Properties and mechanisms of sensory enhancement

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Enacted theories of consciousness conjecture that perception and cognition arise from an active experience of the regular relations that tie together sensory stimulation and associated motor actions [1,2]. By employing the technique of sensory substitution [3] and sensory augmentation [4] previous experiments explored this assumption. In the latter study the sensory augmentation device delivered global orientation information by mapping directional information of a compass to a set of vibrators, activating the element pointing north [4]. Here we use it to investigate the impact of newly supplied directional signals on cortical plasticity, sensory processing and spatial cognition.

The training belts consisted of 30 piezoelectric, vibrotactile actuators, a 3DM GX3 compass, a control-box and battery packs. They were to be worn by the subjects during all waking time. A dedicated MRI-compatible belt was based on identical piezoelectric vibrators. Ten subjects (age 19-32y, four female, one control) were wearing the belt during all waking hours over a period of six weeks. We compared belt-on and belt-off conditions in a series of measurements including homing, multimodal integration, nystagmography, sleep-EEG, fMRI, and subjective methods before, during and after training.

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(1) In the homing task using on polygons of varying complexity we observe a slight reduction of the systematic error and a larger reduction of the stochastic error in belt-on condition after the training period. (2) Integration of the newly supplied signals with visual information in a psychophysical task was rather limited and just noticeable differences of rotation (yaw) were surprisingly high in belt-off as well as in belt-on condition. (3) Nystagmography demonstrated an increase of the time constant of per-rotatory nystagmus (slow phase) after training in the belt-on condition as compared to the belt-off condition indicating a firm integration in sensory processing. (4) Sleep-EEG uncovered an increase of REM-sleep during the early training phase. In contrast, no such change is observed in stage 3 sleep. (5) Most areas that were reported in a previous fMRI study on navigation [5] could be replicated in all our subjects. Furthermore, we observe widespread cortical activation in belt-on condition after training as compared to the pre-training baseline. (6) Subjective reports indicate that by training with the feelspace belt the scope of perceived space grows wider and includes areas that are not within reach or directly visible; subjects feel more secure in known as well as previously unknown environments; and navigational abilities improve and emphasize an egocentric reference frame.

The data provide evidence for an integration of the newly supplied signals in sensory integration (homing, nystagmography), cortical processing (sleep-EEG, fMRI) and spatial cognition (subjective methods). However, further analysis is needed to elucidate significant individual variations.

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