Context specific analysis of the sound environment at the workplace and its relation with a task

Jikke Reinten[1,2], Helianthe Kort[1], Maarten Hornikx[2], Armin Kohlrausch[3]

[1] Utrecht University of Applied Sciences, Research Centre for Innovations in Healthcare, Utrecht, The Netherlands (corresponding author)
[2] Eindhoven University of Technology, Building Physics and Services, Eindhoven, The Netherlands
[3] Eindhoven University of Technology, Human Technology Interaction, Eindhoven, The Netherlands

Corresponding author's e-mail address: jikke.reinten@hu.nl

ABSTRACT

A method to analyze the sound environment and its relation with typical professional tasks is described in which structured non participative observations are combined with audio recordings. First results of a field study are reported, directed towards the day shift of hospital nurses, working at a surgical ward.

With this method we want to contribute context specific outcomes which we consider a prerequisite for the design of dedicated laboratory experiments which can reveal insights transferrable to natural work settings. In our reading of the literature we see many studies on task-sound interaction with one or more of the following shortcomings:
1. The sound conditions used in the experiment are not representative for the dedicated environment.
2. The experimental task is not representative for tasks performed in the dedicated environment.
3. The task-sound interaction is such that subjects are instructed to ignore environmental sounds while in real life they first need to attach meaning to each sound in order to decide whether it is (ir)relevant.
It is our expectation that the proposed method helps design experiments that overcome these shortcomings.

INTRODUCTION

A coffee machine, the voice of a colleague, heels in the distance and a phone that rings are just some examples of typical sounds that can be heard at any workplace. The combination of these and/or other sounds and building acoustics determine the sound environment which influences the way people perform their job, as sound can be, for example, distracting [1,2], stimulating [3], annoying [4,5], comforting [6] or providing important information regarding the task [7]. Scientists from several disciplines, including (psycho)acoustics, architecture, ergonomics and psychology, are interested in exactly how the sound environment influences a person performing a job or task, either to understand more about the processes in the human

brain or, as in our case, to gather knowledge on how to create circumstances that allow people to perform at their best.

An extensive literature search [8] resulted in a large amount of empirical studies in which some aspect of the sound environment is manipulated to measure an effect on human performance. In a majority of these documented experiments, subjects are seated in a sound proof room in which sound is offered either through headphones or strategically placed speakers in that booth. They are asked to perform a task, designed to measure an ability, such as memorization [9] or number facility [10], and subjected to sound conditions which vary in sound level [11], speech intelligibility [7,12] or source type [13]. Furthermore, the participants are, in the case of background speech, often instructed not to pay attention to any sounds that are heard. [2,9,10,12,14].

The results of these experiments are very meaningful from a cognitive psychology point of view, as they reveal information on the influence of very specific aspects of sound on human abilities. Translating the results to how a person is affected by the actual sound environment at his or her own workplace, however, is difficult considering the complex tasks they are performing and the interaction between the sound environment and the task/job at hand. The reason for this is that either the sound conditions used in the experiment are not representative for the dedicated environment, the experimental task is not representative for tasks performed in the dedicated environment, or the task-sound interaction is such that subjects are instructed to ignore environmental sounds while in real life they first need to attach meaning to each sound in order to decide whether it is (ir)relevant.

As an example, we are taking a closer look at nursing. During a typical shift, a nurse working at a hospital ward may perform over 80 different tasks [15], walk 6.6 km [16] and enter various spaces with different sound environments comprising, amongst others, speech of known and unknown voices, familiar beeps, ringtones and medical equipment. We argue that an analysis of the tasks, the abilities they require, the sound environment in which the different tasks are performed is required to design an experiment to measure the effect of the sound environment on nursing performance. In order to be able to attend to the patients' needs, a nurse has to be constantly aware of the sound environment. This requires a specific mindset, a situational awareness that has to be present in an experiment as well. Furthermore, as it is our aim to guide strategies which improve the sound environment at a workplace, the difference between experimental variables should be such that they could be realized in the natural environment. This would require an analysis of the interaction between the task and the sound environment.

This contribution presents an approach designed to gather data on the sound environment at a workplace, and its interaction with the tasks that are performed. It is centered around a nurse working in a hospital ward, but a similar approach could be applied in other work environments as well. A structured non-participant observation study combined with audio recordings in a hospital ward was conducted. In total, 10 observations of one nurse during the first three hours of the day shift were performed. Preliminary findings of one of the observations are presented and discussed here based on the possibilities for data analysis.

METHOD

The current observation has taken place in a surgical ward (orthopedics) in a Dutch top-clinical hospital. To gain insight in the nurse's decision making, planning, attention and distraction, they were instructed to speak their thoughts out loud following the principle of the think aloud method [17]. The nurse's intentions for future activities provides information on which activities are planned for a certain moment, whether they are executed in time or at all, and on the amount of activities that a nurse has to remember during the shift. The

observations were carried out by two researchers. Researcher A, the first author with an academic background in building acoustics, kept a log about the sound environment. A time log was kept containing the location of the nurse, the type of sound sources and location of sounds, specific information about sound events and direct consequences (if any) of each sound for the nurse. The nurse looking at her ringing pager and pressing the mute button, or waving at a greeting colleague are examples of direct consequences. Researcher B, a registered nurse, kept a time log of all the nurse's activities, ranging from closing the curtains to putting a waste bag in the garbage disposal system. Additionally, as the nurse was asked to think aloud, all intentions for future actions that were spoken out were logged. If for example while reading a patients file the nurse saw that antibiotics had to be administered at a certain time, and she made a mental note of this, the intention to administer the antibiotics was logged. An intention could be also be the result of a conversation, with a doctor for example who instructed that an extra check was needed with a patient.

Participant

The participating nurse in the current observation is a 30-year old female with 4 years of working experience as a nurse. She has worked at the ward for one year. The nurse volunteered to participate in the study and received a small incentive. The nurse was, together with another colleague, responsible for 6 patients.

Recruitment and consent

The nurse was recruited during a staff meeting, as were the 9 other nurses who participated but not included in this paper. Prior to participating, the nurse was informed of the study procedures and data management, but not of the exact purpose of the study as this may have influenced her behavior. Informed consent was signed retrospectively.

Patients were informed of the researchers' presence and audio recordings through an information letter which was handed out on the day prior to each observation. Verbal information was provided by a nurse working the evening shift. Patients who could not be informed, due to a late admission or because they were admitted during the observation period, were informed verbally by the participating nurse while the researchers stayed outside the patient's room. All patients were informed of their right to refuse the recording of the audio. Visitors and other staff were informed through information letters which were visible at the entrance of the ward, the coffee corner and the nurses' station.

The study was approved by the hospitals ethical board.

Study procedures

The nurse was shadowed by two researchers during the first three hours of her shift, from 7.00 AM to 10:00 AM. Instructions were given to do her work as usual, with the only exception of introducing the researchers to new patients and to verbalize her thoughts according the Think Aloud method (TA). One day prior to the observation, a phone call was scheduled with the nurse to make sure all instructions were clear and the nurse had the opportunity to ask questions.

Material and equipment

Both researchers used an individual observation scheme on a clipboard, a digital clock was attached to the clipboards such that the time was always visible. Audio was recorded with a TASCAM DR-40 and external in-ear microphones. A calibration measurement was performed before and after the observations. Researcher A was wearing the in-ear microphones and stayed as close as possible to the nurse without obstructing care by getting in her way.

MAXQDA 12 software was used to transcribe, annotate and code the audio data.

The ward consists of two corridors, crossing each other in the middle, as can be seen in Figure 1. A closed nursing station with a desk in front is visible from almost every position in the corridors. The ward consists of single patient rooms, 22 in total, only. The visitor's entrance is separated from the service entrance to part the different traffic flows. A small coffee corner and seating area are situated in a wider part of the corridor, near the visitor's entrance. Besides patient rooms and the nursing station, there are a large meeting room, a doctors' office, a medication room, a rinsing room and storage rooms. The walls in all spaces are either plastered, covered with wallpaper or made of glass. The floor has a hard coated finishing, except for the area around the seats which is carpeted. The ceilings in the corridor, (except for the area above the seats), nursing station, medication room and rinsing room are suspended; a mix of glass wool panels and perforated gypsum. The walls and ceilings in the patient rooms and above the seating area are not suspended and do not have any substantial acoustic sound absorption material. Additional panels of mineral wool were installed on the walls of the nursing station and the meeting room. Measurement of room acoustic parameters is planned for a later stage.

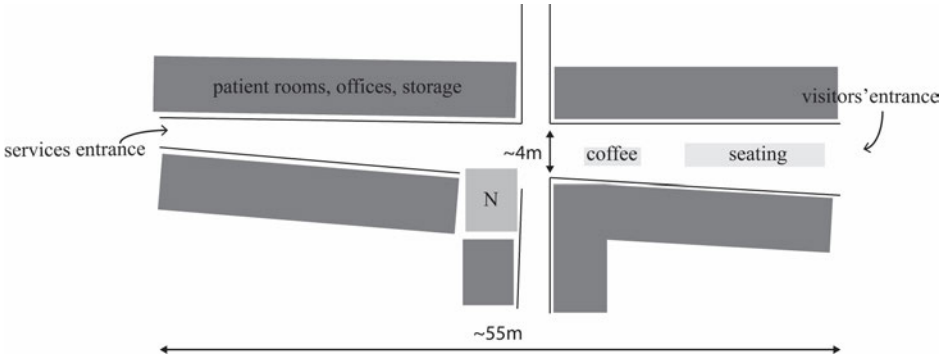

Figure 1: A schematic layout of the ward. N indicates the location of the nursing station.

PRELIMINARY RESULTS

From one of the observations, an 11-minute fragment has been selected for preliminary analysis. In these 11 minutes the observed nurse is performing a specific task. She is reading about her patients for the day in the electronic patient documentation, a task that requires, amongst others, attention. During this task, the nurse has to process information and use it to plan ahead. To misread or miss information about a patient could lead to omissions of care. There are several locations where reading can take place, in the nursing station, the doctor's office (which is not just to be used by doctors) or a large meeting room. The nurse decides where to read, based on preference and availability of computers. In the presented case, the nurse is reading from a computer screen in the nurses' station. The presented segment starts at 07:18 AM which is 12 minutes after the start of the observation.

Figure 2 shows the code line plotted in MAXQDA which is derived mainly from the audio recordings. On the horizontal axis the time stamp of the audio recording can be seen in minutes, start- and end time of sound events was noted per second. The labels that are used for the different sound events are plotted on the left, with the current activity, reading, in the top row. While the labels were predetermined on a broad level, some labels were added in the process. Whenever the nurse ('N'), is speaking out her thoughts, in this segment reading out loud and planning care, the label 'TA' is used. A different label is used for when the nurse is speaking in a conversation and when she is laughing. When the nurse is diverted from her task, the label 'distracted is used. In the current segment, only 2 types of conversation partners are distinguished, 'NCA' which is the label for the specific colleague with whom the

nurse shared the responsibility for patients that day, and ‘NCB’ for all other nurse colleagues. Separate labels are used for background speech nearby, which means that the conversation takes place within the same room at a maximum of 4 meters from the nurse, and background speech far which is used for all other background speech. Another distinction has been made for intelligible and unintelligible background speech; all speech that could be understood by Researcher A when listening to the audio was labeled as intelligible. The code line also shows other sound events, such as pen clicks, lockers opening or closing and computer sounds, the current location (NS for nurses’ station) and whenever there is an interaction with the researchers. In the current segment, which was at the very beginning of the shift a TA reminder was required as the nurse fell silent for a while, and a short instruction not to explain her job but to just say what she was thinking.

Based on the transcripts of the audio file and the logs of Researcher B, information was gathered on the activities planned for each patient. Table 1 shows which intentions were formed by the nurse while reading. No inconsistencies were found between the log and the audio recording.

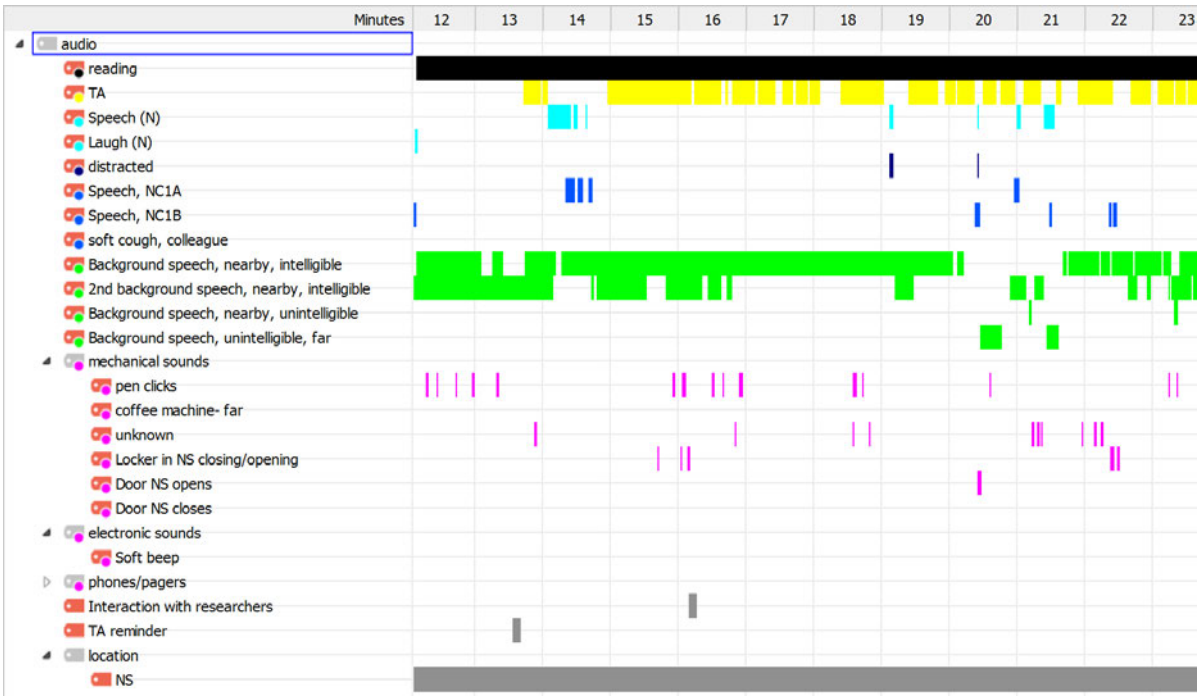

Figure 2: A segment of the code line in MAXQDA

Table 1: Intentions formed between 07:18 AM and 07:29 AM by the nurse

Time	Quote	Intention
07:20:39	..here i read antibiotics, Kefsol, the patient may have it at 07:50 AM, 03:50 PM and at 10:50 PM..	Administer Kefsol at patient X at 07:50 AM
07:21:34	..so we should monitor the production of urine, this has tob e between 4 to 6 hours, she needs to have spontanous micturiation. And this is something to err.. place in my head as an alarmbell...	Monitor micturition of patient X
07:23:09	..is not yet very stable on crutches, so we need to practice this for a while..	Practice walking with crutches with patient Y
07:23:09	..and then she is allowed to go home..	Patient Y can go home after practicing with crutches
07:23:44	..at this time there is a compress because there was leakage, we want to remove this later on..	Remove compress at patient Z
07:24:12	..and then we try to mobilize as fast as possible with this one ..	Mobilize patient Z ASAP
07:25:17	..mobilize and see if he can go home at the end of the day..	See if patient Z can go home after mobilizing
07:28:37	..I will keep communicating with my hallway buddy, NC, about what we do..	Keep communicating with NC
07:28:53	..and then I will just start with ADL care..	Start ADL care activities

Table 2*:* Mean sound energy levels and context of specific fragments

Fragment	Description	Mean sound energy levels
07:17:26 - 07:18:36	N is reading (no TA) from a computer in the nurses' station. Two conversations are taking place in the same room at a close distance from N	67 dB
07:23:42 - 07:24:19	N is reading and explaining what she reads (TA) from the computer, about a patient that needs to be mobilized. Then N says she is looking up whether antibiotics should be administered. At this point, only one conversation is taking place in the same room, colleagues are discussing how to bandage (crossing or no crossing) in a certain case.	75 dB
07:24:19 - 07:24:25	N was looking up whether antibiotic should be administered, but is visibly distracted by the background conversation about bandaging. Right <u>after</u> this fragment N says: " But you always need to cross it right ?".	72 dB

Figure 2 shows that, while reading, the nurse is almost continuously subjected to nearby background speech, multiple conversations take place within the nurses' station. From the transcript it could be read that the topics of these conversations ranged from social interaction, organizational discussions and patient care. The nurse was visually and audibly, by responding to the sound environment, distracted by those conversations twice. One of these instances is reported in the bottom row of Table 2. The second distraction was caused by a colleague from the night shift who was leaving the nursing and said goodbye.

As the measurement setup was calibrated, sound levels can be derived for any segment, either when the nurse is not speaking, when she is thinking aloud, right before a distraction took place or when involved in a conversation. Using the sound analysis software PRAAT [18] the equivalent sound level for three meaningful fragments was derived, the results are shown in Table 2.

DISCUSSION

The preliminary results of the selected segment are discussed here in light of the three shortcomings that were identified in the literature.

Analysis of the sound environment

Based on the analysis of 11 minutes of audio and observation data, we are able to describe the sound environment in a nurses' station during a typical complex nursing task. This description contains annotations of all sound events, transcriptions and therefore content of speech and relevant sound levels. Further analysis of the current observation and the recordings of another 9 observations, will provide data on the typical sound environments surrounding a nurse during each task

Analysis of the task

By using the think aloud method combined with audio and observations the presented task (reading patient data) could be analyzed. Based on this single observation, a realistic view on the amount of patients, amount and type of information that has to be remembered and the amount of planning and decision making that is involved with this task was formed. Data from the other observations will help to strengthen this view. Performance indicators for this specific task can be derived such as the time required to read, the percentage of information that is processed correctly and the actual execution of planned care. It is expected that further analysis will lead to a quantification of nursing tasks. Information such as the time that is spent on each task, the complexity of a task and the abilities required to perform well can be used to design representative experimental tasks.

Analysis of task-Sound interaction

In the presented segment, two moments are identified at which the nurse responds to the sound environment, one of which is shown in Table 2. In this case, the interaction with sound environment was not related to the task and regarded as a distraction. Annotating and transcribing all available audio data may reveal insights that help determine the amount and content of distracting conversations and other sound sources, but also the amount and content of task related information that is communicated to the nurse through sound.

CONCLUSION

Based on audio recordings, the sound log and the activity log, both qualitative and quantitative analyses can be performed on the sound environment, tasks and sound-task interaction of a nurse in a hospital ward. It is expected that a similar approach can be used in other work settings. The results of such analyses may help design experiments in which the sound conditions, the task and their interaction have a better correspondence with the dedicated work environment.

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