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The Situational Awareness using the Peripheral Soundscape: A Comparison Study

between Musical and Natural Sounds

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Abstract

The multiple resource theory states that cross-modal time-sharing results in less task interference than intra-modal time sharing. Sonification is a useful tool for the purpose of situational awareness. In this experiment, the participants will perform a visual tracking task while listening to a soundscape that represents changes in temperature. The effectiveness of soundscapes made of natural sounds and sounds of musical instruments will be studied. The structure of the soundscapes will be manipulated to find the optimal design for the soundscape.

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The area of multitasking received the spotlight during the period of World War II because of the practical impacts it had on cockpit designs and other multi-task environments arisen from combats. Today, multitasking is more prevalent than ever as people are responsible for greater number of tasks in a compressed period of time. Multitasking can be found at a workplace, at home environment and during commuting. Some examples are driving while talking on the phone, typing while talking to a person, and a pilot landing an aircraft. It has been concluded that performing two or more tasks at once is more difficult than performing a single task. It has also been concluded that task interference does not solely depend on the quantitative aspect of tasks (Wickens, 2002). In other words, having tasks that require more mental resource independently does not necessarily mean more task interference and reduced performance when combined. For example, when a task is said to be completely *automated*, the task does not require any mental resource and leaves more resource for other tasks. Automacity is best represented as a spectrum with less mental resource required as a task becomes more automated (Fitts and Poster, 1967 as cited by Wickens, 2002).

The multiple resource theory proposed by Wickens (1980) (as cited by Wickens, 2002) incorporates the qualitative aspects of multitasking. The multiple resource theory has been the most useful theory among many other theories of multitasking in that it can predict dual-task performance and task interference. One of the four dimensions of the multiple resource theory is the *perceptual modality*. There are two modalities – auditory and visual. While doing two things at once, presenting one set of information in auditory form and another in visual form results in less task interference than presenting both sets of information in the same modality. In other

words, cross-modal time-sharing (AV or VA) is better than intra-modal time-sharing (AA and VV).

Sonification is the “use of nonspeech audio to convey information” (Kramer, Walker, Bonebright, Cook, Flowers, Minor, & Neuhoff, 1997). Sonification has had the most successful implementations in the field of medical and cockpit designs. In addition, it has been most successful at presenting continuous data variations (Kramer et al., 1997). Since the emergence of personal computers, ever-increasing volumes of data are presented at once. Conventionally, most, if not all, data are presented in a visual form. Sonification can be an effective tool for a multimodal presentation of data as it prevents the overload of visual stimuli and the resulted task interferences (Kramer et al., 1997). Novel ways to present information using sonification is currently studied by many researchers.

Mauney and Walker (2004) studied the use of a peripheral *soundscape* for the purpose of monitoring changes in stock prices. In this experiment, soundscape is the mapping of data using sounds. It was designed for stock traders who are usually very busy and rely heavily on visual displays to help them make decisions about their actions (buying, selling or keeping stocks). “The sound mapping consisted of a threshold-based model in which a percentage change in price value was mapped to an ecological sound to played whenever that threshold or gradient had been reached” (Mauney and Walker, 2004). It should be noted here that the soundscape was not intended to convey specific values. Rather, it was designed to notify traders when the stock price crosses the threshold price. According to the multiple resource theory, bimodal presentation is more effective than visual display alone. There are two things that made their work unique. The first is that they used natural sounds (cricket, cicada, ocean wave, etc.). Because the soundscape was to be played continuously for a prolonged period of time while stock traders were working,

it was important that the soundscape was relaxing and non-distracting. The second is that the changes in complexity, as opposed to changes in tempo, pitch, or intensity as more frequently employed, represented changes in values. The user evaluation from a small sample of stock traders who participated in the experiment brought out several points: the natural sounds were relaxing to listen and were easy to distinguish from other sounds in an office environment, the threshold-based soundscape was intuitive to understand, and the need for training to extract more accurate information from the soundscape. Some limitations for the study were the small sample of participants and the lack of experimental rigor. The study, however, raised many important questions regarding the usability of soundscape.

The current study aims to quantify the results the user evaluation expressed in the above study. It is also different from the above study in that the goal of the soundscape is to provide a situational awareness rather than providing warning signals. Being aware of the current situation and the dynamic changes is the key for responding appropriately when the unexpected occurs. It will lead to a faster and more accurate response to a situation (Kintsh & Ericsson, 1995 as cited by Wickens, 2002). In this task, the soundscape in this experiment is designed to help astronauts who conduct a laboratory experiment while driving a space shuttle. The soundscape will represent changes in temperature of a lab material. The study's aim is to answer the following questions: What are the optimal designs for presenting data in the form of a soundscape? Is a soundscape suitable for the purpose of the situational awareness for environments that require multi-tasking? Lastly, could this form of sonification be used in real life situations? In the current experiment, participants will listen to a soundscape while engaging in a continuous visual tracking task. The user will be asked to indicate a perceived change in values periodically to assess the degree of situational awareness. There will be three types of soundscape designs to

compare the effectiveness of them. They are the soundscape using musical instruments, the soundscape using natural sounds, and the soundscape used in the experiment by Mauney and Walker (2004). Sounds of musical instruments and natural sounds are selected because they have a possibility of being relaxing for listeners when played at low intensity, and the sounds are distinguishable from the sounds emitted by machines and equipments. Also, the sounds were selected so that they are not too similar to each other and not counterintuitive to listeners (Mynatt, 1994). The difference between the soundscape using natural sounds proposed here and the one used by Mauney and Walker (2004) is that the former has more structure than the latter. This experiment will study whether the structure in the soundscape helps listeners to make more accurate assessment. The structure of the soundscape is placed to add more contexts to the soundscape without cluttering the soundscape. The listener will hear the sounds and determine which temperature changes they are associated with. The listener has to be aware of when a particular sound stops playing as well. The dependent variables are the presence of feedback, the accuracy of perceived changes in values, and the reaction time between the questions and the responses. The participants will complete a user evaluation form at the end of the experiment in order to collect qualitative feedback.

Methods

Participants

The participants will be 30-40 undergraduate students (males and females) who will be taking introductory psychology courses at the Georgia Institute of Technology in Spring 2005. They will participate in the experiment in exchange for extra course credits. The restrictions for participants are the normal or corrected to normal vision and hearing.

Material

The primary task. The primary task will be the visual tracking task borrowed from a study by Bevis (2003). The tracking task was developed using Visual Basic 6.0. The task consists of ten columns from the tops of which balls dropped at random intervals. The goal of the task is to move a bin at the bottom of the screen with the left/right keyboard arrows to catch as many of the falling balls as possible, without letting them drop “through” the bottom of the screen. The number of missed versus caught balls will be recorded to an Excel spreadsheet.

The secondary task. The secondary task will be the monitoring of changes in temperature using an auditory soundscape. There will be 7 levels of temperature changes: the baseline, and the increase and decrease of temperature by 1, 2, and 3 degrees. Consequently, there will be 7 sounds to represent each level of the temperature. The baseline sound will always be present. Additionally, the sounds will be presented in layers. For example, to indicate a temperature increase by 3 degrees from the original temperature, the sounds that correspond with an increase in 1, 2, and 3 degrees as well as the baseline sound will be played simultaneously. In a similar manner, to indicate a temperature decrease by 2 degrees, the sounds that correspond with a decrease in 1 and 2 degrees as well as the baseline sound will be played simultaneously.

The first soundscape will be composed of musical instruments. This selection was made because sounds of musical instruments can be pleasant to listen and distinguishable from other sounds emitted by machines and equipments. The structure of the soundscape is such that sounds representing the increase and decrease by 1 degree have similar musical characteristics (e.g., string, percussion, etc.) and sounds representing the increase and decrease by degrees have similar musical characteristics, and so forth (see Figure 1). In addition, sounds representing the increase in temperature will have higher pitches compared to sounds representing the decrease in

temperature. It should be noted that pitches does not be correlated with changes in temperature; it was implemented to provide additional context and structure to the soundscape.

The second soundscape will be composed of natural sounds. Natural sounds are also appropriate for the purpose of situational awareness because they are relaxing to listen and considerably different from sounds emitted from machines. In the same manner, sounds will be paired for the increase and decrease by the same degree. For example, sounds representing the increase and decrease by 1 degree will be birds of different types. (See Figure 1.)

Procedure

Cover Story. The participants will be told that they will be engaging in a tracking task similar to any medium intensity visual maneuvering tasks such as driving a car or a space shuttle, and listening to an auditory graph that represent changes in temperature at the same time. The participants will be asked to perform the tracking task with a few mistakes as possible and respond as quickly as possible whenever they are indicated to give changes in temperature.

Learning phase. The experimenter will explain the tracking task and the participant will practice the task for one minute. Then the experimenter will explain the soundscape and how the participant should respond to it. The participant will listen to the soundscape and practice the responses for two minutes. Lastly, the experimenter will explain how the two tasks will be played simultaneously.

Testing phase. The participant will perform four practice trials before starting the experiment. Half the participants will listen to the musical soundscape first and the other half will listen to the natural soundscape first for counter-balancing. Both tasks will last for 400 seconds (6.67 min). There will be a one-minute break between two tasks. After completing two

tasks, the participant will complete a survey that measures the participant's perceived usability. The participant will also choose a soundscape he/she prefers more (musical or natural sounds).

Expected Results

Method of Analysis

The participant's accuracy on the tracking task would be determined by examining the Excel spreadsheet and dividing the number of balls caught by the total number of balls dropped. To determine the degree of situational awareness, the correct estimation of changes in temperature and the reaction time will be analyzed. An ANOVA will be performed on the accuracy scores on the tracking task and the degree of correct situational awareness using the soundscape.

Possible Outcomes

There are 4 possible outcomes from this experiment: 1) the degree of situational awareness is the same for all 3 conditions, 2) the situational awareness is better using soundscapes with more structure, 3) the situational awareness is better using a soundscape composed of musical instruments, and 4) the situational awareness is better using a soundscape composed of natural sounds.

This experiment will study the designs for the effective soundscape for the purpose of situational awareness in multi-tasking environments. Specifically, the benefits of having the more structured soundscape and the natural of the sounds in the soundscape will be examined.

Future Works

The sounds of musical instrument and natural sounds were selected to maximize the pleasantness. The sounds, however, were not selected based on scientific data or a large survey.

Therefore, it is possible that the sounds selected for this experiment do not represent the optimal sounds that could be used for the purpose of situational awareness.

The effect of task interference can be better assessed using a real driving simulator rather than a tracking task for the primary task.

Also, it would better fit the multiple resource theory if the response reaction for the secondary task were verbal as opposed to key input. That way, visual stimuli are responded using visual output and auditory stimuli are responded using verbal output.

Figure Caption

Figure 1.

Nature		
Temperature change	Sound	Type
+3	Blackcap	bird
+2	Ketrelbird	bird
+1	Geese	bird
0 (baseline)	Waterfall	
-1	Cricket	insect
-2	Katydid	insect
-3	Cicada	insect

References

- Bevis, K.J. (2003). Effects of an auditory interface for mobile phone operation while distracted. Unpublished.
- Kramer, G., Walker, B., Bonebright, T., Cook, P., Flowers, J., Minor, N., et al. (1999). The sonification report: Status of the field and research agenda. *Report prepared for the National Science Foundation by members of the International Community for Auditory Display. Santa Fe, NM: International Community for Auditory Display.*
- Mauney, B. S., and Walker, B.N. (2004). Creating functional and livable soundscapes for peripheral monitoring of dynamic data. Proceedings of ICAD 04. Sydney, Australia: The tenth international conference on auditory display.
- Mynatt, E.D. (1994). Designing with auditory icons: How well do we identify auditory cues? *Report prepared for CHI Conference, 1994.* (pp269-270).
- Wickens, C.D. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science, 3(2), 159-177.*
- Wickens, C.D. (2002). Situation awareness and workload in aviation. *Current Directions in Psychological Science, 11(4), 128-133.*