Use of Suborbital Flight to Elucidate the Role of Tonic Otolith Stimulation Due to Gravity in Balance Testing and Orientation Tasks. C.Wall, Harvard Medical School and Massachusetts Eye & Ear Infirmary, Boston MA 02114, cwall@mit.edu.

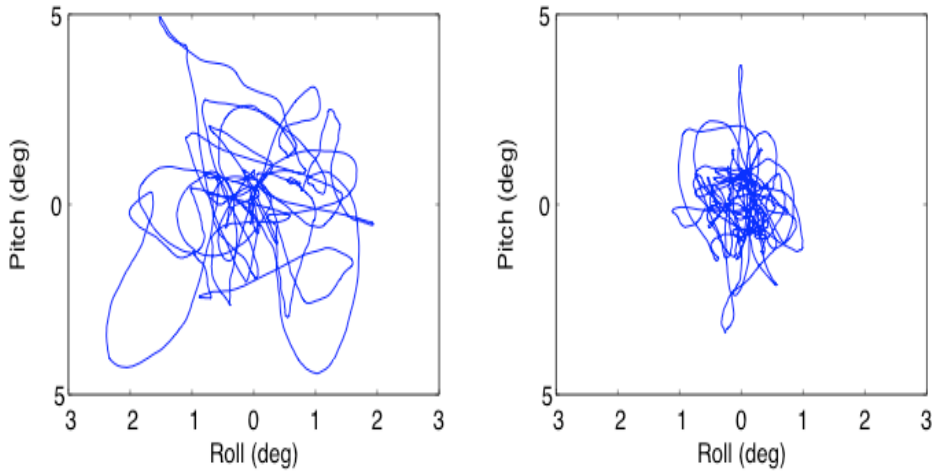
Introduction. Suborbital fight provides an opportunity for further understanding of tests for the clinical evaluation of otolith function, the tonic effect of gravity upon certain tests of oculomotor function, as well as a better understanding the use of tactile cues for spatial orientation. Each of these three ideas will be briefly explored.

Clinical evaluation of otolith function. The vestibular evoked myogenic potential or VEMP uses sound to stimulate the saccules that are the portion of the otolith organs exposed to a tonic 1 g field on Earth. The saccular response to sound activates the vestibular nucleus and generates a reflex in the sternocleidomastoid muscle in the neck. This almost completely unilateral reflex is measured using electromyography (EMG) and is usually an averaged response to a succession of tone bursts. Abnormalities are commonly detected as a change in the amplitudes of certain parts of the averaged response. The vestibular afferent nerves are characterized by spontaneous activity whose amount depends somewhat on the diameter of an individual nerve fiber, but also upon the strength of the gravity field. How much the average EMG response depends on the latter is not well studied. Suborbital flight, with moderate exposure times to altered gravity, is a way of better understanding the effect of tonic gravity upon the VEMP. The test procedure and apparatus could both be quickly adapted for use in suborbital flight experiments. One factor that is crucial for taking VEMs is the correct loading of the sternocleidomastoid muscle itself. In some cases, the weight of the head is used to load the muscle. This would obviously not work in suborbital flight, but it is not difficult to have the subject apply a known force against a pad to accomplish correct loading. Experiments would likely start with subjects having normal 1 g VEMP responses, then progress to subjects with saccular lesions.

Oculomotor function tests. While the effect of gravity on responses to optokinetic stimuli such is moving striped patterns is well known, the gravity effects on certain volitional tasks is not as well-studied. Saccades or voluntary quick eye movements from on target to another have been studied in parabolic flight, but the emphasis has been on so-called “reflexive” saccades. Making a movement to a target that is no longer visible – a so-called “memory” saccade is less well studied, and may very well be influenced by g level, since g level effects the sense of orientation. For this test, the subject must look back to the site of a *previously* shown target using memory of where that target had been. A sound cue then prompts the subject to shift gaze back to the site of the memorized target. The accuracy and timing of the memory saccade would be recorded. These non-reflexive saccades are thought to be sensitive to mild brain disorders, including mild traumatic brain injury (TBI) that could have an effect on cognitive function. Thus, it may be possible to see whether the exposure to microgravity on suborbital flight has an subtle effect on brain function. Both the test protocol and the eye movement response measurements for these tests should be quickly adaptable to suborbital experiments.

Tactile Cues for Spatial Orientation. Vibrotactile cues have been successfully used for pilot orientation, and recently have been shown to help those with balance disorders better maintain their balance while standing and walking in a 1 g setting. One interesting finding is that the spatial resolution of the vibrotactile display needed to maintain postural

stability is unexpectedly low. Using tactile vibrators placed on the cardinal body orientations (forward, right, backward, and left), a spatial resolution of 90 degrees does as well as using 16 directions with a spatial resolution of 22.5 degrees. The figure shows typical responses with and without vibrotactile feedback of body position This result may be attributed to the idea that there are really only two postural control systems in humans while standing in 1 g: an anterior-posterior one and a mediolateral one.



Vibrotactile feedback reduces the degree of wavering while standing on a moving surface. Left figure shows subject wavering with vibrotactile belt turned off. Right is with belt turned on.

But what about using vibrotactile displays to orient people in microgravity? Would a spatial resolution of perhaps 45 degrees be sufficient for self-navigation in microgravity? Another related question is whether it is possible to give a person their own “artificial horizon” in microgravity using a vibrotactile display. Limited data from subjects with Mal de Debarquement Syndrome suggest that such a display can help a person who subjectively feels they are walking on a downward sloping ramp, but logically knows they are not on a slope be able to use the vibrotactile display to “cancel out” the illusion of the slope. Thus, experiments with vibrotactile displays in suborbital flight would be helpful in evaluating this type of device for more prolonged flight.

Conclusions. Suborbital flight would seem to provide a micro gravity environment of a sufficiently long duration so that the effect of gravity upon these three approaches to vestibular/balance testing and potential spatial orientation could be evaluated in a time- and cost-effective way.