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Remote psychoacoustic experiments on audio-visual interactions

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ABSTRACT

The term "remote psychoacoustic experiments" describes the situation that - in contrast to traditional psychoacoustic experiments - the experimenter and the subject are located in different places, like different offices, buildings, cities, countries, continents. In essence, the psychoacoustic experiment is performed via internet. In particular, calibration problems have to be solved that the (remote) subject is presented the sounds at appropriate level, at least approximately. For the example of audio-visual interactions, the setup and calibration procedure are described in detail. Results from remote psychoacoustic experiments concerning perceived loudness differences of trains in different colour, but at same SPL are compared to data for traditional psychoacoustic experiments with the same stimuli.

INTRODUCTION

In many traditional psychoacoustic experiments, the experimenter and the subject are located in the same room, only separated by a sound proof booth. In contrast, the term "remote psychoacoustic experiments" describes the situation that the experimenter and the subject are located in different places, like different offices, buildings, cities, countries, continents. In these cases, the psychoacoustic experiment is performed via internet. Remote psychoacoustic experiments are of great advantage for example in cross cultural studies: More or less the same experiments can be performed by an experimenter with subjects in different countries, saving time and travel money. However, calibration problems have to be solved that the (remote) subject is presented the sounds at appropriate level, at least approximately.

In this paper, as an example of remote psychoacoustic experiments, studies on audio-visual interactions are reported. In traditional psychoacoustic experiments it was found (Patsouras et al. 2002, Fastl 2004) that - despite same SPL - red trains are perceived as being louder than green trains. Using the same sound files and images as in Fastl (2004), remote psychoacoustic experiments were performed with the experimenter in Germany and subjects in different locations like USA. The results obtained by remote psychoacoustic experiments versus traditional psychoacoustic experiments are compared.

REMOTE PSYCHOACOUSTIC EXPERIMENT

Concept

The remote psychoacoustic experiment is realized as a distributed application structure with a server at the location of the experimenter and a client at the location of the subject. This concept is illustrated by Figure 1.

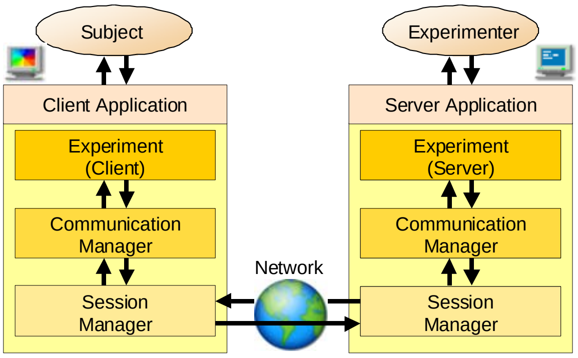


Figure 1. Concept of remote psychoacoustic experiments

The communication over the network is handled in the respective Session Manager by using a simple protocol called SDXP (simple data exchange protocol) over a persistent TCP connection. The handling of the data is accomplished by the respective Communication Manager. Finally, the experiment itself is realized in self-contained modules. To improve performance it is of advantage to handle playback of sound files and videos in the client application.

In essence, for the remote psychoacoustic experiments a concept was realized which allows to bi-directionally transmit and modify experimental parameters and to exchange data packages and data files. The implementation of the client and server applications for this remote psychoacoustic experiment was realized in the programming language Delphi, although the basic principles of this architecture can be applied to most other high-level programming languages that are capable of communicating over a TCP network connection.

Calibration procedure

Since in the remote experiment described here, the influence of different colours of trains on their perceived loudness is studied, intrinsically the colours reproduced on the screen should be calibrated, e.g. by using spectrophotometers. However, since it can not be expected that participants in the remote experiments possess the respective hard- and software, it was decided not to attempt to calibrate colours. This seems to be acceptable, since in pilot studies we found that the exact colour is not so critical for the audio-visual interaction with images and sounds from trains.

As concerns the sound pressure level of the train-sounds presented in remote locations, at least an approximate calibration was envisaged. It goes without saying that relative levels can be easily controlled with high precision by the client application, but the absolute sound pressure level largely depends on the setting of the volume control. Of course, the easiest way would be to measure the sound pressure level at the ears of the (remote) subject by a sound level meter. However, since it can not always be expected that such a device is at hand, a subjective calibration using the most comfortable loudness level (MCL) was developed.

The psychoacoustic concept of most comfortable loudness level relies on the observation that for synthetic signals, subjects use rather similar values of sound pressure level to arrive at a comfortable loudness perception.

In order to estimate differences in MCL attained in the scenario of remote psychoacoustic experiments, a pilot experiment was performed as follws:

Subjects were presented from low-fi desktop loudspeakers or loudspeakers in laptops 1/3-oct band noise centered at 1 kHz with 500 ms on- and off time. They were requested to adjust the volume until a comfortable loudness was reached. The corresponding A-weighted level was measured by a sound level meter. In order to simulate realistic situations, the evaluations were not performed in a sound proof booth, but in typical laboratory surroundings with background noises. After the measurement of the MCL, the subjects were also asked to adjust the level of the 1 kHz noise until it was just audible in the respective background noise. Some results of this pilot study are displayed in Figure 2.

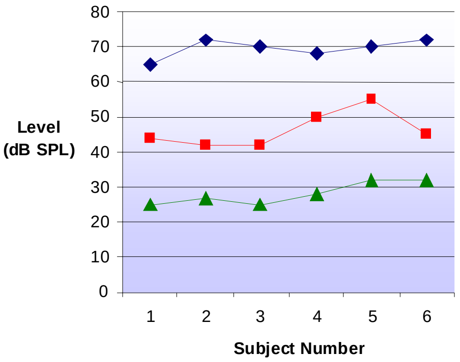
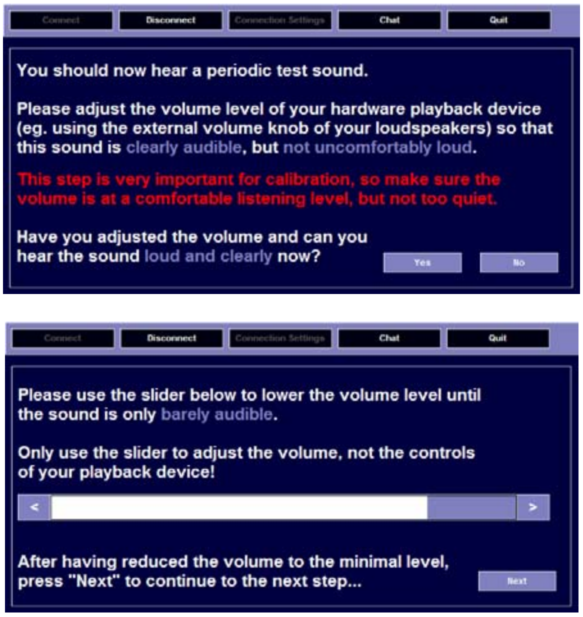


Figure 2. Most comfortable loudness level MCL (diamonds) and just audible level (triangles) of 1/3-oct band noise at 1 kHz in different background noises typical for laboratory surroundings (squares).

The results plotted in Figure 2 show for all six subjects tested rather similar values of most comfortable loudness level (diamonds) around 70 dB. The background noises (squares) in the different laboratory surroundings reach values between about 40 and 55 dB(A); the just audible levels (triangles) lie around 30 dB. It is well known in psychoacoustics (e.g. Fastl and Zwicker, 2007) that narrow band sounds can be detected in broadband sounds despite the fact that their level is by 10...20 dB lower than the level of the broadband sounds. This means that despite "suboptimal conditions", data displayed in Figure 2 are in line with classic psychoacoustic results.

When the MCL is taken as a reference, the data plotted in Figure 2 would seem to suggest that an estimate of the absolute level (in this case around 70 dB) can be obtained with an accuracy of 5 dB or even better. Moreover, in the laboratory surroundings chosen, the dynamic range for the 1 kHz noise between MCL and threshold masked by background noise is in the range of 40 dB.

To further illustrate the calibration procedure, in Figure 3 the instructions on the screen for adjusting the MCL (upper panel) as well as the threshold masked by background noise (lower panel) are given.



You should now hear a periodic test sound.

Please adjust the volume level of your hardware playback device (eg. using the external volume knob of your loudspeakers) so that this sound is clearly audible, but not uncomfortably loud.

This step is very important for calibration, so make sure the volume is at a comfortable listening level, but not too quiet.

Have you adjusted the volume and can you hear the sound loud and clearly now?

Please use the slider below to lower the volume level until the sound is only barely audible.

Only use the slider to adjust the volume, not the controls of your playback device!

After having reduced the volume to the minimal level, press "Next" to continue to the next step...

Figure 3. Screenshots of the instructions to find the most comfortable loudness level MCL (upper panel) as well as the threshold, masked by background noise (lower panel).

Experiment

The remote psychoacoustic experiment performed used the same stimuli as in the "traditional" psychoacoustic experiment described in Fastl (2004). Figure 4 illustrates the images of ICE-trains in different colours presented together with the sounds of passbys by trains, respectively.

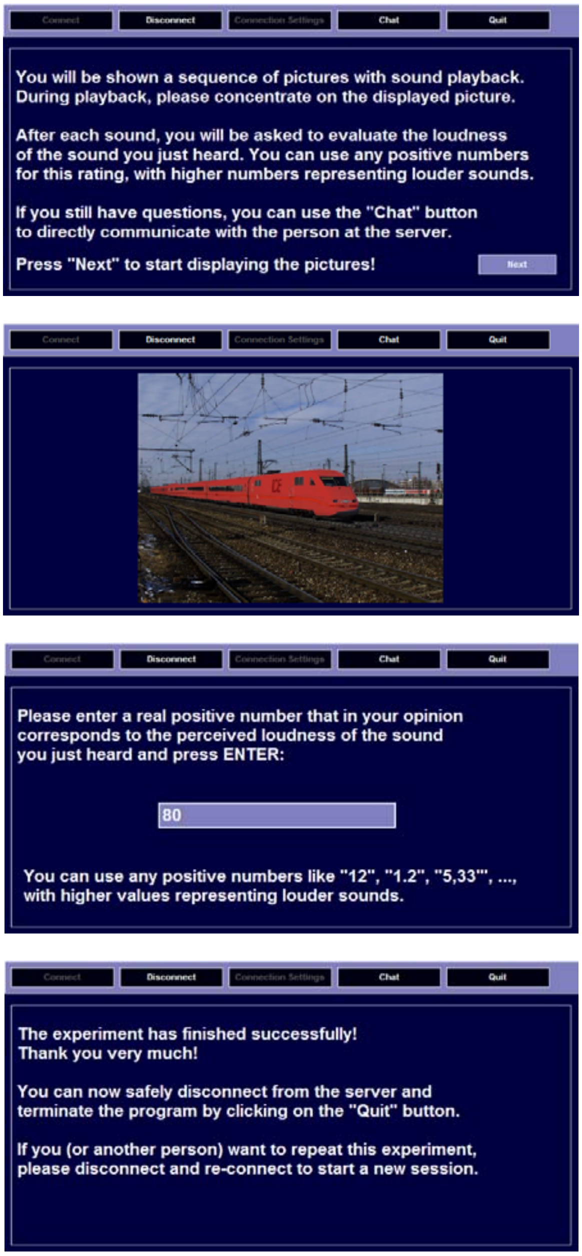
The sounds of the train passbys were presented either in original level, or at levels reduced by 10 dB and 20 dB. Each combination of image and sound was repeated five times in scrambled order. Therefore, 60 combinations of image and sound (4 colours x 3 levels x 5 repetitions) had to be evaluated in the remote psychoacoustic experiment. In addition, before the start of the experiment, four combinations of sound and image, chosen at random, were presented for training.

Figure 4. Images of ICE-trains in white (original), green, red, and blue presented on the (remote) computer screen together with train-passby sounds (from Fastl 2004).

The task of the subject was as follows: 1) Observe the combination of image and sound, 2) Rate the loudness of the train passby sound using magnitue estimation by entering the appropriate number into the computer, 3) Get the next combination until the experiment is finished.

To further illustrate the remote psychoacoustic experiment, Figure 5 shows corresponding screenshots displayed to the subjects via the client computer.

Nineteen subjects participated in the remote experiment on audio-visual interactions. In extreme cases, the experimenter and the subjects were located in different continents, i.e. in Munich in Europe and in Berkeley in the USA. On average it took the (remote) subjects 13 minutes to complete the experiment.



You will be shown a sequence of pictures with sound playback. During playback, please concentrate on the displayed picture.

After each sound, you will be asked to evaluate the loudness of the sound you just heard. You can use any positive numbers for this rating, with higher numbers representing louder sounds.

If you still have questions, you can use the "Chat" button to directly communicate with the person at the server.

Press "Next" to start displaying the pictures!

Please enter a real positive number that in your opinion corresponds to the perceived loudness of the sound you just heard and press ENTER:

80

You can use any positive numbers like "12", "1.2", "5,33'", ..., with higher values representing louder sounds.

The experiment has finished successfully! Thank you very much!

You can now safely disconnect from the server and terminate the program by clicking on the "Quit" button.

If you (or another person) want to repeat this experiment, please disconnect and re-connect to start a new session.

Figure 5. Screenshots displayed to the (remote) subjects. From top to bottom: instruction for experiment, image of ICE-train, instruction for magnitude estimate of loudness, end of experiment.

Results and Discussion

The results of the remote psychoacoustic experiment on audio-visual interactions are plotted in Figure 6. The loudness rating is given as a function of sound pressure level.

The results displayed in Figure 6 show – as expected – that the loudness rating increases with level. On the average, a level increase by 10 dB leads to an increase in loudness rating by about a factor of two. This result is in line with “classic” psychoacoustic data (e.g. Fastl and Zwicker 2007). Even more interesting is the fact that – at same level – the loudness rating depends on the colour of the train in the image presented together with the passby sound. At all levels considered, the red train is perceived as being louder than the green or blue train. The loudness rating for the white train usually is between red and green.

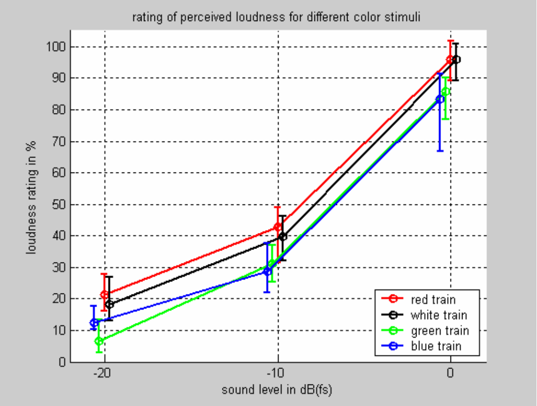


Figure 6. Loudness rating of passby sounds from ICE-trains as a function of level for different colours of trains.

Results plotted in Figure 7 give more details: For the three levels considered, the respective lowest rating is set to 100 % and the other ratings are normalized accordingly. Each column given in Figure 7 represents the median of 95 (remote) ratings by 19 subjects.

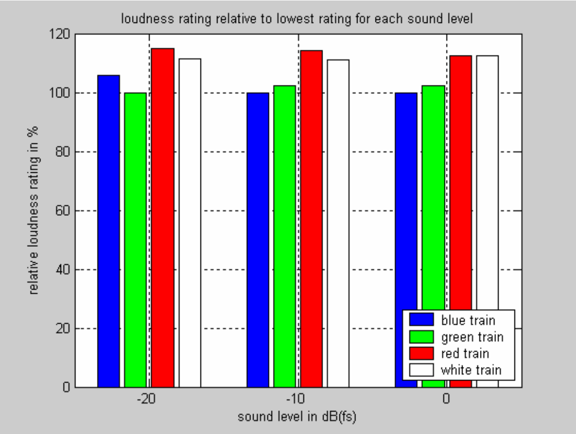


Figure 7. Loudness rating of passby sounds from ICE-trains as a function of level for different colours of trains. At each level, the lowest rating (median of 95 data, respectively) is set to 100 % and the other ratings are normalized accordingly. The sequence of colours is blue, green, red, and white.

Again, the data displayed in Figure 7 reveal that at each level considered, the train sound combined with an image of an ICE-train in red produces the largest perceived loudness. In contrast, the lowest loudness values are reached for green and blue trains.

When considering the loudness differences between green and red trains, despite same level, the red train is perceived as being about 15 % louder than the green train. This result is in perfect agreement with data from traditional psychoacoustic experiments performed with German subjects (Fastl 2004).

Traditional psychoacoustic experiments were also performed with Japanese subjects and the same stimuli (Rader et al. 2004). Figure 8 shows the results for both German and Japanese subjects (Fastl 2005).

The results displayed in Figure 8 reveal that for subjects with rather different cultural background, the influence of train colour on loudness rating is rather similar: For both German and Japanese subjects – at same level – red trains are perceived as being louder than green trains. While for the German subjects – in line with data from the remote experiment with subjects from USA – the loudness difference amounts to about 15 %, for the Japanese subjects, the difference is even lager with about 25 %.

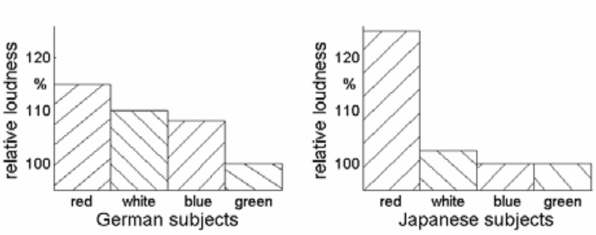


Figure 8. Loudness rating of passby sounds from ICE-trains in different colours, but at same level. Data for German subjects (left) and Japanese subjects (right). From Fastl (2005).

CONCLUSION

In this paper, audio-visual interactions are described for sounds and images of trains. When train sounds of same level are combined with images of trains in different colour, red trains are perceived as being louder than green trains. Similar effects of colour on loudness evaluation were described by Menzel et al. (2008) for combinations of sound and images of sports cars. Using remote psychoacoustic experiments it could be shown that – despite same level - subjects in Europe, Japan, and USA throughout rate the loudness of red trains higher than the loudness of green trains. It is very gratifying that despite compromises in calibration, effects in the same order of magnitude are found in traditional versus remote psychoacoustic experiments. This agreement can be taken as an indication that the (approximate) level calibration by the psychoacoustic phenomenon of most comfortable loudness level (MCL) seems to be rather promising. However, it should not be kept secret that some consent of the client’s system administrator is necessary to set up the remote psychoacoustic experiment in the interactive way proposed in this paper. Therefore, to implement this procedure needs more confidence between partners e.g. in different continents than just questionnaires distributed by intenet.

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