SoZen – Improving Productivity with a Soundscape Generating Zen Garden

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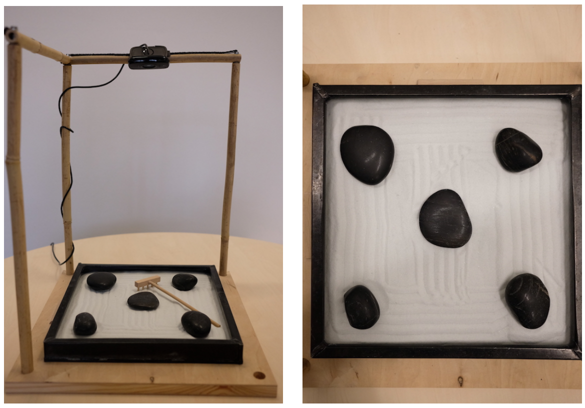
ABSTRACT

This paper presents the SoZen *system, an interactive decorative artifact that can control features of ambient soundscapes. The system aims at improving the sonic quality of work/living space. For that, features such as the placement of stones and patterns in the sand are extracted via a webcam and in turn control directly aspects of the sound playback/synthesis engine. We evaluated* SoZen *in a within-subject study to understand the benefit of interactive ambient soundscapes as participants worked in a sonically simulated office environment. Participants performed significantly better in terms of error rate in a spreadsheet-inputting task under the ambient soundscape condition compared to the baseline condition, and evaluated the system positively in a subsequent survey and interview. However, no significant difference in their psychological states between conditions are found based on the PANAS measure, apart from the Excited affect. SoZen serves as an example for how existing decoration artifacts can be transformed into multimodal (visual, auditory and tangible) user interfaces with positive side effects on their inhabitants in a home or office environment.*

1. INTRODUCTION

Urban living and work environments such as open-plan offices are often troubled by noise pollution. Higher level of ambient noise may increase psychosocial job stress [1], blood pressure and heart rate [2]. This motivates companies to seek and researchers to invent new solutions to improve the sonic environment of workplace in order to provide a healthier experience and to increase productivity. There are many technologies available such as acoustic panels, noise cancellation, and *sound masking*, onto which we focus here.

A common sound masking approach is to simply boardcast music. While music could mask the surrounding to some extent and also increases cognitive arousal and positive mood [3], music itself can attract attention from the main task. This problem is circumvented by using a spectrally flat signal such as white noise or pink noise to overlay environmental noises such as conversations or phone ringing in a workplace [4]. The sound masking technology may involve the use of static noise generators [5, 6], adaptive sound masking with sound level sensors [7] and furniture integrated platform [8]. Although such an approach provides good results in reducing distraction, it is less aesthetically pleasant and thus less likely to attract home users for instance.



(a) Overview. (b) Top-down view.

Figure 1: Photos of the SoZen.

Ambient soundscapes, on the other hand, offer a preferable third alternative as they can be less obtrusive than music and more attractive/pleasant than white noise. There are many benefits of listening to natural soundscapes, as they can support calmness, relaxation and the emotional state [9]. In a recent study, Sayin et. al. found that ambient soundscapes can also improve the perceived safeness of open spaces [10].

We believe that the users' acceptance will be even better if they can influence features of the ambience. Thus we propose a system-guided yet user-driven ambient soundscape artifact for providing calming acoustics content to improve the sonic environment of a noisy office. The soundscape should contain a backgrounding element that does not overtake one's main attention in most of the daily tasks. Concerning the user interface, the interaction should be effortless to use, without requiring the user to give commands such as selecting a song from a playlist or using keyboard or mouse.

Based on these criteria, we designed a cross-modal platform combining ambient soundscape control with a home decorative artifact. By coupling soundscape generation and artifact, it can serve as a control interface but still remains visually blended into the environment as a decoration. This concept is in line with Mark Weiser's definition on ubiquitous and calm computing, which emphasizes the nonintrusive computing and integration with the physical environment [11].

The cross-modal interaction we proposed in this project is a vision-to-sound transformation with tangible interaction. Vision-based sonic interaction and tangible controlled sonic arts have been widely explored in the interactive music and new musical expression communities such as ICMC, SMC, NIME etc. Leichsenring et. al. introduced an ambient soundscape interface using tangible objects to create a decorative interface for the use of multimodal ambiences in the smart bathroom context [12]. [13] presented an interactive music composition platform via paper drawing. Jo and Nagano developed Monalisa, a cross-modal interface to transform between image and sound in both directions [14]. GrainPlane is a tangible instrument that uses actual food grains (e.g. beans and rice) to control parameters of a granular synthesizer and thus generate electronic soundscapes [15]. A famous tangible interface for musical control is reacTable, a tabletop screen surface with tangible objects (cubes) for controlling different sonic modules [16]. Music can be created by placing and thereby combining cubes representing synthesis modules.

2. CONCEPT OF SOZEN

Three key assumptions underlie the project:

- A noisy soundscape can be refined by ambient soundscape in a home or office environment, either to improve the user's perception to the sonic quality of the environment, or to support certain functions such as relaxation, vitalization, cheering up.
- The resulting soundscape should merge into the background and should not add to the users' cognitive load so that they stay focussed on any given task.
- Cross-modal audiovisual interaction can be explored to create interesting smart artifacts for home and office applications providing both visual and audio qualities.

As decorative artifact we chose a miniature Zen Garden. A Zen Garden, originated in Japan, is a visual recreation of mountains and rivers through the special arrangement of stones and sands. In Japanese Buddhism, Zen Garden has various meanings and metaphors, in particular it creates a sense of calmness, which can be beneficial for meditation [17]. A miniature Zen Garden is a small sand plate accompanied with a number of small stones. The user can arrange the stones and carve the sand to create a visual pattern of the plate.

The following section presents the design details of SoZen. In Section 4, a study is presented to investigate how SoZen affects productivity and psychological states in a work environment, leading to discussion and summary.

3. DESIGN OF THE SOZEN SYSTEM

This section begins with an overview of the system architecture, followed by the detailed description of the software architecture with regards to image feature extraction and sound engine. At last, the interaction and mapping design are presented.

3.1 System Architecture

The physical structure of SoZen (cf. Fig. 1) is very simple: the sand plate is situated on a wooden base with bamboo support frames, which are used for holding a webcam or optionally a curtain to assume controlled lighting condition if, for example, the installation is placed near a window. The bamboo as material was selected because it fits to the naturalness of the artifact. The hardware structure and software ambient soundscape generation is bridged by using the webcam to capture the image of the arrangement of the sand and stones.

Concerning the software, the overall structure of the signal flow is depicted in Fig. 2. The captured image is processed in order to extract key features of the arrangement, which are subsequently sent to the sound engine via Open Sound Control (OSC) as control parameters for rendering the sound output. Details of the image feature extraction and sound generation are presented below.

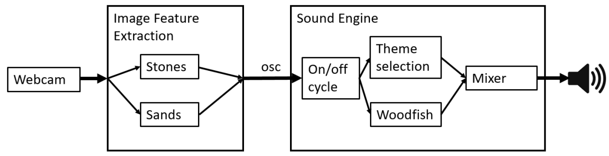


Figure 2: Signal flow of the system.

3.2 Image Feature Extraction

The image feature extraction is written in Python using the OpenCV library [18].

Regarding the stones, there are many details possible to extract, from the stones' (or rocks') size, color, texture, shape, position, orientation in space, etc, to the many details of how sand is distributed and shaped with the provided tool, a miniature wooden fork. For practical reasons, we decided to reduce the complexity by selecting first the most elementary features, leaving the inclusion of more details to future revisions of the system. In first order, the setup is just a spatial arrangement of stones which are only characterized by their overall size and location. The rocks' detection is achieved using a blob detection algorithm, which returns the list of rocks including their size [1] and coordinates.

In the previous version of SoZen [19], we used white and black stones for controlling different sound elements. However, the white stones were prompt to reflection of light, leading to inaccurate detection. For that reason we decided to solely use black stones.

As for the sand features, since we are only interested in the features from the parts which are carved by the wooden fork, Canny Edge detection is applied to only preserve the sand's image with stronger contrast (carved). Initially we applied line and curve detections to detect the lines' shape, however, when the sand is carved, the contrast between the sunken and flatten part is very small. The performance of

[1] The size refers to the diameter of the detected blob treated as a circle.

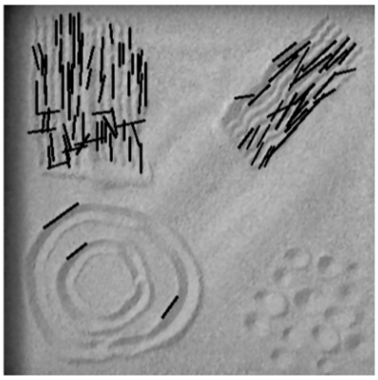


Figure 3: Line detection for the carved sands. The overlayed black lines are the detected lines from the algorithm.

the detection was far from satisfaction, as shown in Fig. 3. In consequence we decided to bin the absolute amount of sand structure from a Canny Edge detection algorithm in a spatial 3×3 grid and ignore all further details.

3.3 Sound Engine

The sound engine is developed on PureData. It consists of mainly four key components: (1) theme selection, (2) sound generation based on a sample-based engine and a granular synthesizer, (3) spatial distribution and (4) an active/sleep rotation. The structure is shown in Fig. 4.

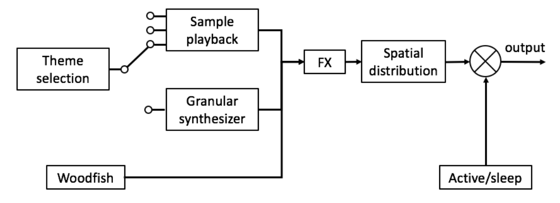


Figure 4: Core structure of the sound engine.

Firstly, the installation has four themes available for more sound possibilities. They are: Forest, Ocean, Fireplace and Electronic Ambience. The first three themes are sample-based. Each theme consists of a collection of sound samples that belong to the theme, e.g. leaf sound, birds, and a little creek are comprised in the Forest theme. In contrast, sea waves, and cries of seagulls belong to the Ocean theme. The samples are tagged with another property, which is whether the sample is suitable for the ambient sound S_a for long time playback (environmental ambience) or object sound S_o for short time occurrence. The fourth theme is a real-time granular synthesizer that creates an evolving a pad-like electronic soundscape. Parameters such as pitch, randomness, grain speed and duration are available to control.

In addition to core theme sound elements, there is another sound which independent to the theme: the woodfish sound. A wooden fish is a percussive instrument used by Buddhist monks to keep the rhythm during sutra chanting. Since the Zen Garden has the means to assist meditation, we take the wooden fish to create a more zen-like sense to the soundscape. The only control parameter for this sound is the repetition interval, which is mapped to the mean histogram vector of the image.

The generated soundscape is then passed through the effect section with basic effects such as delay and reverb. The spatial distribution section pans the sound elements according to the stones' spatial arrangement to either a 4-channel or stereo setup.

Finally a gating function (fadein/fadeout) is applied to alternate between an active and sleep (muted) phase. This is because SoZen is designed to be used for long term, hence playing the soundscape constantly could lead to listening fatigue. The gating function provides an adjustable cycling between active (default 1 minute) and muted phase (default 30 seconds).

The control interface is shown in Fig. 5. First it is important to note that SoZen does not require the user to interact with the GUI and can run directly by interacting with the zen garden. The GUI provides extra functionality for information display (e.g. what samples have been selected, whether the sound is active or in sleep mode), theme selection (see 'Pack' in Fig 5) and active/sleep phase time adjustment (see 'Metronome' in the same figure).

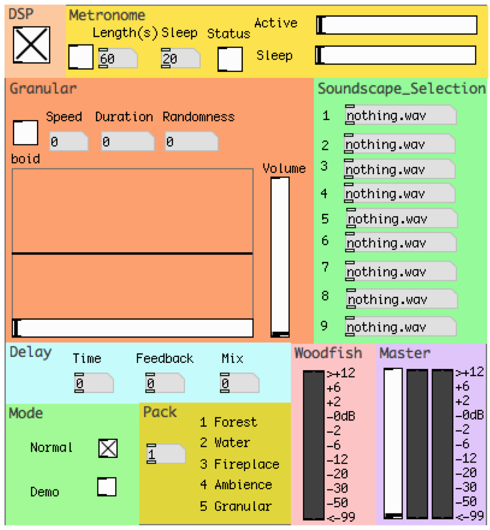


Figure 5: Sound engine user interface.

3.4 Interaction Design

This section describes how the extracted image features affect the sound, control the sound engine's components and thus correspond to the overall ambient soundscape.

There is no fixed rule for arranging the rocks and sand on the plate, thus one can create any pattern as desired (an example can be seen in Fig. 1b). Once the user finishes the arrangement by withdrawing her/his hands, the system will automatically take a snapshot of the plate and analyze image features which subsequently determine a generated ambient soundscape. A continuous video processing can be avoided, since the system is designed to be a backgrounding ambient device rather than a musical instrument, thus real-time interactivity is not required.

The parameter mapping logic depends on the selected theme as follows:

If a sample-based theme is selected: The plate area is divided into a 3×3 grid. If each grid cell is occupied by at least one stone, a sound element will be triggered. This means the system allows a maximum of 9 sound elements to be played in the stream. The biggest stone will trigger the environmental sound S_a as a loop that plays continuously. The rest of the stones, if any, will trigger a randomly selected object sound S_o respectively. Since the object sound only lasts for a short time, there is a randomized gap (1-8 seconds)) between a new object sound to be selected to play.

The coordinates of the stones are mapped to the spatialization of each individual sound. The standard spatialization set up is designed for a 4-speaker system where each corner of the sand plate represents the position of each speaker. When using a stereo set-up, only the x coordinates (left-right) are considered for the panning. The size of the stone decides the amplitude of the sample (larger size = louder).

As for the sand, the total value of the histogram in the edge detection image controls the interval of the woodfish sound, which means that the more complex the sand is carved the more frequent the woodfish sound will repeat. As for the histogram in each grid cell, they affect the appearing rate of the elements in the soundscape, which means the more complex the sand pattern is, the more frequent the sound elements will appear throughout.

Overall, the control logic is that users can put more stones and carve more sand shapes if they want a 'busier' sound environment. A quieter and slower evolving sound environment results if the zen garden's arrangement is more simplistic.

If the electronic ambient theme is selected: Same as above, the 3×3 grid division is applied. Yet here each cell represents a pitch-shift in a major pentatonic scale with the middle being the unshifted tone (cf. Fig. 6). The stones then function as a note selection, hence only the grid cells filled with stones trigger their corresponding tones during playback. In addition, only one note can be played at a time and the cell to be played is chosen as a random sequence. A randomised silence gap of 1-5 seconds between each pitch change adds to the perception of a rhytmically more interesting composition. Pitch changes will happen more frequently if the total histogram count of sand patterns in that cell is higher. The woodfish sound is controlled in the same manner as in the sample-based condition. In this theme, the SoZen generates a randomized melodic granular soundscape. The users can define the limitation of the possible pitches and the alteration rate by the arrangement of stones and sand.

-10	-8	-5
-3	0	+2
+4	+7	+9

Figure 6: SoZen pitch grid uses for the electronic ambient theme: Stones in a cell trigger musical pitches whose semitone offset to the center cell are specified by the depicted value, resulting in a major pentatonic scale over 2 octaves.

To summarize, the control logic of the system is straightforward: a minimal arrangement leads to minimal soundscape, and more complex arrangements lead to more sound elements and variations. In the previous iterations of the design process, we experimented with various other mapping methods such as using patterns (e.g. a 'L' shape vs. 'X' shape stone arrangement) and using stones features to fine tune the granular synthesis' parameters (e.g. grain length and position). However, we found that although they offered more possibilities in crafting difference sonic outcomes, they complicated the interaction and required the user to learn and memorize the methods. For that reason, we rather simplified the mapping to create a control logic that is easy-to-use for everyone and makes sense intuitively. Interaction examples for the SoZen system are provided online as supplementary material [2] .

4. STUDY: PRODUCTIVITY TEST IN A SONICALLY SIMULATED NOISY OFFICE

In the experiment, SoZen was evaluated in a sonically simulated office environment. Our hypothesis is that a noisy office environment can be acoustically improved with the use of SoZen and its soundscape in terms of productivity. Productivity is defined as the 'state or quality of being productive'. It is a combination of quality and quantity. Also we looked into whether SoZen could have a positive effect on the participants' psychological states (mood).

4.1 Experimental Setup

20 participants took part in the study in English, 10 male 10 female from 13 countries. The average age of the participants was 26 ± 3. For the experiment, we sonically simulated an office environment by playing a sound of a busy office, which includes the sounds of conversations, phone ringing, typing keyboard, copy machine, door sound, etc.

In the study we asked the participants to fill a spreadsheet printout into a computer. The spreadsheet consists of four columns and a large enough number of rows so that it is impossible to finish within the given time. The contents of each spreadsheet cell is a randomly generated code consisting of both numbers and case sensitive letters, e.g. JADS7236JH. In this context we understand higher productivity as the amount of inputs (I_c), whereas the number of errors (e) indicate lower productivity.

The study is a within-subject design with two conditions: a control condition where only the simulated office sound is played; and the SoZen condition in which participants use the SoZen to generate a soundscape that blends (and to some degree masks) the same simulated office sound played exactly as before. Prior to the SoZen session, the participants were explained the usage and given 5 minutes to explore the installation until they settled with a soundscape for the experiment. The sequence of the conditions was randomly assigned so that equally many particpants started with control condition and with SoZen. For the consistency of the soundscape, only the forest theme was used in the study. Each condition lasted 20 minutes with a 5 minutes break in between. The test required the participants to input as many rows as possible from the printout

[2] DOI: 10.4119/unibi/2913135

to the computer. At the 15-minute mark of each condition, the participants were interrupted and asked to fill in the PANAS scale. PANAS is a standardized affect measurement of positive and negative psychological states [20].

The equipment setup is shown in Fig. 7, two loudspeakers (active monitors GENELEC 8020C) were placed in front of the subject and two behind. The volume of each loudspeaker was calibrated to deliver equal sound level at the participant's head position. To simulate the office sound environment, one of the frontal loudspeakers (left or right) and the diagonal opposite loudspeaker (right or left) are used to play the same office sound. The other front speaker and diagonal rear loudspeakers play the ambient soundscape. The distance between all speakers are kept short (approx. 50 cm). The rationale of this speaker arrangement is to blur the distinction between the two sources. Because if the two sound entities are clearly coming from 2 different directions (left and right to our ears) we can separate the sources well rather than the desired blending effect perceptually. The office sound was recorded at around 50-55 dB(A) at the receiver's end. The sound intensity level was measure with a Voltcraft Sound Level Meter. With the soundscape added, the receiving loudness increased to around 55-60 dB(A). This sound intensity level is common in office and conversational environment.

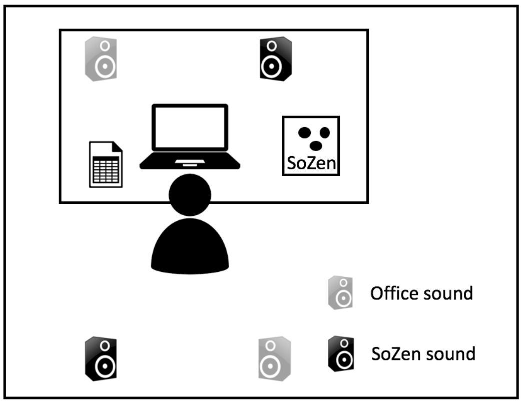


Figure 7: Graphical illustration of the loudspeaker setup and SoZen placement used for the study.

After the two test phases, all participants completed a questionnaire and were briefly interviewed.

4.2 Productivity Results

A two-tailed paired t-test was used to analyze the difference between the total amount of of inputs and errors under each condition. No significant difference is found in the number of row inputs between the control condition (56.5 ± 20.1) [3] and the SoZen condition (55.4 ± 19.6), $t(19) = 0.5, p = 0.62$. However, a significant difference is found in the number of errors between the control condition (16.6 ± 15.8) and the SoZen condition (12.1 ± 10.1), $t(19) = 2.44, p = 0.02$. As shown in Fig. 8, the participants input a similar amount under both conditions yet made less errors when using the SoZen condition, especially in the first two quartiles.

[3] reported as sample mean $\pm$ corrected sample standard deviation

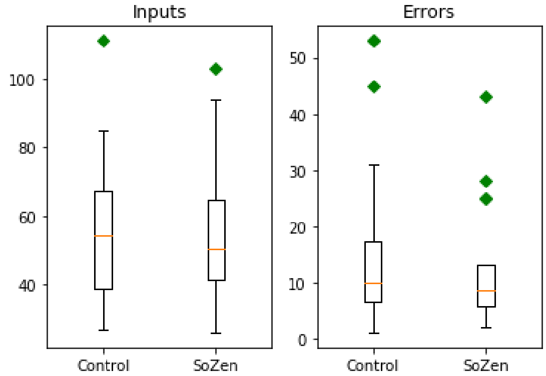


Figure 8: Boxplots of the inputs and errors for both conditions.

We speculate that the reasons why there is no difference between the amount of inputs between two sessions are: 1. The time for each session is short (20 minutes); 2. The participants were told to try to fill in as many as possible within time, thus the participants could fully commit on entering the spreadsheet regardless of the conditions.

Furthermore, we analyzed the error rate ($r = n_e/n_i$). The paired t-test shows a similar result to the analysis of the number of errors, with the control condition (0.3 ± 0.25) yielding significantly higher relative error than the SoZen condition (0.23 ± 0.18), $t(19) = 2.32, p = 0.03$.

Based on the significant reduction both in absolute and relative error, we conclude that the addition of the refined acoustic environment has a positive effect on reducing errors and, according to our definition, improves productivity in the office environment.

4.3 Affective Measures (PANAS)

The Positive and Negative Affect Schedule (PANAS) consists of 20 different emotional labels with 10 positive affects (e.g. interested, proud) and 10 negative affects (e.g. upset, hostile). They measure the positive and negative affects independently. In our study, however, we removed 8 affects (4 positive and 4 negative) for the following reasons: 1. some affects are irrelevant: *strong*, *guilty*, *ashamed*, *determined* [4]; 2. Word confusion (90% of the participants are not English native speakers): *jittery*; 3. some affects have very similar meaning: *afraid* (similar to *scared*), Enthusiastic (similar to *excited*).

The final selected affects for the study are:

- Positive affects: *Interest*, *Excited*, *Alert*, *Inspired*, *Attentive* and *Active*.
- Negative affects: *Distressed*, *Upset*, *Scared*, *Hostile*, *Irritable* and *Nervous*.

The resulting score of the positive affects is shown in Fig. 9. In general, participants scored a higher number in the SoZen session than in the control session apart from the *alert* attribute. Among the attributes, a significant difference ($p < 0.05$) is found in the ratings for attribute *excited*: participants rated their affect 'excited' higher under the SoZen condition.

[4] Although "determined" is somewhat relevant, we decided to remove it to achieve an equal number of affects for both positive and negative.

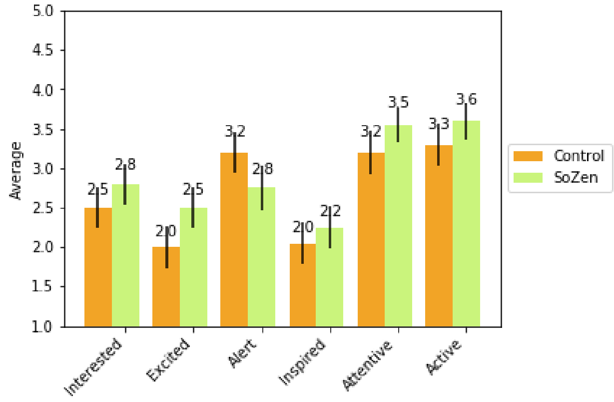


Figure 9: Positive affects of specific attributes. The Y-scale ranges between 1 (not at all) to 5 (extremely). Error bars are the standard error.

The result of the negative affects is shown in Fig. 10. Overall, the scores between the two conditions are very similar. *Upset* and *Irritable* are the only two attributes that have a lower value under the SoZen condition. However, a t-test shows no significant differences among the individual negative affect between conditions.

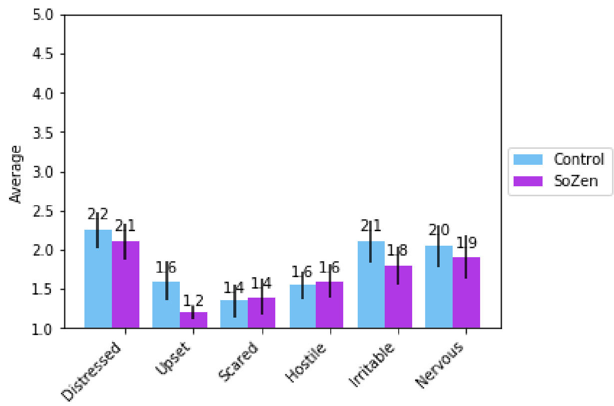


Figure 10: Negative affects of specific attributes.

The total positive and negative affects are calculated by summing up all affects in each polarity. Fig. 11 presents the distribution of the overall affects. In general, all participants indicated stronger positive affects (16.3 ± 4.83) than negative (10.5 ± 3.89) in both sessions ($p < 0.05$). When comparing between sessions, the positive affects in both sessions are similar apart from higher values in the median and the lower quartile. In terms of the negative affects, both sessions again share similar results but with a higher score on the upper quartile with SoZen. No significant results ($p < 0.05$) are found in both affects when comparing between conditions.

4.4 Survey Results

The survey looked into four areas: 1. Obtrusiveness; 2. Usability; 3 Aesthetics; 4. Acceptance. Participants answered the questionnaire on an integer scale between 0 (strongly disagree) and 6 (strongly agree). The results are shown in Fig. 12.

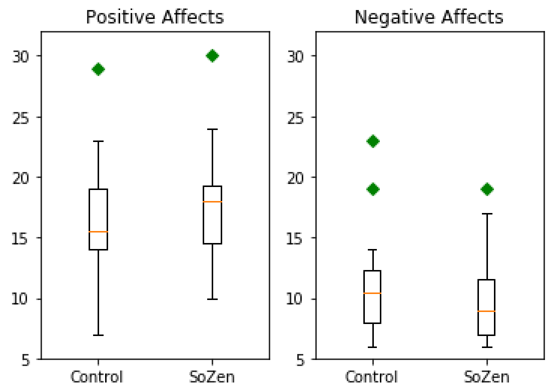


Figure 11: Comparisons of the overall positive and negative affects in both conditions.

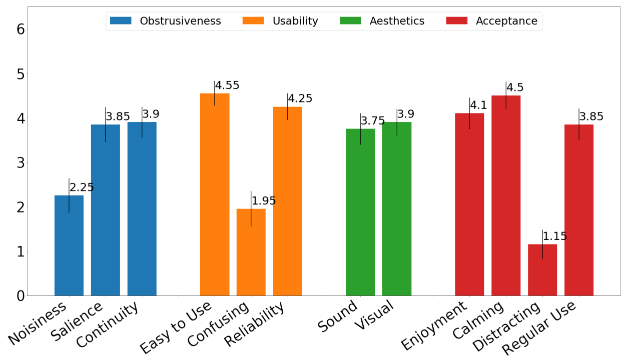


Figure 12: Survey results.

In terms of *obtrusiveness*, the participants overall find the SoZen to be salient (3.85 ± 1.74) and not noisy (2.25 ± 1.73). They are in favor of having the soundscape played more continuously rather than sparsely (3.9 ± 1.55). However, since the experiment with SoZen only lasted for 20 minutes, the opinion can not well be generalized to long-term usage.

Favorable opinions (mean>4) are gathered in the *usability* section, as participants expressed that the system is easy to use and reliable. Although a low mean value of 1.95 is recorded regarding whether the system is confusing, the error bar shows a high standard deviation of 1.8.

In terms of the *aesthetics*, the opinions are also above average but rather deviated. This indicates some further work is required to improve the sound design and visual attractiveness of the system.

Lastly, favorable opinions are expressed in the *acceptance* section. The participants found the experience of using the system to be enjoyable and the soundscape to be calming. They did not find the soundscape to be distracting.

4.5 Content Analysis of Interview

In addition to the questionnaire, an interview was conducted after the experiment. We asked the participants to comment on four aspects:

1. What is the impression of the office sound?
2. What is the impression of the soundscape?

Office Sound	+	Silence distracts me more (1)
	−	Irritating (3)
		Distracting (9)
		Phone rings especially (3)
		Make me stressed (1)
	Neutral	Not disturbing (2)
		Used to it (7)
		Depends on importance of work (3)
SoZen Sound	+	Concentrate more (4)
		Relaxing (4)
		Pleasant (2)
		Helpful (1)
		Calming (4)
		Woodfish sound helped me get back to work. (1)
	−	Distracts me more (3)
		Prefer no noise (2)
		Don't like woodfish sound (1)
	Neutral	No strong,difference (1)
Installation	+	Interesting (3)
		Nice (7)
	−	I will not use it. (1)
		Not like a real garden (1)
	Neutral	Ok (3)

Table 1: Collected replies on questions 1-3 of the interview.

3. What is the user experience?
4. How does the conversation in the office sound affect your action in particular?

The collective results of the first three questions are summarised in Table 1. Notice that the contents in the table are the keywords from the comments, thus they are not necessary the exact words from the participants and one could make multiple comments.

Regarding the office sound, the majority of participants states either negative or at best neutral attributes. The negative comments circle around the phrases distracting and irritating. Three participants specifically mentioned that the phone rings were even more distracting than the rest. One participant expressed that the sound made him more stressed. Interestingly, one participant preferred such a noisy environment over silence for work. Most neutral comments focus on the fact that they are used to this kind of sound based on personal experience. This seems to be a reflection of the current circumstance that it is very common to have a noisy work environment. Three mentioned that if the work is important they manage to ignore the noise, and vice versa.

In contrast, the soundscape from SoZen is generally well regarded with 16 positive comments. Participants found the soundscape to be relaxing ($\times 4$) and calm ($\times 4$). Four participants stated that it helped them concentrate better during the task. However, 3 participants found the soundscape to be even more distracting while two participants thought that any sound could be distracting.

Regarding the installation, 15 participants out of 20 commented on this aspect. The majority (67%) holds positive impression, while two disliked the installation. 3 participants thought it was just average.

From the above three questions, we conclude that the office sound in general elicits negative attributions. It could distract people from work and cause a negative mental effect to the people involved. In contrast, the SoZen is both visually and sonically regarded as pleasant and instead evokes a positive improvement of the office sound environment, which is also supported by the productivity analysis discussed in Section 4.2. It is important to notice that some participants are well used to noisy work environments and some simply cannot stand any noise, in which cases the SoZen may not be effective and could worsen the experience. However, it is to be expected that personal preferences play an important part in any design and we cannot assume our approach to be suitable for everyone.

When asked how conversation sound in general could affect participants' work, 6 participants mentioned that it was very distracting if they understood the language. Interestingly, 4 other participants thought the opposite – that they would be distracted if the language is incomprehensible. 30% of the participants stated that they treated conversation as a background noise similar to any other sound sources regardless the language.

5. SUMMARY

In this paper we presented an ambient soundscape system that is driven by image features of a Zen Garden. The design concept is to use a backgrounding visual decoration to provide controllability for generating ambient soundscapes. The system is intended to be used in work environments as a way to improve the sonic quality of the space.

We conducted a study to investigate participants' work performance and psychological states when working in a noisy office environment using the system. We observed a significantly higher productivity (measured by lower absolute number of errors and lower error rate) when the soundscape was in use. No difference is found in terms of the quantity. In terms of their mental states, the PANAS scale shows an overall positive state among the participants. The participants were found to be more excited under the SoZen condition. No statistically significant difference is found in other affects. From the survey and interview, we see that participants generally have a strong negative opinion to the office sound and a positive opinion on the soundscape and installation.

In our current design, the pattern of the sand, e.g. direction or curvature is not used to control the soundscape. This is due to the difficulty of low visual contrast and high irregularity of sand pattern. Currently, we are undertaking a machine learning solution to recognize certain shapes of sands. Other further improvement of SoZen may involve using a light sensor to detect the luminance and create an adaptive system for the feature extraction based on the brightness of the room.

We acknowledge that the productivity result and affective measures relate more to the soundscapes themselves rather than the system as an interactive artifact. Thus, at the current state of research, this study provides supports of the benefit of calming ambient soundscapes used in a noise office environment. The test results cannot directly lead to the conclusion that SoZen helped improve the productivity. The study requires further investigation of the longitudinal effect of using this installation in the office environment, which is planned as the next phase of the research. However, the questionnaire and interview do show a general positive impression of the system among the participants.

To sum up, the SoZen system contributes to the ubiquitous computing vision of calm technology, where computers disappear but nonetheless rich means are offered to control and interact with our environments. Particularly, the anchoring of aesthetic soundscape control to mindful interactions with a visually aesthetic decoration artifact provides an example how to make the intuitive shaping of non-graspable sound tangible.

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