage participants to recall memories of their past experiences and to reflect on those memories and possibilities for the future (second and third steps of the path of expression).

Incubation periods are important for participants to internalize their observations and experiences regarding the topic of the study. On the experimenter side, they are used in our research timeline to analyze participants' responses to the diary and to the interview.

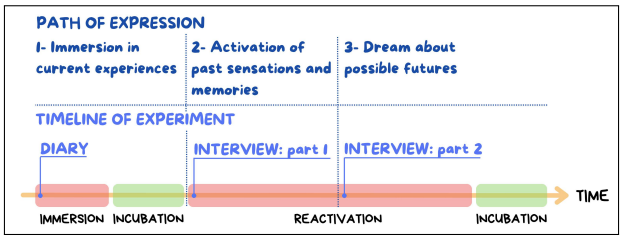

Figure 3. Study design following the first three steps of the path of expression, including different periods: immersion through a diary, reactivation through an interview and incubation.

4.2.2 Diary content

The diary consists in 4 tasks, through which participants go through three stages of observation, reflection, and design of their work environment, as presented in Figure 4.

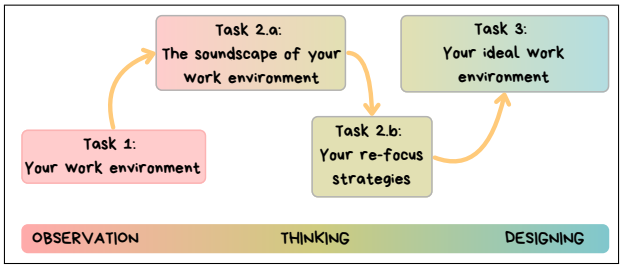

Figure 4. People are encouraged to observe, think and design sounds through four tasks in the diary by documenting information about their current work environment (1), its soundscape (2.a), their re-focus strategies (2.b) and their ideal work environment (3).

Supplementary materials will be provided to participants to complete the tasks, including a black pen, a pencil, an eraser, colored stickers and a box of 12 colored pencils. Furthermore, the tasks are defined as follows:

1- *Your work environment*. This first task is designed to invite participants to observe and explore their work environment by documenting the areas they use in their workplace and, for each area, the activities they do, their feelings about it and the time they spend there. They also have to draw their workspace to show its layout.

2.a- *The soundscape of your work environment*. The second task is used to make participants aware of their sound environment. It opens thinking about sound by asking participants to complete the task several times a day for several days if possible. They have to pay attention to the sounds they hear and give each sound a name, express a global feeling (positive, negative, neutral) with some corresponding colored stickers, and explain in more detail what they feel when listening to these sounds. They are also asked to indicate the location of each sound in the workspace by reporting the associated sticker on the drawing of the first task.

2.b- *Your refocus strategies*. To help participants deepen their thinking, the third task proposes to consider the effect of sound on work, by considering each time participants feel annoyed or disturbed by something involving sound while working. For each perturbation, participants are asked to document their feeling at the time, what caused this feeling, and their strategy to refocus on their work. Later in the day, they have to specify whether the strategies they used did work or not and why. As for the

second task, the refocus strategies should be completed as many times as possible to provide various examples.

3- *Your ideal work environment*. To conclude the diary, but open participants' creative mindset, this final task asks them to think about their ideal work environment by first describing it in writing and then drawing the environment as they have described it. The aim of this task is to access some idealistic ideas about sound that could lead to functional aspects and needs in shared offices.

4.2.3 Interviews

One-on-one interviews are designed to first discuss the participants' diary responses and ask for details, complete certain observations, and confirm our analysis and interpretations through personalized questions. Then we will propose an activity to put the participants back into the work context and try to engage their creativity around sound (the last task of the diary will be used as a transition from their experiences and feelings to a creative mindset).

4.2.4 Pilot study

A pilot study was conducted with four laboratory interns and Ph.D. students. The studied environment was an office shared by two to six people. This allowed us to get some feedback on the diary tasks and make it more comprehensive and intuitive. This also gave us an idea of the results we can expect (see Section 5).

4.3 Participants recruitment

The population targeted for participation in the study is people who work several times a week in shared offices such as open-plan offices, coworking areas, etc. We are interested in people who have mainly individual activities at work. This choice is motivated by the idea to define different types of work environment according to the type of activities (telephone activities, collaborative work-based activities, differentiated work-based activities, and open access activities) [3]. Furthermore, some results in the literature showed that noise does not impact performance in the same way depending on the task being performed. Complex cognitive tasks such as reading, writing [21], memory, and mental arithmetic [22] are found to be very sensitive in speech conditions.

People are informed of the study through posters and flyers in coworking areas around the laboratory or through in-person presentations in some companies and laboratories. People who are interested can then give some information about their work environment and habits using an online form (accessible via a QR-code). As of the time of writing of this paper, 12 people are recruited for the study. Among them, 7 people are recruited in different coworking areas in the third and fourth districts of Paris, 3 people work in Ircam Amplify open-plan office (Paris), and 2 people in the open-plan office of a research laboratory in Nantes (LS2N). We hope to continue recruiting both in coworking areas and companies' open-plan offices to reach around 30 participants fairly evenly distributed between both types of environment.

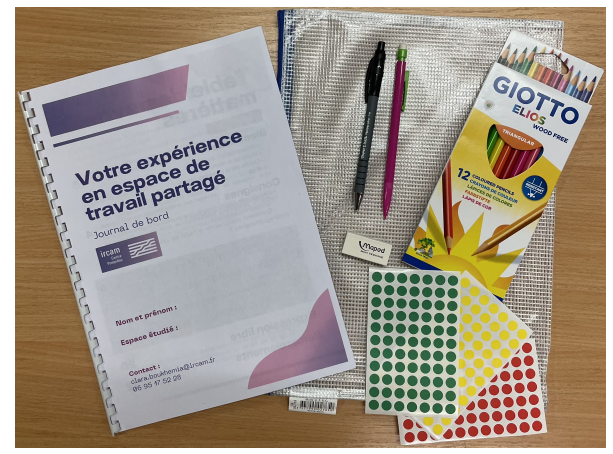

Figure 5. Participants are provided a toolkit containing the material necessary to carry out the tasks (the diary, a black pen, a pencil, an eraser, colored stickers and a box of 12 colored pencils).

4.4 Procedure

A first appointment is established with people who filled the form, during which they are provided with an instruction sheet summarizing the progress of the study. Before validating their participation with the consent form, they are presented the toolkit including the diary as shown in Figure 5. The participants can then choose when to start the study according to their schedule and have two weeks from this date to complete the diary on their workspace. A follow-up message will be sent to them after one week, and a second appointment will be set at the end of the immersion period to get the diary back.

After a first analysis of the diary, the participants will be contacted again to schedule the interview that will take place in the laboratory in a quiet office. As described in Section 4.2.3, the interviews are separated into two parts.

The first one will last around 35 minutes and consists of coming back to the diary with the participants. Then 10 minutes will be spent doing the activity, so the entire interview will take about 45 minutes. The interviews will be recorded. At the end of the interview, the participants will be paid 40 euros for their participation in the study, and we will propose to re-contact them in anticipation for another study on the same topic (see Section 6).

4.5 Analysis

The data collected during the study will be analyzed using a thematic analysis method [23]. The diary will be slightly analyzed before the interviews to collect personalized questions for each participant and then after the interviews to identify themes from the collected data. Following the same idea, the recorded interviews will be transcribed using speech-to-text software, and some recurring themes will be deduced from the transcribed version.

5. EXPECTED RESULTS

5.1 Confirming results from the literature

Several results from the literature lead to hypotheses about people's experiences. The following results were also mentioned by people who participated in the pilot study described in Section 4.2.4. First, we expect intelligible speech to be a very annoying sound in the individual work context [1, 24]. Concerning more pleasant sounds, we assume that natural sounds and music are highly appreciated, perhaps because of the meaning associated with them [5]. In addition, since loudness is an important factor responsible for annoyance [17], we expect people to try to reduce it by using personal music to mask loud and uncontrollable sounds that are irrelevant in the workplace and are perceived as annoying.

5.2 Informing sound augmented reality approaches

As it is the common description used by people who are not used to speak about sound [25], we expect to gather some causal descriptions from the participants (people will describe sounds with the object that cause it), but we especially hope to access reduced characteristics and semantic representations of sound [25] to infer some invariant data that could be used to meet everyone's needs. In fact, the diary study seems to be relevant in revealing stable preferences, as Delle Monache et al. [26] have already used this method to explore profiling and personalization in sleep music design. Furthermore, we need to figure out the practical needs of people to propose a real system that improves sound comfort. We will then consider some environments where the tasks performed require deep focus, and we hope to know more about what people do to refocus when disturbed in their work to bring out some insights about accepted technologies.

6. CONCLUSION

During an exploratory experiment, ventilation noise as typical office noise was masked separately by water sounds that included fountain, rain, stream, waterfall and waves. Sound mixtures were created along two masking approaches (including the concealer approach, an original approach based on a minimal added loudness paradigm) and then presented to the participants to assess their pleasantness. According to the results, the masking effect depends on the water sound used (the stream sound obtained a better masking effect than the others) and the level added (pleasantness decreases with the level of the mixture). Thus, no improvement was observed by applying both masking approaches to the ventilation noise. This raised key questions about annoying and pleasant sounds and more generally about links between sound perception and some contextual elements. Consequently, those contextual elements need to be investigated in the field, and we believe that a diary-interview methodology will allow us to get closer to people's experiences in specific contexts (individual work in shared offices) and to reach the first three steps of the path of expression presented in Section 3.3. In conclusion, we hope to follow up this research with a co-design workshop that could bring some dreamed and realistic ideas for future experiences. In that way, the last step of the path of expression could be addressed, so we would have gained insight into how to improve sound comfort through audio-augmented reality approaches.

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