USE OF SOUNDSCAPES FOR PROVIDING INFORMATION ABOUT DISTANCE LEFT IN TRAIN JOURNEYS

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ABSTRACT

This paper presents a study in the framework of the ISHT – Interior sound design of high-speed trains project. During a train journey between the cities of Stockholm and Gävle, Sweden, 9 travellers participated in a listening experiment to evaluate the use of sonification to convey non-speech based information about the travel. We tested sonification for communicating the distance between two stations in the train journey. The participants could activate an iconographic representation of the sound in the landscape outside and listen to it through headphones in three conditions: with music, with a soundscape or with silence. Their interaction was logged, and ratings of their stated sense of knowing where the train was between the departure and arrival stations were recorded. Preliminary results show that our sonification helped participants to get an idea of the distance left for reaching the next station, and also that listening to the sonification was experienced as an engaging and pleasant activity.

1. INTRODUCTION

We present here a study that has been conducted in the framework of the ISHT – Interior sound design of high-speed trains project. Main goal of the project is the development of design methods and acoustic artefacts for improving the sound environment in high-speed railroad cars of the future, with particular focus on the passenger comfort.

The role of KTH in the project is the testing and design of new sound-based signaling methods for providing travel information to passengers on the train. In the following sections we describe how we implemented and tested sonification as one method for providing information to passengers.

Research focusing on the enhancement of travel experience has seen an evolution in recent years, specially thanks to the availability of mobile devices that can provide information about the traveller’s position, for example through GPS technology. Public transport authorities are making available information about their transport systems to developers through APIs [1]. Researchers have been proposing new mobile phone-based applications for enhancing the travel experience from a social point of view, by for example developing chat systems that are meant for people sitting in the same bus, or information services that are location-based (for example a list of shops and interest landmarks in the proximity of a bus stop) [1]. Some projects have made use of non-speech sounds for providing route information for example by adopting auditory icons which describe modes of transportation and the duration of the journey [2]. In the work by Kainulainen and co-workers [2] the duration of the journey is compressed, each minute of travel is mapped to one second of sound in the auditory icon, e.g. a travel of 10 minutes will correspond to a 10 second sound. In the same study soundmarks have been used for guiding travellers, for example a soundscape could be used for signaling a location. While travellers familiar with the location will recognize the place by its recorded soundscape, this task could be difficult for people unfamiliar with the place and therefore a symbolic soundmark would work better. The latter is the approach that we use in our study for designing the soundscape of the landscape outside the train during travel. In another interesting study Kostiainen and colleagues [3] made also use of sound for in a mobile journey planner application. Among other things they designed an interesting sonification of the time needed for a journey. From user tests it emerged that users could understand the this sonification only after they received instructions how to interpret the sonification. In our study we want to use soundscapes that provide the traveller with an immediate sense of distance and consequentially of time left to destination, without the need for instructions.

Previous work in the field of sonification in train journey have been done by Pohle and colleagues [4]. They used the built-in camera of a mobile phone for filming the environment outside the window in passenger cars. The video was sonified in real-time generating a music composition that gives instantaneous information about the outside environment. Therefore the application of sonification was designed more from an artistic point of view than a practical one, while in our study we wanted to use sonification for providing the typically verbally announced information about the travel by using non-speech sounds.

1 http://ishkonstfack.blogspot.se/
2. AIM OF THE STUDY

The study at hand presents the testing of sonification for communicating the distance between two stations in a train journey. We wanted to investigate if it is possible to provide the traveller with information about the distance left to the next station by using non-speech sounds. The idea is that of using a sonification independent from culture and language, and that can be understood by international travellers.

Distance was considered as time to arrival rather than a physical distance. This distinction was important to the project as high-speed trains often move slowly near stations due to the speed restrictions in urban areas. We believe that it is more interesting to the passenger to know if it is 10 minutes left to disembarking the train than 1 km before arriving at the station; for example the usual voice message used on trains, at least in Sweden, tells the passengers that the train is soon arriving at the next station, and nothing about the physical distance in kilometers.

3. METHOD

We designed the sonification of the distance between two train stations by using an iconographic representation of the sound (soundscape) in the landscape outside. When the train was close to a station we mixed typical city soundscapes (car traffic, train station sounds, crowds), when the train got further away from the station, the sonification used was that of a soundscape resembling a natural environment (birds, forest sounds). The sonification would fade out the city soundscape according to the distance from the station, and similarly fade it in when approaching the next station, and making the opposite fading for the rural soundscape.

Nine participants (8M, 1F) of seven different nationalities (China, Germany, Greece, India, Iran, Sweden, Venezuela) took part in a listening experiment. Participants had a mixed musical expertise; one third of them has been playing an instrument for at least 17 years, one third for about 4 years, and one third does not play any instrument at all. Two thirds of the participants listen to music everyday. The choice of an international panel is motivated by the fact that the sonification should be understood also by international travellers and not only Swedish ones. This is also the reason for choosing a sonification based on non-speech sounds, i.e. to provide information that is language and culture independent.

The experiment was conducted in a passenger car on a train during a return trip between Stockholm and Gävle, Sweden, with stops in Arlanda, Uppsala, and Tierp (see Table 1). The distance in each direction was 182 km, with four stops. Both trips had an estimated travel time of 1.5 hour, and the train was on schedule. The participants did not already know the train route.

The participants were wearing open headphones and during the travel they would randomly listen to either classical music (JS Bach’s Brandenburg concertos), two soundscapes that gave a sense of motion [5], or just silence. Participants could choose to temporarily switch from the music, soundscape, or silent condition and listen to the sonification of the environment outside the train, as often as they wished. While listening, they were asked to rate the sense of how far the train had come on its journey between two stations on a scale from 1 (no sense at all) to 5 (very clear sense).

Participants were also asked to answer to a post experiment survey composed by six questions for checking the degree of acceptance of the sonification proposed. During the trip, they were free to listen whenever and to any extent they wanted. Their instructions were to not engage in conversation with each other, not move focus from the application window (e.g. to start other applications), but apart from that feel free to enjoy the journey. Participants were sitting spread out in the car, placed either alone or next to another participant, see the experiment set-up in Figure 1.

The test was performed with a laptop running a Pure data patch with four experiments accessible from a graphical user interface. (One of the experiments addressed soundscapes specifically and is not reported here.) Each participant had only to press and hold the space key to temporarily switch to the sonification, and to press key 1–5 for rating the experience. For making the sonification of distance, we preprogrammed the interaction to resemble GPS data that many trains can provide today. In order not to adventure the experiment, we chose not to rely on real data, but used the estimated departure and arrival times as input to the system.

The order of the three experimental conditions (sonification and classical music, sonification and soundscape, sonification and silence) was randomized for each participant, and each condition was kept the same between two stations. The same order was followed for both going out from Stockholm and the return travel, so each participant completed two repetitions of the experiments. Each key press was logged to acquire data on listening durations for the sonification. Furthermore, the choice of forcing the

<table>
<thead>
<tr>
<th>Station</th>
<th>Schedule</th>
<th>Duration [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
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<td>-</td>
</tr>
<tr>
<td>Arlanda</td>
<td>12.00</td>
<td>18</td>
</tr>
<tr>
<td>Uppsala</td>
<td>11.42</td>
<td>19</td>
</tr>
<tr>
<td>Tierp</td>
<td>12.27</td>
<td>27</td>
</tr>
<tr>
<td>Gävle</td>
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<td>25</td>
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<tr>
<td>Gävle</td>
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<td>-</td>
</tr>
<tr>
<td>Tierp</td>
<td>15.32</td>
<td>23</td>
</tr>
<tr>
<td>Uppsala</td>
<td>16.00</td>
<td>28</td>
</tr>
<tr>
<td>Arlanda</td>
<td>16.17</td>
<td>17</td>
</tr>
<tr>
<td>Stockholm</td>
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<td>24</td>
</tr>
</tbody>
</table>

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user to keep holding down the space key in order to hear was made to prevent the user from just leaving the sonification “on”.

3.1 The sonification

Since we could not rely on real GPS data, the sonification was made generic for a trip with the characteristics of leaving from urban area, travelling through a rural landscape, and arriving to an urban area. Mostly, this corresponded well to all four trips of our journey.

Five long recordings (between 2:30 and 15 minutes) downloaded from the Freesound.org website were used as source for the sonification. These were urban soundscapes\(^2\), a forest soundscape\(^3\), and a sound from a passing train\(^4\).

The urban soundscapes were played back in Pure data using random starting points and only for short durations (typically less than one second). Each file was accessed simultaneously in many instances by the playback function, resulting in a dense soundscape resembling the original file, but with a non-repetitive and organic feel. Each played fragment was faded in and out with fading characteristics controlled by the position between the stations. When the train was farther away from the station, the playback would be increasingly scattered and attenuated with only single instances of urban sounds slowly fading in and out.

\(^2\) File 14604 from the user acclivity, file 120752 from klankbeeld and file 135537 from inchadney
\(^3\) File 66785 from user inchadney
\(^4\) File 1934 from user RHumphries

The sound of the passing train was played louder when closer to a station and barely noticeable in the landscape area, but mostly used to provide a consistent background to the urban sounds. Similarly, the forest soundscape was gradually faded in as the train left the urban area, and was dominant during the landscape section. For both soundscapes, the starting point for playback was randomized to avoid repetitions.

Each time the participant held down the space bar on the laptop keyboard, the sonification described above would start to play. As a result of the randomized starting playback point, the sonification would never sound the same, thus avoiding the sensation of using prerecorded sounds. This was a reasonable assumption, as it was commented by participants during informal discussions after the experiment.

3.2 Post-experiment questions

Each time the train arrived at a station, participants were asked to answer three questions on a scale from 1 to 5. The questions were the following:

1. Did you like the sound representation of the traveling advancement between stations? 
   \textit{Indicate on a scale from 1 (not at all) to 5 (very much)}

2. Did you experience the sound representation as being informative to you? 
   \textit{Indicate on a scale from 1 (not at all) to 5 (very much)}

3. Imagine you could have this service in your mobile phone. To switch from your music player to the sound representation, you only need to flip the phone over. What would such a service mean to you? 
   \textit{Indicate from 1 (would love it) to 5 (would not use it)}

Mean rates to these answers for each of the three experimental conditions (sonification combined with either classical music, silence, or soundscape) are reported in Table 2. Participants were also asked to answer to other three open-ended questions.

4. Are there benefits of the sound representation you heard?

5. Do you have any comments on the sounds you heard?

6. Do you have any other comments on the experiment?

Some of the comments from the participants are presented and discussed in the following section.

4. RESULTS

Preliminary results suggest that our sonification helped participants to get an idea of the distance left for reaching the next station, and also that listening to the sonification was experienced as an entertaining activity. In general, the
Table 2. Means and their standard deviations for answers to three post-experiment questions. (1) I liked the sound representation of the travelling advancement between stations; (2) I experienced the sound representation as being informative; (3) I will not use this service in the future. Participants made their ratings on a scale from 1 (low) and 5 (high). For explanation of the rating scales used by participants please refer to the text in Section 3.2.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>I like it Mean</th>
<th>I is informative Mean</th>
<th>I will use it Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music</td>
<td>3.63</td>
<td>3.40</td>
<td>3.07</td>
</tr>
<tr>
<td>Std. dev</td>
<td>1.19</td>
<td>1.24</td>
<td>1.28</td>
</tr>
<tr>
<td>Silence</td>
<td>3.62</td>
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<td>2.81</td>
</tr>
<tr>
<td>Std. dev</td>
<td>.885</td>
<td>.98</td>
<td>.75</td>
</tr>
<tr>
<td>Soundscape</td>
<td>3.65</td>
<td>3.61</td>
<td>2.94</td>
</tr>
<tr>
<td>Std. dev</td>
<td>.86</td>
<td>1.07</td>
<td>1.05</td>
</tr>
</tbody>
</table>

participants listened to the sonification of the environment outside the train for longer durations when the train was coming closer to the arrival station.

Figure 2. Mean duration of listening to the sonification for the total travel, and for departure, midway and arrival times. The plot shows duration in seconds for experimental condition.

4.1 Listening durations

In Figures 2 and 3 the mean duration of listening to a sonification is shown in three different locations (departure, midway and arrival), both per experiment and per subject. It is seen that one subject in particular listened to sonification for very long time intervals, more than 300 seconds. The other subjects did not exceed 120 seconds, and typically listened to sonification for much less than a minute. Our expectation was that only a few seconds would be necessary and indeed desirable.

Bearing in mind the subject that greatly influences the mean values, in both Figures 2 and 3 we see a clear trend for the different experimental conditions: the condition with silence results in far longer listening to the sonification. There is also a clear tendency to listen longer to the sonification in the soundscape than the music condition.

Figure 3. Mean duration of listening to the sonification for the total travel, and for departure, midway and arrival times. The plot shows duration in seconds for each subject.

4.2 Rating of the sense of distance

The traveller was asked to continuously rate the sense of distance, and also to rate liking. In Figure 4 both the sense of distance and liking are plotted over duration of listening to the sonification. In the diagram, it is seen that the liking and mean duration have some common variation, but this trend has not been confirmed statistically. Interesting though is to notice that the liking is overall high, considering the very large deviations in listening duration.

In Figure 5, only the return journey is included with all four trips. The reported sense of distance is plotted on top of the listening duration. There is a very clear trend showing that the sense of knowing the position of the train, provided by audio feedback, increases as the experiment progresses. This was also confirmed in the comments mentioned in the following section.

4.3 Post-experiment questions

The comments written by participants for the post-experiment questions were mainly positive. Here follows some examples. Comments to question 4:
Figure 4. Duration (in milliseconds) of listening to the sonification for each subject. The passengers' expressed liking of the sonification is plotted as a line.

Figure 5. Duration (in milliseconds) of listening to the sonification for each of the four trips on the return travel. In the diagram, the rating of sense of distance is plotted.

Yes it’s fun to match what you see with what you hear.

Easy to know the period of the trip, beginning, middle or ending.

The idea to hear something that corresponds to the environment outside you is very good.

I’m pretty sure it actually does help you get a sense of how far you have travelled, which probably could enhance the travelling experience.

Comments to question 5:

Sometime, the sound representation and real surrounding sound overlapped.

I could divide the distance into five segments according to the type of the outside noise I perceived.

The fact that the sounds are heard separately (without soundscape/music at the same time) helps a lot to identify the sonified data. Less than one second is needed when hitting the “space bar” to recognize the sounds.

Comments to question 6:

It’s nice to switch from music to sonification and back. Sometimes you want to listen to the music and sometimes to the environment. Equivalent to opening a window.

Can’t really quantify the distance once you’re away from a station. Someone cannot claim they have a good sense of how far they are, but they do have a good sense that they are far enough or close enough to a station.

At the beginning of the experiment, the sonified data was not completely recognized. With training, at the end of the journey, the sounds were correctly matched.

The above comments reveal that sonification helped participants/travellers to establish an enjoyable and informative audio-visual coupling with the outside environment, which facilitates the estimation of the distance left to the next station.

5. DISCUSSION

The preliminary analysis of data collected in the experiment confirm that it is possible to use sonification for providing a sense of how far the train had come on its journey between two stations by using non-speech sounds. This open for the possibility of developing new sound-based services which can enhance the travel experience from both an informative and aesthetically point of view.

We wanted to explore the concept of using sonification as a method to provide information to travellers in a less intrusive manner than for instance public call systems or large displays in the car. Initially, we considered personalized media players (akin to tablet devices) and in-seat entertainment systems (as found on long-distance flights). Later, the smartphone was chosen as the most probable and convenient device for our purposes. First of all, it has sufficient computational power to run real-time sonifications, and also a set of sensors to control interaction. Specifically, the GPS was found to be promising. During tests, however, we experienced problems with getting a reliable GPS signal from within a train car, and especially within station areas, which caused signal block-out for extended periods.

Because of the remaining problems with smartphones and the demanding situation of running the experiment in a regular train car with other passengers, the method described above with laptops had to be chosen. Using laptop computers was however not judged to be a significant set-back for the test.

On the other hand, real-time information about train speed and position is available in the control room of the train (and in train station control rooms), and it could be used...
for future implementations of sound-based services directly available to the passenger such that tested in our study. The sound could be provided either through a headphone connected to the passenger seat, or through audio streaming to a mobile device.

Sonification of distance was only one of several “channels” of information thought available to the passenger. Other sonifications could include context-aware interaction, such as activating sound based on geographical position and facing direction, or movement characteristics of the train, such as speed, ascension and inclination. Testing these concepts is future work, but we anticipate from the presented study that passengers find real-time information mediated through sound to be a welcome feature to enliven the journey.

Acknowledgments

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6. REFERENCES


