Effectiveness of User Notification in Ambient Soundscapes

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Abstract. In this paper we present an ambient audio notification system for multi-user environments. It provides unobtrusive notification by embedding audio cues in an ambient soundscape consisting of specially arranged pieces of music. The audio cues are distinct either in their instrumentation or in their rhythmic pattern and complement a musical core of the soundscape. To test the effectiveness of our system we conducted a study with 25 subjects and compared notification effectiveness and reaction speed between our approach and salient notification sounds which were not embedded into the soundscape. We present the key findings and some implications following from the evaluation of our study.

1 Introduction

Traditional GUIs, but also modern UI paradigms, such as augmented reality or pervasive computing, address almost exclusively the visual sense. The use of audio is mostly limited to simple sounds and auditory icons for system feedback. If these are played aloud (i.e. not via headphones) in a multiuser environment, they can be annoying for others and distract them from their own current tasks. In order to provide user notification without the disturbing effect of a traditional notification signal, we have developed a system which works in a more peripheral and discreet way. We have composed, arranged and recorded three ambient soundscapes (one of which was derived from a Jazz standard), observing certain rules from cognitive psychology and musicology regarding human perception. The arrangement and separate recording of every single instrument gave us full control of all musical parameters and structural elements. We can thus manipulate the rhythmical, melodical and harmonic properties with respect to parameters such as volume and speed. The soundscapes consist of a background part (core song) and a number of optional parts which are used as notification instruments (figure 1). For the purpose of conducting the study, we implemented a demo interface in which one of three soundscapes as well as one of the available

Fig. 1. Arrangement of an ambient soundscape (musical core and optional parts)

notification instruments can be selected. On a map of the room, the subject's position can be marked for proper spatial rendering of the soundscape. In order to notify a registered user, the system adds his selected notification instrument to the current core song and makes it appear to come from the user's own position. Technical details of our system can be found in [1].

2 Related Work

In 1952 Colin Cherry showed in his cocktail party experiment the limitation of cognitive perception and peripheral awareness [2]. He found out that humans can distribute their cognitive resources between focused and divided awareness and that they can switch between these two types of awareness. This effect has been used in several ambient audio interfaces: Kilander and Lonnqvist have used natural sounds in their work on weakly intrusive ambient soundscapes [4]. These sounds blend into the natural noise of the surroundings and the degree of their intrusiveness can be regulated. They are, however, chosen arbitrarily and don't belong to a common theme, metaphor or even composition. In our work we use notification sounds integrated into composed music. Mynatt et al. used voice, music, sound effects or a combination of these as notification sounds in their audio aura system [6]. In terms of music, they used different short melodies carrying different meanings. These melodies were not integrated into a comprehensive composition playing continuously. The composition and arrangement of musical patterns and songs is the only way to ensure full control of all music factors. Different methods have been used for automatic composition of music, such as grammars, finite state automata or constraints. Roads provides an overview of these techniques in [7]. Zimmermann [3] developed a system for automated music composition in order to assist multi media presentations. In our research we use music composed by humans, but let the system determine the mix of different pre-produced parts.

3 Design of the evaluation study

3.1 Questions and goal of the study

To test the viability of our approach, we decided to compare it against a conventional acoustic alarm sound and conduct a study with the aim of answering for each kind of notification the following two questions:

- How often is a notification recognized (Efficiency)?
- With what delay does the subject react (Reaction time)?

3.2 Participants

We recruited 25 participants (five women and twenty men) at ages from 20 to 35 years with mostly academical education. Most of them had a background in either computer science or music. We didn't succeed in our initial goal to balance the set of participants in every aspect, but were at least able to split evenly between musicians and computer scientists

3.3 Setup of the Study

The study was carried out in an instrumented room equipped with spatial audio hardware providing output through eight speakers mounted in a circular arrangement under the ceiling. Technical details of this setup can be found in [8]. In this way, we were able to position the different parts of the soundscape and the specific notification instruments independently of each other. In addition to this, we prepared a computer with the test software. The study consisted of three parts with a overall duration of 30 minutes.

1. Introduction and sound presentation (15 minutes)
   In an explanatory text the subject was first introduced to the topic of the study and the test procedure and then given the opportunity to ask questions until we could ensure the tasks were fully understood. Subsequently, the subjects learned two personal notification signals and the corresponding soundscapes as well as the conventional alarm sound by repeated listening.

2. Computer-based test (10 minutes)
   The test environment included a question window, a signal button area and a radio button area for possible answers (see 2). We had prepared two recorded and prearranged soundscapes in which the notification instrument learned by the subject in the introductory phase and the conventional alarm

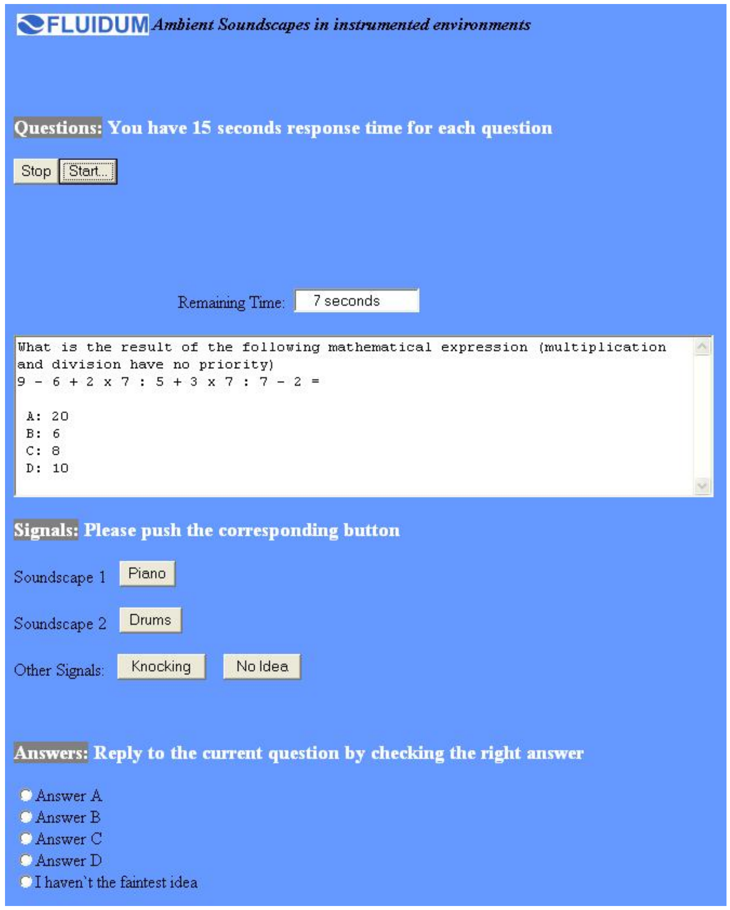
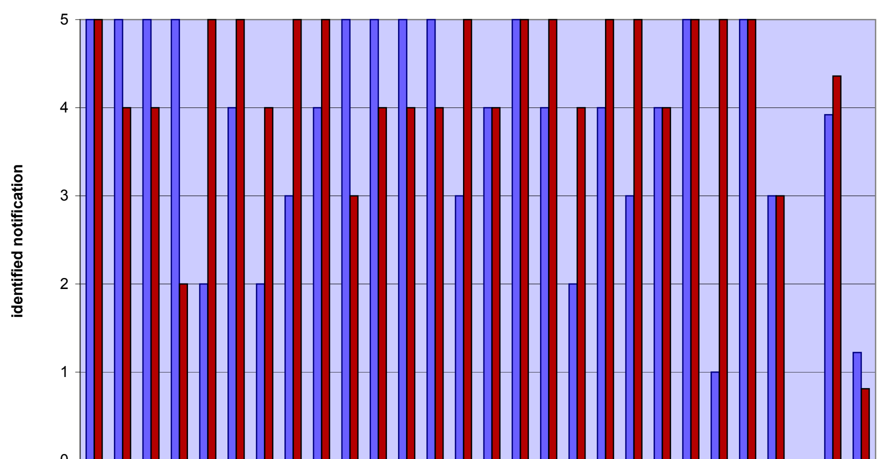


Fig. 2. A screenshot of the test environment

sound appeared randomly. The task for the subject was to press the corresponding signal button after recognition of a notification signal as soon as possible. To prevent subjects from focusing on the background soundscape and to distract them from the auditive stimulus, they had to answer questions under time pressure. As a result of their limited cognitive resources the subjects perceived the audio signals in a rather peripheral way. In ambient soundscape AS01 the piano was made the relevant notification instrument. In the second soundscape AS02 we chose the drums for the audio cues. In contrast to the melody-dominated piano, the drums in AS02 are more rhythmically oriented. As a salient but natural traditional acoustic alarm signal we added a knocking sound randomly to both soundscapes. The volume of salient audio cues is important for the recognition process and we took great care to play the knocking sound at the same volume level as the notification instruments, but while these were part of the composition and matched its overall rhythmic and melodic structure, the knocking stood outside of the overall composition. The two soundscapes were played in a row. users were told to push the corresponding signal button as soon as possible when they perceived an audio cue. The timing of the audio cues and the signal buttons was recorded to measure reaction times. The knocking sound and each notification instrument appeared 5 times for each subject.

3. Questionnaire (5 minutes) After the test, subjects were given a questionnaire of three pages with different styles of questions. In contrast to the computer-based test, the questionnaire was more qualitative in nature. The results are personal opinions and can be influenced by many factors. Thus we only used the questionnaire for retrieving additional information, not for deriving quantitative data. Among other things, subjects were asked:
   – What are the main factors for distractibility?
   – How would you rate the different soundscapes with respect to their role as background music?
   – Besides your notification instruments, what other instruments did you recognize?

4 Results



subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		mean	deviation
Piano (AS01)	5	5	5	5	2	4	2	3	4	5	5	5	5	3	4	5	4	2	4	3	4	5	1	5	3		3,9	1,2
Drums (AS02)	5	4	4	2	5	5	4	5	5	3	4	4	4	5	4	5	5	4	5	5	4	5	5	5	3		4,4	0,8

Fig. 3. Efficiency chart

Our main interest was whether the proposed notification system works efficiently (and potentially more peripheral than traditional audio notification systems). We also looked at the reaction time and some additional information extracted from the questionnaire.

4.1 Notification Efficiency

Figure 3 shows recognition rates of each notification signal for all subjects. The standard deviation of the rate for the drum signal with a value of 0,162 is lower than the piano value (0.244) and clearly lower than the knocking deviation (0,286). Over the course of all 25 subjects, there were 125 piano and 125 drum cues. Of these, 98 piano and 109 drum cues were recognized and identified by the subjects. This suggests that the more rhythmical drums are easier to identify than the a melodical instrument like the piano. Compared to the conventional alarm signal (knocking), the efficiency is surprisingly high (figure 4). Especially the drum notification in AS02 surpassed the knocking sound by seven percent and proved the most efficient of the three notification types.

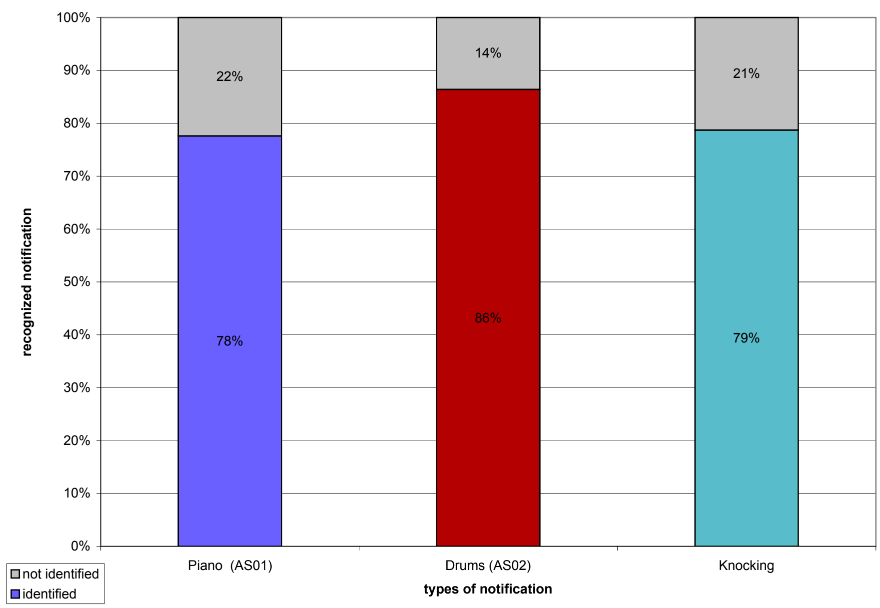


Fig. 4. Overall notification efficiency

4.2 Reaction Time

Our second interest was in the delay between the notification appearance and the act of pressing the button (5). Subjects had to perceive the audio signal, identify it and press the corresponding signal button on the screen. We found that the average reaction time for piano notifications was higher on average (6,59 seconds) than the reaction time for drum (2,1 seconds) and knocking notifications (2,54 seconds). We observed all subjects during the test and took notes whether they first answered the current question or first pressed the signal button. We found out that there seemed to be two types of perception:

1. *Immediate Perception.* The subject recognized the audio signal in the first five seconds after its appearance. The audio cue was focused immediately after the stimulus perception.
2. *Memorized Perception.* The test person pressed the button after the audio signal had already disappeared. The reason for this phenomenon was an effect often described with the words "I think I have heard a signal". In general subjects which had stated in the questionnaire that that they were difficult to distract form their current work had a longer reaction time or missed notifications completely.

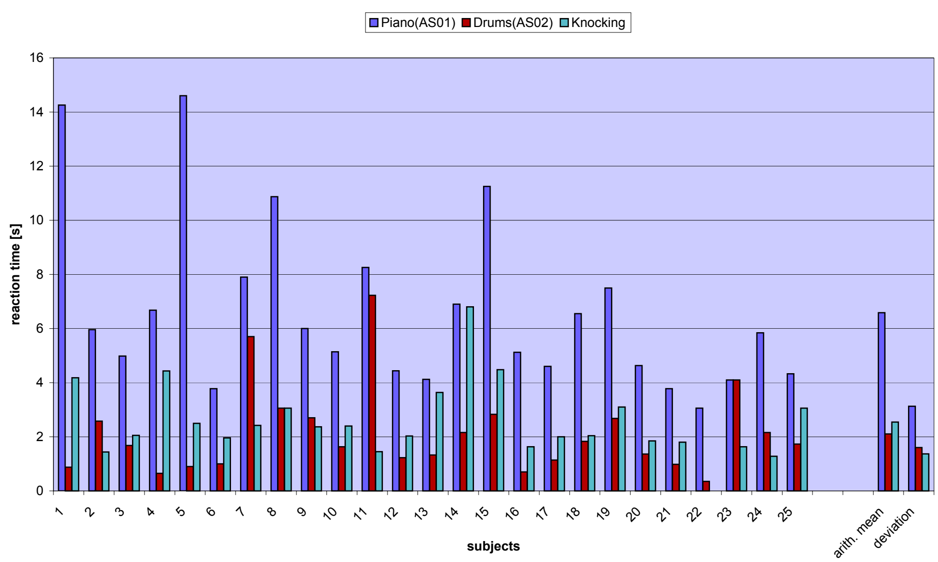


Fig. 5. Reaction time

4.3 Additional Results

With the help of the questionnaire, we got additional information of the subjects. Among other things we asked the test persons whether they can be disturbed easily. 19 out of 25 persons declared that some factors disturb their concentration. Figure 6 shows the main disturbing factors that were mentioned. Although

13.2% declared music as one of their disturbing sources most of them refered to loud music and not to ambient music pieces.

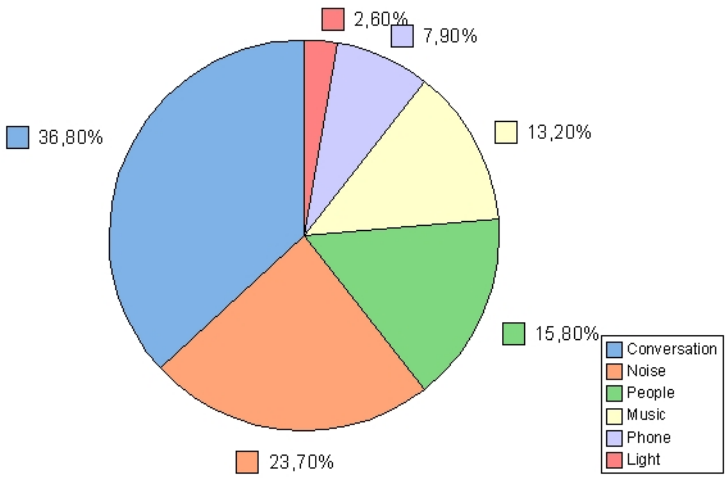


Fig. 6. Main disturbing factors

5 Summary and potential areas of application

We have introduced a system for acoustic notification through peripherally perceived soundscapes and evaluated its effectiveness. While target subjects can be efficiently notified with our approach, other users of the same environment will not be distracted, since the notification sounds are part of the composition of the background music, and will only be recognized as notifications by their target subject. This type of unobtrusive notification gives us the chance to follow a low level privacy approach. We could imagine application of our method in the following areas:

- *Working Area*
  With the core song a comfortable atmosphere can be created. At the same time a seamless user notification can be triggered by arriving mail or upcoming appointments.

- *Clinical Practice*
  Calming ambient soundscapes could be used in examination rooms with unobtrusive notification directed to the staff which are unnoticed by patients

– *Museum Guidance and Public Places*
  Ambient background music in museums and train stations could include information for employees or visitors in the form of audio cues.

A number of obvious scalability issues is discussed in [1], the most prominent being the lack of suitably prepared musical material for large scale deployment. Some potential enhancements of our approach are:

Modularly arranged soundscapes
The musical material used in our system exhibits not only a modular instrumentation of the audio clips. Also the musical structures of the arrangements is kept modular (intro, verse, chorus, interlude, outro etc.). This holds the potential of creating a wider variety of music from the same material by recombining the modular parts in different ways without changing the overall atmosphere of the song.

Mood manipulation by soundscapes
Already today music is used in a variety of environments to influence people's moods. Background music in stores aims to create a comfortable atmosphere and stimulate the spending of money. It would be interesting to see whether audio cues such as those described above could also be used to influence people's behavior in an unconscious way, and whether they can be used at a larger scale, i.e. without the individual learning phase by using known cues, for example, from often-heard music.

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