BRIEF REPORT

Effects of colour exposure on auditory and somatosensory perception – hints for cross-modal plasticity

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Abstract

OBJECTIVES: It is well known that colour exposure can influence emotions, behaviour and perception. To get further insight into these complex synesthetic phenomena, the effect of colour stimulation on auditory and somatosensory perception was systematically investigated.
METHODS: 14 healthy male volunteers with normal colour vision rated the loudness of auditory stimuli with a standardized scale during exposure to white, red and green light. Furthermore temperature perception was assessed during exposure of the different colours using a thermal sensory analyser.
RESULTS: Colour exposure significantly altered auditory and somatosensory perception. Red light enhanced loudness perception and decreased cold pain thresholds, while green light stimulation reduced loudness perception and increased detection and pain thresholds for warm stimuli.
CONCLUSIONS: This data give further evidence for cross-modal plasticity in human perception. Colour stimulation influences auditory and somatosensory perception and may therefore have potential as a new treatment strategy of phantom perceptions such as tinnitus or chronic pain.

INTRODUCTION

The subjective perception of our environment depends on the sensory information of various modalities. The experience of our world is the result of an interaction of these sensory modalities. For humans, vision is the most important sense (Shams *et al*., 2002). However, sensory information of different modalities is not independent from each other but may interact on several levels. For example, visual stimulation has been shown to modify afferent input from the olfactory (Gilbert *et al*., 1996) and the auditory system (Abe *et al*., 1999). But also emotional (Valdez *et al*., 1994), cognitive (Hatta *et al*., 2002) and motor (Imhof, 2004) performance can be influenced by visual stimulation. From a clinical point of view, it is of interest that colour blindness seems to be genetically linked to psychiatric diseases such as bipolar disorders (Mendlewicz, 1976). Furthermore, altered subjectively perceived colour intensity is frequently reported by patients with affective disorders (Pause *et al.*, 2003). However, the neurobiological basis of both, these synesthetic phenomena and the relationship to neuropsychiatric diseases is still largely unknown. A better understanding of these processes may contribute to the elucidation of the pathophysiology of neuropsychiatric diseases and may pave the way for the development of new treatment strategies for perception disorders such as chronic tinnitus or chronic pain (Imhof, 2004; Wilkins *et al.*, 1999). The aim of this pilot study was therefore the systematic investigation of the effect of colour exposure on somatosensory and auditory perception in healthy controls.

MATERIAL AND METHODS

Fourteen healthy male volunteers (age: 18 – 40 years) with normal colour vision were tested on two separate days, after giving written informed consent. The study has been approved by the ethics committee of the University of Regensburg.

Ten out of fourteen underwent both auditory and somatosensory stimulation, while the remaining four were only tested for somatosensory perception for various reasons (e.g., not willing to exercise the use of the standardized loudness scale). Somatosensory and auditory perception was tested each day first during exposure to white light and then during exposure to coloured light (either red or green light).

Auditory perception

In a pre-test, all test persons were familiarized with the experimental design and exercised the estimation of the subjectively perceived loudness of the presented stimuli using a standardized loudness scale (range: 0 = "nothing heard" to 10 = "too loud"). Participants were seated in a comfortable chair wearing video goggles (Sony, personal LCD Monitor PLM-A35E). Each trial started with an adaptation phase without stimulation (5 minutes) followed by stimulation with white light (baseline). A second adaptation phase of 10 minutes without stimulation was followed by colour stimulation (either red or green for 5 minutes). At the end of each stimulation (white, green or red), participants had to rate the perceived loudness of the presented acoustic stimuli (see below). Red and green light were matched for intensity and brightness.

Measurement of hearing threshold and loudness estimation

Measurement of hearing thresholds and loudness estimation were performed in two separate trials using a narrow band tone of either 0.5 kHz and 4 kHz (Rausch-CD; Kind hearing devices), respectively, which were presented by earphones and amplified by an audiometer (Hoernìß and Zeisberg, Madsen Electronics, Germany). Hearing thresholds and loudness discomfort levels were assessed by stepwise increasing the loudness from –10 to 110 dB SPL. Volunteers indicated, when they first heard the tone (hearing threshold) and when the tone became too loud (loudness discomfort level). Subsequently, tones of varying intensities (30, 45, 60, 75, and 90 dB SPL) were presented in a pseudo-randomized order for about two seconds each and the test persons were asked to rate the subjectively perceived loudness on the standardized scale.

Somatosensory perception

Perception and pain thresholds for cold and warm stimuli were assessed by using a thermal sensory analyser (TSA II, Medoc, Israel) according to Summers *et al.* (2004). Thermal stimuli were applied by a Peltier element (9 cm²) attached to the thenar of the right hand producing heating or cooling with a linear rate of 0.5°C/s or 1°C/s for determination of perception and pain thresholds, respectively. Thresholds were measured by increasing or decreasing the temperature until the volunteer indicated by clicking a computer mouse the first perception of the relevant sensation (perception threshold) and when the temperature became painful (pain threshold). The next trial started after an adaptation phase of 10 s at 32°C. Four successive trials were averaged for the perception threshold, three for the pain threshold.

Statistics

For the evaluation of the effects of colour exposure on loudness estimation, repeated measurements ANOVAs were conducted for the two frequencies (0.5 and 4 kHz) with the factors colour (red and green) and stimulation intensities (30, 45, 60, 75, and 90 dB). Effects on hearing thresholds, loudness discomfort levels and perception- and pain thresholds for cold and warm stimuli were tested by multiple t-tests. The level of statistical significance was 0.05. Due to the pilot character of the study no corrections for multiple comparisons were performed. All analyses were calculated using SPSS.

RESULTS

Colour exposure led to a significantly altered subjective loudness perception of the 0.5 kHz tone (interaction colour x intensity: F=5,719, p=0.046), but not of the 4 kHz tone (p>0.05) with increased perceived loudness during red light exposure while green light exposure resulted in an opposite effect (Figure 1). Furthermore, red colour significantly lowered hearing thresholds of the 0.5 and 4 kHz tones (p<0.037), whereas green light had no effect on hearing thresholds. The loudness discomfort levels of both tones were not influenced by colour exposure either.

Similar effects of colour exposure were also observed in the somatosensory perception. The only effect of red light was a significantly lowered threshold for cold pain stimuli as compared to white light (p=0.023; Figure 2). In contrast, green light significantly increased the de-

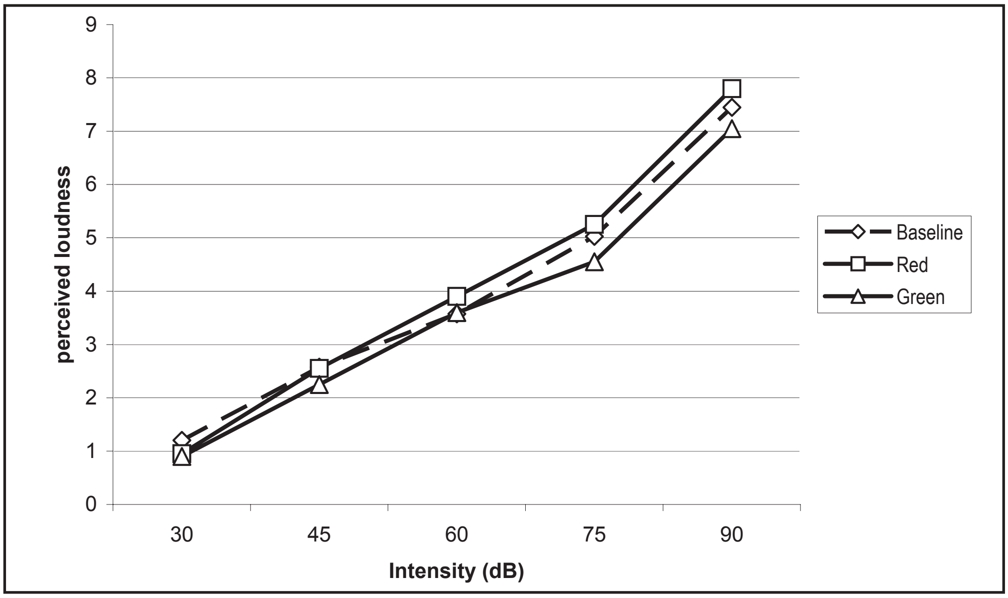

Figure 1: Subjectively perceived loudness of the 0.5 kHz narrow band tone during white light (Baseline) and during red or green light exposure. Red light stimulation led to a significantly enhanced loudness perception compared to baseline while green light had an opposite effect. Y-axis = standardized loudness scale (0 = nothing heard, 10 = too loud).

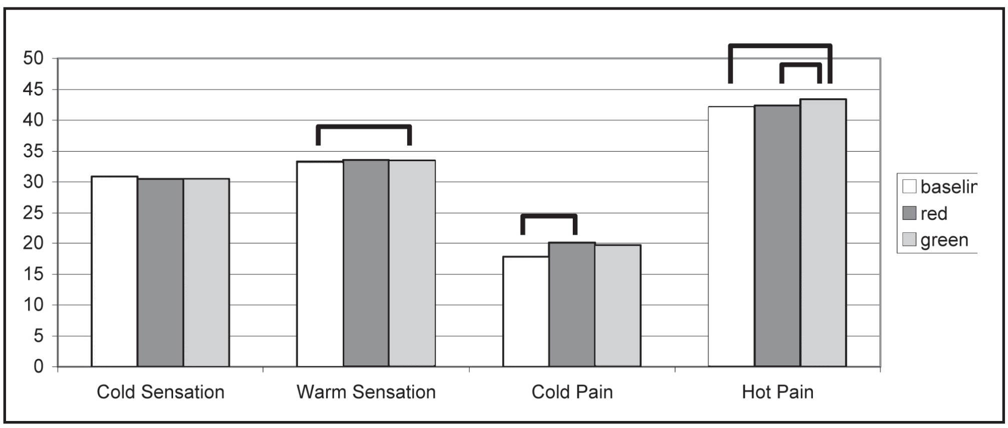

Figure 2: Perception („sensation") and pain thresholds („pain") for cold and warm stimuli under red or green light exposure. Red light stimulation led to a significantly lowered cold pain threshold (i.e. warmer stimuli became painful) compared to baseline. Green light stimulation significantly increased the detection threshold for warm stimuli as well as the hot pain threshold compared to baseline and red light stimulation. Brackets indicate significant differences ($p<0.05$) between conditions; Y-axis = temperature in degree Celsius.

tection threshold for warm stimuli ($p=0.016$) as well as the hot pain threshold compared to white light ($p=0.08$) and compared to red light ($p=0.04$). Taken together, red light stimulation led to a higher susceptibility to cold pain stimuli, while green light stimulation reduced the susceptibility to warm stimuli by increasing the detection and pain thresholds.

DISCUSSION

The aim of this pilot study was the systematic investigation of the effects of colour exposure on somatosensory and auditory perception. Colour stimulation significantly altered both, somatosensory and auditory perception thereby giving further evidence for cross-modal plasticity of different sensory modalities. Exposure to red light led to (1.) significantly lower hearing thresholds, (2.) increased perceived loudness of the 0.5 kHz tone, and (3.) lowered pain thresholds for cold stimuli. Green light had opposite effects on auditory and somatosensory perception.

These results are in line with previous studies showing reduced loudness perception after stimulation with green light compared to red (Abe *et al.*, 1999). However, auditory perception of the 4 kHz tone remained unchanged indicating that cross-modal interaction does not seem to be a general rule. Rather, it might depend on the properties of the stimuli. Support for this notion comes from functional imaging studies which have demonstrated that the amount of neuronal activation in the central nervous system depends on the frequency of the auditory stimuli. In detail, 4 kHz tones lead to much stronger activations of the auditory cortex than 0.5 kHz tones (Lockwood *et al.*, 1999). Thus a possible explanation for our results could be that the weaker neural response to the 0.5 kHz tone might be more vulnerable for cross-modal interaction than the robust activations of the 4 kHz tones.

Somatosensory perception was also affected by colour stimulation. However, the effects of red and green light stimulation on the different modalities varied. This could be due to the fact that cold and warm perception is mediated by different neurobiological systems, which may differ with respect to their sensitivity for cross-modal interaction. However, due to the small sample size of this pilot study, missing effects of colour stimulation could also be due to lack of power. Therefore, these results have to be replicated in a larger sample before further conclusions can be drawn. Nevertheless, these results demonstrate that colour exposure modifies perception of other sensory modalities.

Gender might influence the cross-modal effects of colours, especially since genes relevant for colour vision and red-green deficiency are located on the Y-chromosome. In order to exclude this confounding effect only male volunteers participated in this pilot study. It would be of interest to systematically investigate the influence of gender on the cross-modal interaction between colour stimulation and auditory or somatosensory perception in further studies.

CONCLUSIONS

This pilot study showed a significant effect of colour exposure on auditory and somatosensory perception. With regard to neuropsychiatric diseases like chronic tinnitus or chronic pain, colour stimulation may have potential as a new, innovative and non-invasive treatment approach in the future. Therefore, further studies should focus on the elucidation of the neurobiological mechanisms of these cross-modal interactions between sensory inputs of various modalities using e.g. functional imaging techniques.

REFERENCES

1 Abe K, Ozawa K, Suzuki Y, Sone T (1999). The Effect of Visual Information on the Impression of Environmental Sounds. Inter-noise. **99**:1177–1182.
2 Gilbert AN, Martin R, Kemp SE (1996). Cross-modal correspondence between vision and olfaction: the colour of smells. Am J Psychol. **109**: 335–351.
3 Hatta TI, Yoshida H, Kawakami A, Okamoto, M (2002). Colour of computer display frame in work performance, mood, and physiological response. Percept Mot Skills. **94**: 39–46.
4 Imhof M (2004). Effects of colour stimulation on handwriting performance of children with ADHD without and with additional learning disabilities. Eur Child Adolesc Psychiatry. **13**: 191–198.
5 Lockwood AH, Salvi RJ, Coad ML, Arnold SA, Wack DS, Murphy BW, Burkard RF (1999). The functional anatomy of the normal human auditory system: responses to 0.5 and 4.0 kHz tones at varied intensities. Cereb Cortex. **9**: 65–76.
6 Mendlewicz J (1976). Genetic study of manic-depressive psychoses. Acta Psychiatr Belg. **76**: 301–377.
7 Pause BM, Raack N, Sojka B, Goder R, Aldenhoff JB, Ferstl R (2003). Convergent and divergent effects of odors and emotions in depression. Psychophysiology. **40**: 209–225.
8 Shams L, Kamitani Y, Shimojo S. Visual illusion induced by sound (2002). Cog Brain Res. **14**: 147–152.
9 Summers J, Johnson S, Pridmore S, Oberoi G (2004). Changes to cold and pain thresholds following low and high frequency transcranial magnetic stimulation of the motor cortex. Neurosci lett. **368**: 197–200.
10 Valdez P, Mehrabian A (1994). Effects of colour on emotions. J Exp Psychol Gen. **123**: 394–409.
11 Wilkins AJ, Baker A, Amin D, Smith S, Bradford J, Zaiwalla Z, Besag FM, Binnie CD, Fish D (1999). Treatment of photosensitive epilepsy using coloured glasses. Seizure. **8**: 444–449.