Can different colours influence most comfortable level of speech and music?

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It is known from previous studies that different illuminations of the surrounding room can affect the adjustment of most comfortable level of speech. In this experiment, the goal was to examine effects of different colours on most comfortable level. Therefore, adjustments of most comfortable level of speech, classical, and rock music were performed while pictures of differently coloured radios were shown on a display. The sounds were presented diotically via headphones. Average adjusted levels are about 62dB SPL for speech, 65dB SPL for classical music, and 69dB SPL for rock music. While most subjects do not seem to be influenced by different colours, others show deviations in adjusted level dependent on colour of up to 6dB.

Introduction

The possibility of interactions between the visual and auditory modalities has been demonstrated in various psychoacoustic experiments. For example, pictures of differently coloured trains and sports cars were able to modify loudness judgments (Fastl 2004, Menzel et al. 2008). In these studies, red vehicles – at same SPL – lead to an overestimation of loudness compared to pale- or dark-green vehicles. Also, Viollon and Lavandier (1999) showed that ratings of pleasantness could be influenced by depictions of different environmental settings.

Following a scenario suggested by Haverkamp (2009), it was then found that the level of speech necessary to produce most comfortable loudness changes with illumination (Menzel 2009). In total darkness, subjects adjusted speech sounds about 1 dB lower than under normal illumination.

It thus seemed promising to investigate the possibility that different colours would also be able to influence adjustments of most comfortable level. An experiment was performed measuring the level of speech and music necessary to produce most comfortable loudness while simultaneously presenting images of differently coloured radios.

Experiment

Participants and instructions

Twenty-six normal hearing subjects (3f, 23m, 22 to 51 years, median 24.5 years) took part in this experiment. They had the task to adjust speech and music to a comfortable loudness. The instructions stated that the speech or music should neither sound too soft nor too loud. Also, the subjects were asked not to close their eyes for longer periods of time.

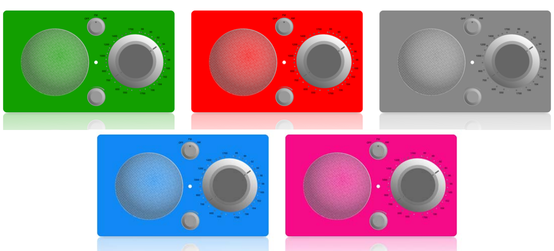

Fig. 1: Coloured drawings of radios used as visual stimuli during the level adjustment.

Apparatus and procedure

A sound-proofed and darkened booth was used to conduct the experiments. As visual stimuli, drawings of radios were used, as they could easily be changed to specific colours and represented known and plausible sound sources. The drawings were presented on a calibrated 21" LC display (EIZO CG211) with a viewing distance of about 70 cm. They had an on screen size of about 10 by 15 cm. The five drawings used in the experiment can be seen in Fig. 1. The specific colours were chosen so that they have approximately equal lightness L* as measured with a spectral photometer (GretagMacbeth i1) when presented on the LC display.

Excerpts of English male speech from the EBU sound quality assessment material CD (EBU 2008) as well as classical music (Dvorak Cello Concerto in B minor Op. 104) and rock music (Marilyn Manson, New Model No. 15) were used as acoustic stimuli. The level-time-functions of the signals can be seen in Fig. 2.

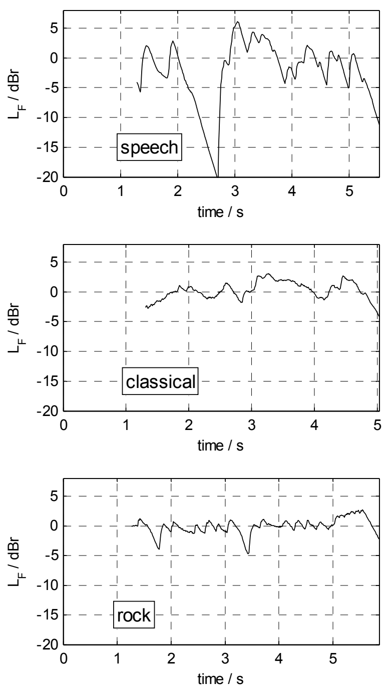

Fig. 2: Level-time-functions of the three signals used in the experiments. Depicted is the unweighted level measured with time constant "fast" and normalised to the RMS level of the entire signal.

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They were presented diotically via calibrated electrodynamic headphones (Beyer DT48) with free-field equalisation as described by Fastl and Zwicker (2007, p. 7). The initial SPL of the sounds was chosen pseudo-randomly to be either low or high. A sound with low initial level started between 40 and 45 dB SPL, a sound with high initial level started between 75 and 80 dB SPL. These ranges of initial level were selected with the intention of producing sounds which are either too soft or too loud (as indicated by Fastl 1976), so that a subsequent adjustment of loudness would always be necessary.

The level of the sounds could be varied by the subjects by turning the scroll-wheel of a computer mouse. Each rotational step of the wheel corresponded to a change in sound level of 0.2 dB, depending on the direction of rotation. Clicking one of the mouse buttons enabled the subjects to listen to the stimulus at the currently adjusted level. This sequence of adjusting the level and listening to the stimulus was repeated by the participants until the goal of comfortable loudness was reached, which had to be indicated by pressing a button on a keyboard. Subjects had the opportunity to familiarise with this method during a short training sequence at the beginning of the experiment.

Each subject adjusted all combinations of the three sounds and five images with both initial levels two times in pseudo-random order, resulting in 60 adjustments.

Results

Fig. 3 shows the resulting adjusted levels for each sound. Circles and lines indicate quartiles calculated from data intra-individually pooled for high and low initial levels. Upward/downward pointing triangles show medians for high/low initial levels separately.

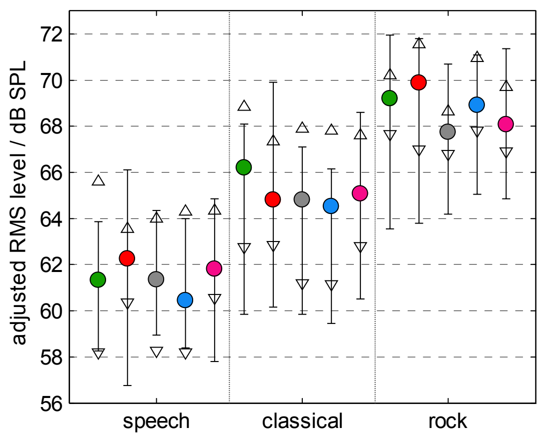

Fig. 3: SPL of speech, classical, and rock music adjusted for most comfortable loudness while viewing radios coloured green, red, grey, blue, and pink. Upward/downward pointing triangles show medians for high/low initial levels; circles and black lines indicate medians and interquartile ranges of intra-individually pooled data for both initial levels.

It can be seen that in this experiment most comfortable loudness is reached at about 62 dB SPL for speech, about 65 dB SPL for classical music, and about 69 dB SPL for rock music. Adjustments started with high initial levels always result in higher median levels than those started with low initial levels. Colour does not seem to have a large influence on adjusted level for any sound. Also visible is the substantial spread of the data with interquartile ranges of up to 10 dB.

Repeated measures analysis of variance indicates highly significant main effects of initial level [$F(1,25) = 92.1$; $p < 0.0001$] and sound [$F(2,50) = 33.06$; $p < 0.0001$], and a highly significant initial level by sound interaction [$F(2,50) = 13.05$; $p < 0.0001$]. No significant main effect of colour was found.

To focus on possible effects of colour independent of absolute level or sound, intra-individual differences between adjusted levels for each colour and the average adjusted level per sound were calculated. The inter-individual quartiles of these values can be seen in Fig. 4.

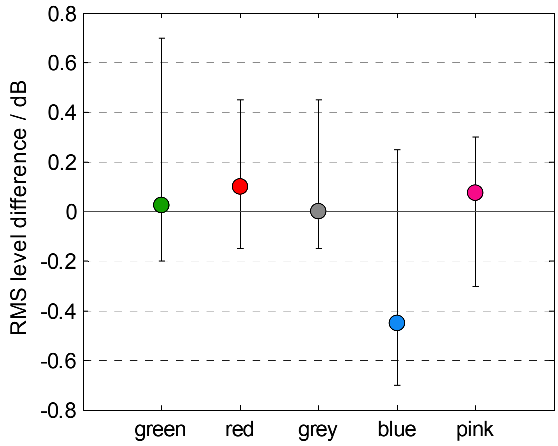

Fig. 4: Inter-individual medians and interquartile ranges of intra-individual differences between the adjusted level while viewing each colour and the average result per sound.

As in the case of absolute adjusted level, level differences show only small tendencies of colour influence. Blue radios seem to be causing level adjustments slightly below average, but according to analysis of variance this effect is not significant [$F(4,100) = 1.01$; $p = 0.41$].

During the examination of the experimental data it was noticed that the magnitude of the influence of different colours varies strongly between different subjects. Accordingly, hierarchical clustering (Ward method, see Bortz 1993), based on the colour dependent level differences as introduced in Fig. 4, reveals two distinct groups of subjects (Fig. 5).

The first group with 21 members seems to be less influenced by different colours, as can be seen in Fig. 6 (top), while the second group with five members shows larger variability in their adjustments regarding different colours (Fig. 6, bottom).

Group 1 nevertheless shows a significant effect of colour, which, according to post-hoc tests (Tukey, $\alpha=0.05$), occurs between grey and blue stimuli, with blue producing levels below the average by about 0.5 dB.

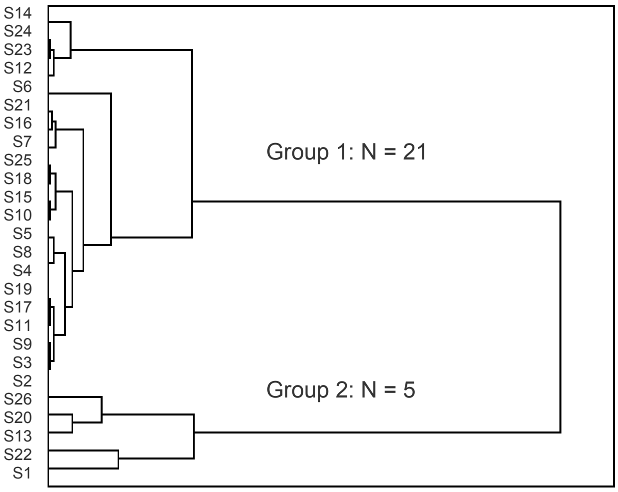

Fig. 5: Hierarchical clustering of subjects based on colour dependent level differences reveals two distinct groups.

Group 2 also exhibits significant effects of colour, specifically between red and grey stimuli, with red causing above (+0.5 dB) and grey causing below (-1 dB) average level adjustments.

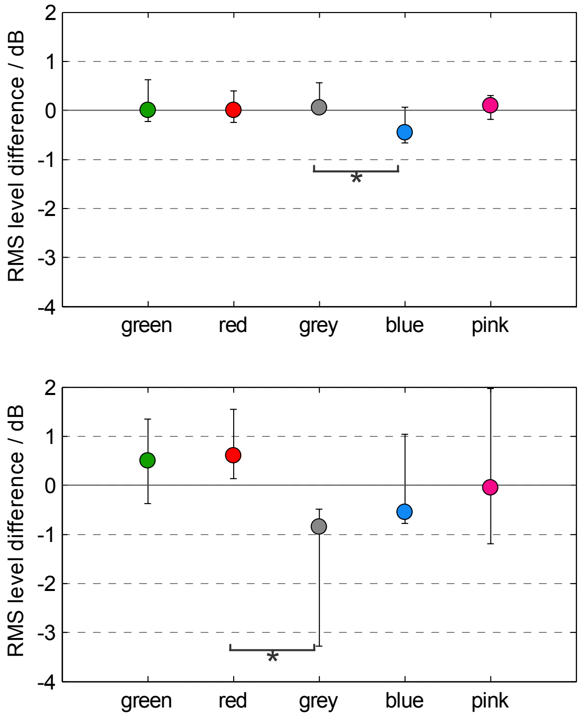

Fig. 6: Medians and interquartile ranges of colour dependent level differences for group 1 (top) and group 2 (bottom).

Discussion

Some subjects seemed to be more strongly influenced in their level adjustments by the presented colours than others. Also, the effect of specific colours varies between subjects. This might lead to the observed situation, where, regarding the median of the data of all subjects, no overall effect of colour was found, while particular groups of subjects did exhibit small significant effects.

To increase the effect size and better study the individual differences, it could be necessary to also increase the connection between the involved sensory modalities. One possibility could be the use of real objects instead of drawings. This would presumably lead to experimental situations that are more familiar to the subjects, and thus could be able to strengthen the connection between auditory and visual stimuli.

Conclusions

No global influence of colour on adjusted SPL necessary for most comfortable loudness of speech and music has been found. However, two groups of subjects could be identified that show small significant effects of colour in the order of 0.5 – 1 dB, with below average adjusted levels while viewing blue or grey drawings of radios.

Acknowledgements

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