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3pPP2. Touch the sound: The role of audio-tactile and audio-proprioceptive interaction on the spatial orientation in virtual scenes

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Being able to localize objects in the space close to the body is an important prerequisite for precise object interaction. It is also very important for the spatial orientation in virtual scenes. Since sound is usually produced by the vibrations of a body, sound emitting objects, such as shaver or hair dryer, provide both auditory and haptic information. This study focuses on auditory-haptic localization in the spatial domain. We carried out two experiments to investigate the interaction effects. In the first experiment, the influence of tactile signals on auditory localization task was investigated. Similar to the ventriloquist effect from auditoryvisual interaction, the results of the first experiment show that the perceived location of auditory stimuli is influenced by tactile stimulation. The results also indicate some hints that there may be an audiotactile precedence effect. In the second experiment, the influence of auditory signals on proprioception was investigated. The results show that the auditory and proprioceptive information can be combined in such a way that the localization errors in a virtual scene are minimized.

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1. INTRODUCTION

Spatial orientation in space is a basic prerequisite for our daily activities. Perception is a multisensory phenomenon and one major capability of our perceptual system is the integration of the multisensory stimuli which are generated by a multimodal event. During the evaluation of multi-modal events, visual, tactile and auditory information interact and possess a substantial influence (Altinsoy, 2006). Most investigations dealing with multi-modal localization are related to auditory and visual modalities, while only very few investigations are addressing auditory and tactile interaction. The ventriloquist effect is a well-known auditory-visual interaction phenomenon (Thurlow and Jack, 1973). The perceived location of an auditory event is shifted towards the visual event, if the spatial origins of the auditory and visual information are slightly different. Other psychophysical studies showed that the perceived distance of the auditory stimulus is also influenced by visual stimulus, which is placed in front or behind of the auditory stimulus (Brown et al., 1998). A growing number of researchers have recently conducted auditory-tactile interaction experiments, in which auditory and tactile stimuli have been presented from different locations (Kitagawa et al., 2006, Kitagawa and Spence, 2005, Llyod et al., 2003). Although these studies provided inconsistent results, most studies showed that auditory-tactile interaction exists in the space immediately surrounding the head (Calvert et al., 2004; Kitagawa et al., 2006; Kitagawa and Spence, 2005). In a study conducted by Tajadura-Jimenez et al. (2009), it was shown that the spectra of the auditory-tactile stimuli may also play a role on the multisensory spatial integration.

Although in our daily life the relationship between sound and vibration (frequency, intensity, location, etc.) is determined by clear physical rules, in the virtual environments it is possible to break these rules and to find ideal multimodal stimuli combinations to optimize object interaction regarding various tasks. In recent years a variety of customer products that have haptic input and output capabilities have been developed (For example, Apple iPhone, different touch-screen applications, Wiimote, Kinect, etc.) (Altinsoy and Hempel, 2011). The usage of the optimum stimuli combinations on such kind of applications can be very promising. Taking into account the importance of the spatial orientation in virtual environments, the present study reports two different experiment sets designed to investigate the role of audio-tactile and audio-proprioceptive interaction on the spatial orientation in virtual scenes.

2. EXPERIMENT 1

Eight participants (mean age 25; age range from 22 to 29 years; four females) took part in the experiment. All participants had normal hearing and were right handed. The experimental setup and the procedure were same as in the study of Altinsoy (2010). The noise and vibrations of a shaver were recorded using a microphone and accelerometer. A loudspeaker array which consists of nine loudspeakers was used to present the acoustic stimulus. Loudspeakers were placed 75 cm in front of the subject. Electrotactile stimulation was used to present the vibrations. The big advantage of the electrotactile stimulation is that it is completely silent. The experiment set contained both only auditory and auditory-tactile conditions. In the first experiment, one anchor stimulus from directly ahead was presented subjects, followed by one test stimulus. In each run subject was asked to state whether second auditory event lay to the right or to the left of the first. In the second experiment, subjects were asked whether the position of the auditory event and the position of the tactile information coincide or not.

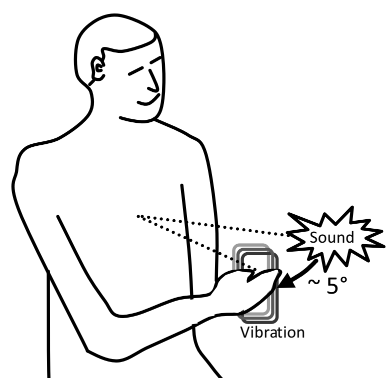

FIGURE 1. The tactile stimulation pulls the auditory source to the direction of its location.

The results of the first part of the experiment 1 show that the localization blur of the shaver stimuli is 2.2° ± 0.4°. The localization blur ($\Delta(\varphi = 0)_{min}$) of scraping sound from the front with simultaneous tactile stimulation is 4.5° ± 0.6°. Simultaneously presented electrotactile stimulation enlarges the localization blur and the tactile stimulation pulls the auditory source to the direction of its location.

3. EXPERIMENT 2

In our recent study, it was observed that, during the exploration of a virtual room/scene and recognition of the objects in this room/scene using the proprioception, subjects experienced various difficulties (Stamm et al., 2010). The aim of this experiment was to investigate whether auditory feedback can improve the human proprioceptive localization. Therefore unimodal (using only body's own proprioceptive signals) and multimodal conditions were investigated. Twelve participants (mean age 27; age range from 21 to 34 years; ten males) took part in the experiment 2. A virtual workspace, which is shaped like a cuboid, is defined for the experiment (Figure 2). Its width is 25 cm, its height is 17 cm, and its depth is 9 cm. The entire cuboid can be constructed with 3825 small cubes whose sides measure 1 cm. A sphere with a diameter of 1 cm was randomly positioned inside the virtual workspace and thus inside one of the cubes. The subjects were asked to search for the hidden sphere in the virtual workspace. The PHANTOM Omni haptic force-feedback device from SensAble Technologies was used in the present experiment. The position of the haptic interaction point is transferred through the phantom to Pure Data. The localization error was measured as evaluation criteria.

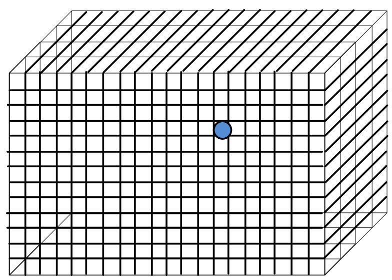

FIGURE 2. A representation of the virtual workspace.

The results of the experiment show that in all directions the localization performance of the subjects increased, if auditory feedback supports the proprioception (Figure 3).

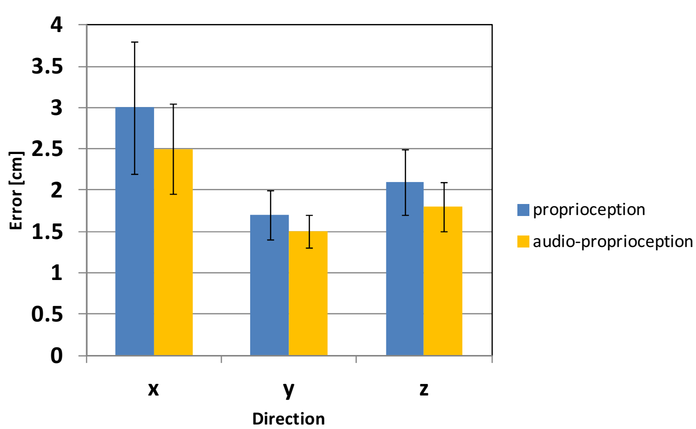

FIGURE 3. The average localization errors in three directions for both experiment conditions (only body's own proprioceptive signals and audio-proprioception).

4. CONCLUSIONS

Audio-tactile and audio-proprioceptive interaction play an important role on the spatial orientation in virtual scenes. Therefore they should be taken into account in virtual reality applications. The results of the first experiment show that the perceived location of an auditory event is shifted towards the tactile event. The results of the second experiment show that spatial auditory signals might even improve human proprioceptive localization performance in virtual workspaces.

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