

FUNCTIONAL IMAGING OF HUMAN VESTIBULAR CORTEX ACTIVITY ELICITED BY SKULL TAP AND AUDITORY TONE BURST

F. Noohi¹, C. Kinnaird², S. Wood⁶, J. Bloomberg⁷, A. Mulavara⁸, R. Seidler^{1,3,4,5}

¹School of Kinesiology, ²Department of Mechanical Engineering, ³Department of Psychology, ⁴Neuroscience Program, ⁵Institute of Gerontology, University of Michigan, Ann Arbor, Michigan, ⁶College of Liberal Arts and Sciences, Azusa Pacific University, Azusa, California ⁷NASA Johnson Space Center, ⁸Universities Space Research Association, Houston, TX

The current study characterizes brain activation in response to two modes of vestibular stimulation: skull tap and auditory tone burst. The auditory tone burst has been used in previous studies to elicit either the vestibulo-spinal reflex (saccular-mediated colic Vestibular Evoked Myogenic Potentials (cVEMP)), or the ocular muscle response (utricle-mediated ocular VEMP (oVEMP)). Some researchers have reported that air-conducted skull tap elicits both saccular and utricle-mediated VEMPs, while being faster and less irritating for the subjects. However, it is not clear whether the skull tap and auditory tone burst elicit the same pattern of cortical activity. Both forms of stimulation target the otolith response, which provides a measurement of vestibular function independent from semicircular canals. This is of high importance for studying otolith-specific deficits, including gait and balance problems that astronauts experience upon returning to earth. Previous imaging studies have documented activity in the anterior and posterior insula, superior temporal gyrus, inferior parietal lobule, inferior frontal gyrus, and the anterior cingulate cortex in response to different modes of vestibular stimulation. Here we hypothesized that skull taps elicit similar patterns of cortical activity as the auditory tone bursts, and previous vestibular imaging studies.

Subjects wore bilateral MR compatible skull tappers and headphones inside the 3T GE scanner, while lying in the supine position, with eyes closed. Subjects received both forms of the stimulation in a counterbalanced fashion. Pneumatically powered skull tappers were placed bilaterally on the cheekbones. The vibration of the cheekbone was transmitted to the vestibular system, resulting in the vestibular cortical response. Auditory tone bursts were also delivered for comparison. To validate our stimulation method, we measured the ocular VEMP outside of the scanner. This measurement showed that both skull tap and auditory tone burst elicited vestibular evoked myogenic potentials, indicated by eye muscle responses. We further assessed subjects' postural control and its correlation with vestibular cortical activity.

Our results provide the first evidence of using skull taps to elicit vestibular activity inside the MRI scanner. By conducting conjunction analyses we showed that skull taps elicit the same activation pattern as auditory tone bursts (superior temporal gyrus), and both modes of stimulation activate previously identified vestibular cortical regions. Additionally, we found that skull taps elicit more robust vestibular activity compared to auditory tone bursts, with less reported aversive effects. This further supports that the skull tap could replace auditory tone burst stimulation in clinical interventions and basic science research. Moreover, we observed that greater vestibular activation is associated with better balance control. We showed that not only the quality of balance (indicated by the amount of body sway) but also the ability to maintain balance for a longer time (indicated by the balance time) was associated with individuals' vestibular cortical excitability. Our findings support an association between vestibular cortical activity and individual differences in balance.

In sum, we found that the skull tap stimulation results in activation of canonical vestibular cortex, suggesting an equally valid, but more tolerable stimulation method compared to auditory tone bursts. This is of high importance in longitudinal vestibular assessments, in which minimizing aversive effects may contribute to higher protocol adherence.