Locomotion and spatial navigation in vestibular pathology

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This paper reviews first the functional organization of the vestibular system and the main functions in which it is implicated. It also summarizes the three main syndromes occurring after unilateral lesion of the peripheral receptors: the posturo-locomotor syndrome, the vestibulo-ocular syndrome and the perceptive syndrome. The specific contribution of the vestibular system to perception of body orientation in space, control of posture and locomotion trajectory, and spatial navigation is documented through the comparison of healthy subjects and vestibular-defective patients. It is evidenced herein that the vestibular-induced tilt of the perceived vertical, as well as the tilt of head and body and the direction of the locomotion trajectory deviations are strongly context-dependent. Direction of all deficits is reversed, from the lesioned side to the intact side, when patients’ examination is performed without or with vision. The data clearly show that the vestibular system contributes not only to basic reflex functions but also to high level cognitive processes involved in the internal spatial representation of body orientation in space. This hypothesis is corroborated by the deficits of the spatial performance shown in vestibular-deficient patients tested in navigation tasks. Turn errors and distance errors are found, which depend on both task complexity (simple path reproduction versus more complex return path or shortcut) and sensory cues availability (real navigation in darkness versus visual virtual navigation). The vestibular system contributes therefore to dynamic mental representations of space involved in the internal spatial representation of the extrapersonal space.
Studies of spatial navigation in humans with vestibular loss have shown clear evidence of navigational impairment in patients compared to controls. Guidetti found that compared to controls, patients with compensated uni-lateral vestibular neuritis required more time to walk on a memorized square, circle, or triangular path with their eyes closed, but not eyes open. This finding suggests an impairment in spatial navigation when visual cues are removed [62]. Vestibular patients require more attentional resources for locomotion than controls, particularly when visual cues are absent. Celeration to function. Gravity, the major source of lin-ear acceleration on earth, is largely absent in a microgravity environment such as in space. In everyday life, spatial navigation involving locomotion provides congruent visual, vestibular and kinesthetic information that need to be integrated. Yet, previous studies on human brain activity during navigation focus on stationary setups, neglecting vestibular and kinesthetic feedback. The aim of our work is to uncover the influence of those sensory modalities on cortical processing. 1Neurobiopsychology, Institute of Cognitive Science, University of Osnabrück, Osnabrück, Germany. 2Neuroinformatics, Institute of Cognitive Science, University of Osnabrück, Osnabrück, Germany. 3Department of Neurophysiology and Pathophysiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany.