Situated Visualizations of Office Noise to Promote Personal Health

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ABSTRACT

In this student project, we explore how situated visualization of office noise can help desk workers become more aware of the noise they produce and are exposed to. People spend a significant amount of time working in offices. Office work has been associated with a number of health issues and, in particular, noise has been identified as a cause of health concerns; including the inability to concentrate and elevated stress. We contribute a beginning design study for a situated visualization of office noise. Specifically, we ran a design workshop with office workers to elicit design requirements. From the workshop we conducted a larger online survey on noise exposure in office spaces. From the results of the workshop and survey, we finally derived first design mockups on which we also report.

1 INTRODUCTION

Our goal is to visualize noise-related data in offices to allow individuals to be aware of factors that can affect their health at work, and to potentially promote behavior change. Noise has shown to be one prominent influence on employees' psychological and physical health [2, 7]. We focus on developing *situated visualizations* that represent data near the place where it is collected [14]. Situated visualizations surface data in physical environments to promote insight and rapid decision-making. In particular, we envision to build *ambient* situated visualizations [11] that are located in end users' peripheral environment, and provide them with a summary of noise data without disturbing their everyday work activities. To elicit requirements for our first prototypes we ran a design workshop with 10 participants. In this almost two hour long session, we elicited perceived problems with office noise, discussed potential visualizations, and data to visualize. We analyzed the results and then designed an online questionnaire which was sent to a broader group (84 valid responses). Based on the analyzed output of the questionnaire and the first workshop, we derived designs for a situated visualization prototype and sensor-based data collection setup. The sensing and visualization setup will consist of a collection of microphones, shared displays, and individual e-ink displays placed on employees' desks. Future steps will involve the development and deployment of the visualization. Here, we report on our first phases of development and the prototypes that we intend to develop further.

2 RELATED WORK

In contrast to factory workers, office workers are rarely exposed to dangerously high noise levels. Nevertheless, office workers are often exposed to different types of background noise that can come from either inside or outside their office. Noise is defined as sound that is unwanted by the person who is hearing it, because it is unpleasant, irritating, or disruptive [8]. Different studies have suggested undesirable psychological effects of noise on desk workers such as loss of motivation [3], an increase in annoyance and employee dissatisfaction [9], or an inability to concentrate and an increase in stress levels [3, 4]. Moreover, noise has been shown to cause a significant decrease in employees' performance, particularly if their work requires sustained cognitive effort [6]. All of these undesirable effects have the ability to negatively impact mental health.

Many visualization techniques exist for representing sound. Next, we highlight three systems that are closely related to our goal of designing ambient situated visualizations of noise. *Activity wallpaper* is an ambient visualization on the wall of a café that shows noise levels as an indication of café activity [13]. The visualization shows real-time noise levels and historical data for the last seven days, which is related to one of our designs. *Conversation clock* is an ambient tabletop visualization showing the acoustic contribution of people sitting around the table [1]. Each person's acoustic contribution is shown with a circular bar chart that represents the average amplitude of each person's speech level. *SoundEar* is a commercial situated visualization of noise levels for office workplaces, whose aim is to promote behavior change among employees [5]. Noise levels are captured from a network of sound meters and the data is shown on a shared display in the office and on individual displays shown near each person's desk. This system is the most related to ours but uses very simplistic visualizations of only six noise levels.

3 ESTABLISHING REQUIREMENTS

To ground our design we conducted a two-part requirement analysis.

Design Workshop: First, we organized a focus group with 10 office workers from our own lab who were interested in becoming more aware of noise in their workplace through visualization. Our goals were to understand what types of noise were the most prevalent and the most disturbing to people, to elicit visualization design ideas, and to collect data to construct a more formal and broader questionnaire. We found that people were most annoyed by a beeping security sound (7 people) and to a lesser extent by office equipment (e. g., computer fans) and other people Skyping (4 people each). Our participants were interested in seeing a visualization of the noise levels over time inside their office and also in the hallway to show others about noise exposure coming into the office.

Online Survey: Informed by the results of our workshop and by noise surveys conducted in the past [10, 12], we designed and deployed a questionnaire asking participants to rate different sources of office noise. Participants rated 7 different sources of noise inside and 8 outside their office on a 10-point Likert scale ("not disturbing at all"–"highly disturbing"). Participants could also respond that they were not exposed to a noise and add additional sources of noise in a free-form textbox. We received 84 valid responses out of which 56% shared an office with ≥ 5 co-workers and 14% worked alone.

Fig. 1 shows the average disturbance for each source of noise. People were on average not highly disturbed with all avarages < 5.5. Participants reported to be more disturbed on average by noise inside the office than outside. Most disturbing noise is caused by other people, either talking in groups or making calls.

4 DESIGN AND IMPLEMENTATION

We decided to focus on sound inside the office to raise people's awareness on where noises come from, who produces these noises, and to what extent (e. g., how loud, how often, and how long). We reasoned that making people more aware of this information may promote positive behavior change. We, thus, chose to use a collection of multiple sound sensors (microphones) in order to capture sound levels at each office desk. In terms of information

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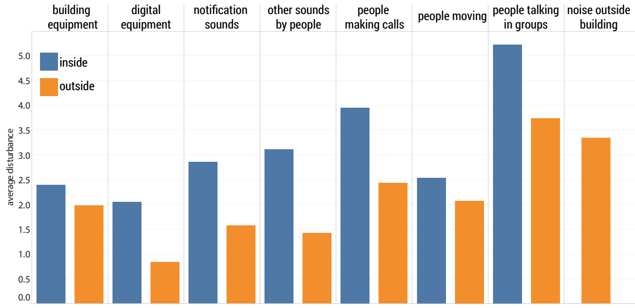

Figure 1: Survey responses: Average disturbance by different types of sound inside/outside the office, reported on a 10-point Likert scale.

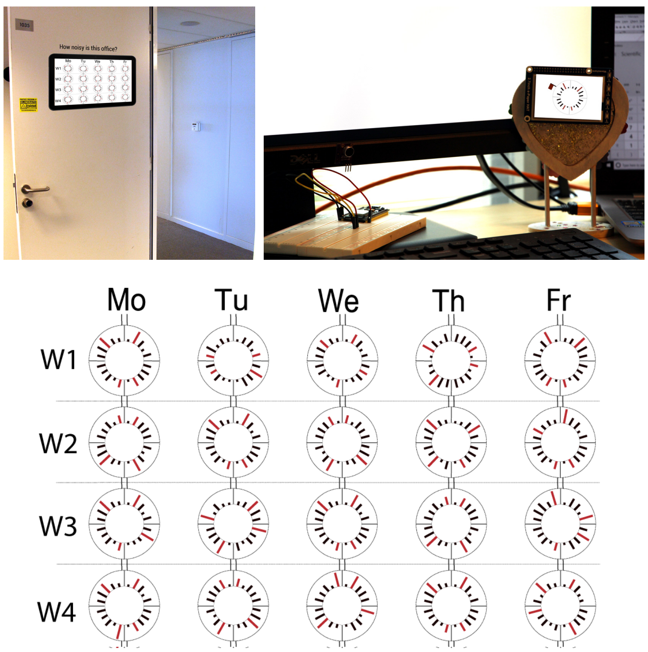

Figure 2: Possible visualization designs (mockups). Top left: A situated visualization of noise on an office door Top right: Small personal display of daily noise exposure on an office desk. Bottom: Radial bar charts for a month's worth of noise data.

presentation, we will use a set of very small displays (e-ink displays). Small and lightweight displays can be placed more flexibly than a large and bulky display, and are potentially less distracting visually. In addition, having sound sensors and displays that are physically detached allows for more flexibility in the way the entire setup is designed. The small displays may be complemented with one or more large ambient displays placed in public or semi-public areas.

We will experiment with different physical setups for the placement of sound sensors and displays. As a first step, we will test a layout where each desk has a microphone placed next to it, and a single overview visualization will be displayed on a tablet or desktop monitor in a semi-public area (e. g., next to an office door that people pass by regularly as can be seen in Fig. 2: top left). As a second step, we will extend the previous setup by placing a personal e-ink display next to each desk as in Fig. 2: top right.

We are working on two visualization designs: one for daily noise levels and one with a month's worth of data (Fig. 2: bottom). One is a radial bar chart showing noise levels for each working day of the month. The circular graph is divided into four time slots between 9 am to 9 pm. In each time slot the noise level is drawn as an average for thirty minutes and times that exceed a critical threshold are marked in red. We also consider visualizing who contributed which amount of noise. With this visualization co-workers can get an overview about a specific room and see whether or not it is generally noisy or quiet. The individual small displays will only show one day's data and inform an office worker primarily about the sound they produce and less about the sound they are exposed to.

We are currently also in the process of building data capturing devices using Adafruit electret microphones and wireless Espressif ESP32 microcontrollers. To have a reproducible sound response we calibrate all microphones using the same speaker. The sound capture devices are always on and communicate average sound level data via Wifi once every minute to an MQTT broker. This server, in turn, provides the data wirelessly to the e-ink displays that are also driven by ESP32s. These display nodes are battery-powered and can be placed at various locations in the office, and request data once every minute and remain in deep-sleep mode otherwise. For the future we are envisioning server-side historic data graphs which are created individually for each sensor, and which the individual e-ink display nodes can request as binary images for direct display.

5 Future Work

We plan to evaluate and test several more design alternatives with our own team and then deploy and study the setup in an external office space. In particular, we are interested in how the two different types of displays (personal and shared) influence how information is experienced. This study will help us to more broadly reflect on how situated and embedded visualizations could be used and help people related to their personal data.

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