INTERACTIVE SONIFICATION OF MEDICAL DATA

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ABSTRACT

In this paper we describe the development of a sonification system to represent time-dependent data. The system's aim is to support therapists of anorexic young women to analyze questionnaires filled in by their patients. The mapping we adopted was suggested by the therapists and reflects the "mood" of the variables we used in the sonification (e.g. depression). Our main questions were, whether sonification is applicable in this context, whether the mapping we chose was appropriate and whether users get an overall impression of the patients' development. The results of this pilot study indicates that our approach is promising.

KEYWORDS

Sonification, time-dependent data, evaluation, information interfaces.

1. INTRODUCTION

In recent years, the ability of computers to process and present data has increased tremendously. Information visualization is applied to give users a concise overview of data, but they are often overwhelmed by the sheer amount of information on the screen. Sonification might be used to alleviate this problem and complement information visualization. It should be pointed out, however, that there is still not very much information about the potential benefits of this combination.

In this paper, we describe the development and evaluation of a sonification tool to support therapists analyzing time-dependent data about their anorexic patients. The data used for this study was previously used for the development of an information visualization tool [5]. In the course of the previous study, we realized that the potential benefit of the visualization system might be enhanced by sonification giving the users a more comprehensive overview of the data. We decided to first investigate whether sonification might, in principle, be an advantageous solution to the problem of information overload in our context. Therefore, we developed a stand alone system without combining it with an information visualization tool.

The system we developed was aimed at supporting therapists in their work with anorexic young women. These patients, and also their relatives, have to fill in many questionnaires before, during and after the therapy. Interesting variables in this context might be, e.g., depression or number of friends the patients have. The therapists need these data to clarify which factors influence the success or failure of the therapy and to predict the outcome of the therapy process. Time-dependent data play an important role in this context. In sonification, the change of variables over time can be displayed quite naturally [4].

In this paper, we first discuss related work. Then we describe the system we developed. This system presents information from four different questionnaires (that is, four different sounds) at the same time. In this way, users not only get information about single values, but should also get an overall impression of the patient's development. We also tried to develop a mapping which is meaningful to the therapists working with the patients (e.g. dissonance as indicator for a negative development). In the last section, we describe a short usability study to assess whether this approach works and potential users can derive insights from such a tool. The main contribution from this work is to investigate a sonification system presenting variables in parallel streams. This will be of interest to designers of sonification systems as well as to persons wanting to analyze complex questionnaire data.

2. RELATED WORK

Traditionally, sonification is used to support visually impaired people. In recent years, the combination of visual and auditory stimuli has been investigated, either to ease the problem of information overload (see e.g. [6]) or to study how design principles from information visualization might be applied to sonification (see e.g. [8]). Salvador et al [6] show that the combination of sound and InfoVis methodologies can yield better results than both methodologies used individually.

Brewster [1] lists several advantages this combination of output modalities in computer interfaces could have. Among others, he mentions that auditory information display can reduce the cognitive load on the visual channel. Walker and Mauney [7], e.g., point out that one of the most important issues in sonification is the mapping of variables to sound dimensions. Some guidelines exist which are valuable for the design of sonification systems (see e.g. [4, 2].) Flowers [4] gives a comprehensive overview about design guidelines for sonification. He especially outlines which features of a sound may be used for representing what kind of data. In this context, he points out that the sensitivity of the auditory system for temporal changes is very high, and that such changes sometimes might be better represented in an auditory form than in a visual form. He also suggests not using loudness to represent continuous variables. Brown et al [2] also developed a fairly comprehensive system of guidelines. In their studies they found out that users prefer parallel mode to sequential mode of data presentation and that this mode was also more efficient.

The guidelines developed by [2,4] informed the design of our system, especially the recommendation to use parallel mode, but to design the system carefully to enable users to distinguish the different variables. Flowers [4] points out that there are still no obvious solutions in this area and more research is necessary. Recently, some sonification systems were developed to support scientists in the analysis of large amounts of data (see e.g. [3]). These efforts seem to be quite successful and interesting and inspired us in our work. A longterm goal of our work is also to investigate the combination of visualization and sonification, although it is not a specific issue in this paper.

3. DESCRIPTION OF THE INVESTIGATION

3.1 The sonification system

The sonification system was developed in close cooperation with the therapists from the hospital. They also provided the data. The system represents data from questionnaires which were presented to therapy patients five times (before, three times during, and after the therapy). The therapy lasted approximately one year. For the purpose of the development of the sonification system we used the data of six patients and four representative questionnaires:

1. Beck-Depression Inventory (depression)
2. Phobia Scale (anxiety in social situations)
3. Self-Efficacy (whether patients believe they can act effectively and reach their goals)
4. Euthymia (whether patients enjoy rewarding and relaxing activities)

The first prototype approach was to make the mapping of questionnaire values and sounds as simple as possible. The different questionnaires were represented by various timbres, the single values by pitch. We developed a small prototype which we showed to the therapists to get feedback from them about the mapping of the variables. The therapists suggested using different metaphors for the sonification to correspond with their perception of the patients. They argued that a more meaningful mapping could support them better in the process of data interpretation. They both came to very similar suggestions. Depressive patients, e.g., should be described by musical sounds of low volume in a minor key. It should be pointed out, however, that sounds in a low volume, if presented in combination with other sounds may not be audible. This has to be taken into account when designing such an interface. In general, the therapists proposed that patients with a positive development should be represented by harmonious sounds and patients with a negative development by dissonant sounds. We discarded the first prototype and developed the final system based on the therapists' suggestions. The following mapping was developed:

Beck-Depression Inventory (measuring depression)

positive: major key, loud

negative: minor key, low

Social Phobia Scale
positive: low-pitched, loud
negative: low-pitch, low/hushed
Self-Efficacy
positive: fast tempo (rhythm)
negative: slow tempo (rhythm)
Euthymia (whether patients enjoy rewarding and relaxing activities)
positive: light timbre, gay
negative: dark timbre, dissonant, bleak

Each dimension consists of a scale ranging from 1 to 5. The mapping reflects this structure of the scales and presents different sounds for every point of the scale. The sounds representing the four dimensions are presented in parallel. This is recommended by e.g. [2]. The development in time is presented in a discrete fashion. The users may interact with the system to decide when and how long they want to hear a sound.

The sonification system was developed using the software SuperCollider for the Mac. For the evaluation (see next section), a graphical interface was developed, also using SuperCollider (see Figure 1). The interface consists of different buttons. There is one set of buttons in the top right corner presenting single sounds when pressed. These are the reference sounds of the four different scales (e.g. SPS is the Social Phobia Scale). All other buttons present composite sounds, that is sounds consisting of four individual sounds. In the upper half of the screen are test sounds for the learning phase, in the lower half are sounds representing the tasks of the test phase.

3.2 Evaluation

In the study, we want to clarify three issues: Is sonification applicable in the context of time-dependent medical data? Was the mapping we chose appropriate? Does the mapping help to give users an overall impression of the development of the patients?

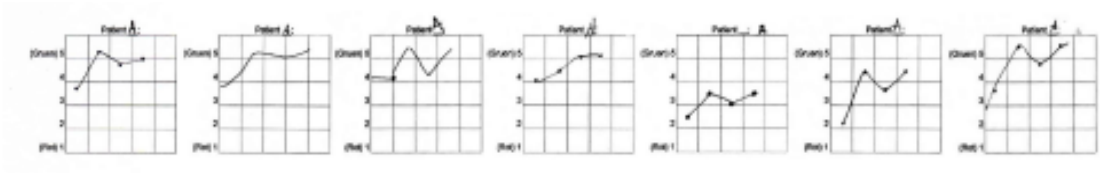
We tested six subjects (two therapists, two musicians, two laypersons). Five of the subjects were male and one was female. The age range was between 25 and 55 years. The evaluation methods were observation, a semi-structured interview after the test and the analysis of the diagrams the subjects had to draw (see below). The testing consisted of an introduction, a learning phase and a test phase. The introduction consisted of an audiometric test and a short introduction into the domain. During the test phase, they had to assess the overall development of six patients based on the values of the four dimensions described above. For most of the dimensions, values for five points in time were available. They had to decide quickly whether the patients' development was positive or negative. Then they had to draw a curve of the development of these patients (see Figure 2). During the tests the subjects were allowed to listen to the reference sounds as often as they wanted. They did this quite frequently, some of them more than 100 times. It took the subjects between six (musician) and sixteen minutes to finish all the tasks. The whole user test took approximately one hour, including the audiometric test, the learning phase, the test phase and the interview.

There is some indication that the sonification system is relatively successful. The evaluation shows that the subjects mostly stick to one specific way of forming an overall impression of the patients' development. The subjects computed the average of the single values of the single dimensions (resulting from the questionnaires). Figure 1a represents an "ideal" diagram of one patient based on the numerical results from the questionnaires. In approximately 80% of the cases the subjects adopted this approach. The musicians were in general more accurate than the other subjects. The diagrams (see Figure 1b) indicate the overall development of the patients. The overall form of the curves is fairly correct, but the absolute level of the subjects' assessments does not conform to the reference curve. It is an open question whether this can be improved by practice.

The observation of the subjects indicates that they could describe the single values fairly well and understood the mapping. Differences in the quality of the mappings could be observed. Subjects complained that especially Beck's Depression Inventory was difficult to perceive, especially because of the use of volume as a method to represent the value of the variable. The mapping of self-efficacy (rhythm), on the other hand, could be perceived very well. Most subjects started with this variable when trying to give their assessments.

Observation and interview yielded additional information. In general, the mappings were found to be quite good (apart from the Beck's Depression Index). One question asked in the interview was whether the

subjects tended to interpret the sound as a whole or rather tried to assess every single component separately. There does not seem to be a consistent strategy. Some subjects adopted a more holistic approach, others did not. Observation indicates that concentration seems to be a very important factor in sonification. Some of the subjects remarked that using sound as a representation of quantitative values was quite unusual which made it so difficult. It is an open question whether this is a kind of literacy which can be learned or not.



a b1 b2 b3 b4 b5 b6

Figure 1a. Reference value. Fig. 1.b.1-6: Subjects' assessments of patient A's development

4. CONCLUSION

In this paper, we presented results from a pilot study investigating the usefulness of adopting sonification for the analysis of time-dependent data in medicine. The results seem to be promising, and a more in-depth study is certainly necessary. In answer to our questions our results show that sonification is, in principle, applicable in this context, although subjects were certainly not used to this kind of presentation of information. To analyze sonifications is certainly taxing. This might be due to the fact that this is an unusual form of presentation. Further research adopting longer phases of learning and adapting to the system is necessary to clarify this issue. The mapping seems to be appropriate.

Subjects could identify most of the sounds we presented to them, although some modifications are certainly necessary. We did not get a definitive answer to the question whether our mapping enables users to get an overall impression of the patients' development. Subjects seem to adopt different strategies. More research is necessary to clarify this issue. It was especially valuable to have potential users (the two therapists) and musicians as subjects. In the future, we want to do additional research using more data and to combine the sonification with the already existing visualization.

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