Functional Imaging of Human Vestibular Cortex Activity Elicited by Skull Tap and Auditory Tone Burst

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The aim of the current study was to characterize the 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 saccular Vestibular Evoked Myogenic Potentials (VEMP) (Colebatch & Halmagyi 1992; Colebatch et al. 1994). Some researchers have reported that air-conducted skull tap elicits both saccular and utricle VEMPs, while being faster and less irritating for the subjects (Curthoys et al. 2009, Wackym et al., 2012). 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 the vestibular disorders related to otolith deficits. Previous imaging studies have documented activity in the anterior and posterior insula, superior temporal gyrus, inferior parietal lobule, pre and post central gyri, inferior frontal gyrus, and the anterior cingulate cortex in response to different modes of vestibular stimulation (Bottini et al., 1994; Dieterich et al., 2003; Emri et al., 2003; Schlindwein et al., 2008; Janzen et al., 2008). Here we hypothesized that the skull tap elicits the similar pattern of cortical activity as the auditory tone burst.

Subjects put on a set of MR compatible skull tappers and headphones inside the 3T GE scanner, while lying in supine position, with eyes closed. All subjects received both forms of the stimulation, however, the order of stimulation with auditory tone burst and air-conducted skull tap was counterbalanced across subjects. Pneumatically powered skull tappers were placed bilaterally on the cheekbones. The vibration of the cheekbone was transmitted to the vestibular cortex, resulting in vestibular response (Halmagyi et al., 1995). 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 activation, indicated by eye muscle response.

Our preliminary analyses showed that the skull tap elicited activation in medial frontal gyrus, superior temporal gyrus, postcentral gyrus, transverse temporal gyrus, anterior cingulate, and putamen. The auditory tone bursts elicited activation in medial frontal gyrus, superior temporal gyrus, superior frontal gyrus, precentral gyrus, inferior and superior parietal lobules.
In line with our hypothesis, skull taps elicited a pattern of cortical activity closely similar to one elicited by auditory tone bursts. Further analysis will determine the extent to which the skull taps can replace the auditory tone stimulation in clinical and basic science vestibular assessments.