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Role of Orientation Reference Selection in Motion Sickness

Semiannual Status Report
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STATEMENT OF WORK SUMMARY

The overall objective of this proposal is to understand the relationship between human orientation control and motion sickness susceptibility. Three areas related to orientation control will be investigated. These three areas are 1) reflexes associated with the control of eye movements and posture, 2) the perception of body rotation and position with respect to gravity, and 3) the strategies used to resolve sensory conflict situations which arise when different sensory systems provide orientation cues which are not consistent with one another or with previous experience. Of particular interest is the possibility that a subject may be able to ignore an inaccurate sensory modality in favor of one or more other sensory modalities which do provide accurate orientation reference information. We refer to this process as sensory selection. This proposal will attempt to quantify subjects' sensory selection abilities and determine if this ability confers some immunity to the development of motion sickness symptoms.

Measurements of reflexes, motion perception, sensory selection abilities, and motion sickness susceptibility will concentrate on pitch and roll motions since these seem most relevant to the space motion sickness problem. Vestibulo-ocular (VOR) and oculomotor reflexes will be measured using a unique two-axis rotation device developed in our laboratory over the last seven years. Posture control reflexes will be measured using a movable posture platform capable of independently altering proprioceptive and visual orientation cues. Motion perception will be quantified using closed loop feedback technique developed by Zacharias and Young (Exp Brain Res, 1981). This technique requires a subject to null out motions induced by the experimenter while being exposed to various confounding sensory orientation cues. A subject's sensory selection abilities will be measured by the magnitude and timing of his reactions to changes in sensory environments. Motion sickness susceptibility will be measured by the time required to induce characteristic changes in the pattern of electrogastragram recordings while exposed to various sensory environments during posture and motion perception tests.

The results of this work are relevant to NASA's interest in understanding the etiology of space motion sickness. If any of the reflex, perceptual, or sensory selection abilities of subjects are found to correlate with motion sickness susceptibility, this work may be an important step in suggesting a method of predicting motion sickness susceptibility. If sensory selection can provide a means to avoid sensory conflict, then further work may lead to training programs which could enhance a subject's sensory selection ability and therefore minimize motion sickness susceptibility.

SUMMARY OF PROJECT STATUS

During the last year we have been focusing most of our attention on starting a major set of experiments to measure reflex, perceptual and sensory selection parameters in human subjects in order to find correlations with motion sickness susceptibility. We have been adding software and hardware enhancements to the two-axis rotator, and developing protocols for these experiments.

Previous experiments have been completed and will be used as pilot data for our present study. One set of experiments involved the characterization of the dynamic response characteristics of torsional VOR eye movements during roll rotations about an upright position. A second set of experiments determined the influence of visual, somatosensory, and vestibular motion cues on the control of posture. The latter data were presented at the Association for Research in Otolaryngology conference in February 1992, and at the XIth International Symposium on Posture and Gait in May 1992.

A previous set of experiments involving the perceptual feedback technique developed by Zacharias and Young (Exp Brain Res, 41:159-171, 1981) has been published recently in the Journal of Vestibular Research (2:59-69, 1992).

TWO-AXIS ROTATOR DEVELOPMENT

The two-axis rotator is a versatile, general purpose stimulator for vestibular and visual-vestibular interaction studies. It consists of two gimbals powered by rotary hydraulic actuators. A single DC torque motor is interchangeable with either of the hydraulic actuators. The inner gimbal produces yaw axis rotations of the subject. The outer gimbal rotates the subject about a horizontal axis which passes through the subject's ears. Development of this chair is essentially complete, though we continue to make "fine-tuning" changes. We are currently adding software and hardware enhancements to help with our present experiments.

In response to a recent study by Diamond and Markham (Aviat Space Environ Med 62:201-205, 1992) which has shown a strong correlation between disconjugate torsional eye movements and motion sickness, we have begun work on adding a second video camera and video recorder to our present eye movement recording system in order to record binocular eye movements. We have been investigating video camera and recorder options as well as adding hardware to our present camera mounting system in order to accommodate two cameras.

We are also looking at using serial time code for video timing instead of our present VITC time code. Serial time code can be used for two cameras and two VCRs with just one time code generator. This would be a

monetary savings as well as a possible solution to our present equipment dilemma. The dilemma is that two critical pieces of equipment (video time code generator/reader and frame grabber on the DEC LSI 11/73) are no longer available, and repair service on our existing equipment is doubtful. Since serial time code generators/readers are readily available, repairs or replacement equipment would not be a problem. We have also recently purchased a frame grabber for the Macintosh IIfx in order to move the video eye movement analysis from the DEC to the Macintosh. This will enable us to take advantage of the increased speed of the Macintosh as well as allow for repairs or replacement equipment.

EXPERIMENTS IN PROGRESS

We have begun preliminary experiments that address the key goals of the overall research grant: the correlation of motion sickness susceptibility with various reflexive and motion perception response parameters. The data from two former experiments are currently being analyzed and the results prepared for publication. One is an investigation to characterize the influence of visual orientation cues on the control of posture. The second is to measure the dynamic response properties of human ocular torsion in response to roll rotations. The protocol and results of both of these experiments have helped us to develop protocols for our most recent experiments.

Reflex studies for correlation with Motion sickness susceptibility

We will be measuring subjects' reflex, perceptual and sensory selection responses and trying to correlate the responses with motion sickness susceptibility. The subjects chosen will be screened for general healthfulness and their ability to participate in many test sessions over several months. We are not looking for "super normals", but rather for subjects that will give a wide range of responses and therefore will facilitate the development of significant correlations with a minimum of subjects. Presently seven subjects have undergone full clinical laboratory testing consisting of ENG, moving platform posturography, and rotation tests.

We are planning to study moving platform posturography, ENG, postural control during sinusoidally-oscillated visual field motions, ocular torsion, perceptual feedback, off-vertical axis VOR, and horizontal and vertical VOR (vestibulo-ocular reflex), VVOR (visual-vestibuloocular reflex), OKR (optokinetic reflex), and VOR fixation suppression. We must still develop protocol for off-vertical axis VOR and perceptual feedback tests on the two-axis rotator. All other protocols are defined and are presently being tested. We are particularly interested in reflex and motion

perception tests that give highly repeatable within-subject results and also show a fairly wide range of among-subject variability. From our previous experiments, it appears that both the torsional VOR and body sways induced by sinusoidal visual field motions satisfy this criteria. A subset of the protocol used in our previous ocular torsion study will be used to measure the reflexes of our latest subjects.

We have added to the protocol for the sinusoidally-oscillated visual field platform tests that we used in our recently completed pilot experiment. We have added 4 conditions, and dropped the highest frequency previously used and added a lower frequency. The change in frequency range was based on the desire to aid in the characterization of subject variabilities. At the highest frequency, 0.5 Hz, most subjects produced similar patterns of sway, whereas pilot data of the lowest frequency, 0.05 Hz, showed potential for larger variability between subjects.

In our pilot study we delivered two different stimulus conditions: sinusoidally oscillated visual surround and fixed or sway-referenced support surface platform. In our present study, we have added 4 conditions to these two: 1) fixed visual surround with sinusoidal platform motion, 2) eyes closed with sinusoidal platform motion, 3) sway-referenced visual surround with sinusoidal platform motion, and 4) both platform and visual surround sinusoidally oscillated at the same amplitude and frequency. These conditions may help to characterize the way in which individuals utilize sensory information to maintain their balance. We are hoping that individual variations in sensory utilization may provide us with a scale of performance against which motion sickness susceptibility may be compared.

Presently two subjects have completed testing and five subjects are currently being tested on the six condition platform tests. We are beginning preliminary analysis on the data of these seven subjects.

SCIENTIFIC PAPERS AND PRESENTATIONS

- A paper describing our perceptual feedback experiment results titled "Relation between perception of vertical axis rotation and vestibulo-ocular reflex symmetry" has been published in the Journal of Vestibular Research 2:59-69, 1992. (Copy attached.)
- A paper titled "Role of somatosensory and vestibular cues in attenuating visually induced human postural sway" was presented at the Association for Research in Otolaryngology at St. Petersburg, Florida in February 1992. (Copy of abstract attached.)
- A paper titled "Effect of visual field motion on postural sway in normal and bilateral vestibular loss subjects" was presented at the XIth International Symposium on Posture and Gait: Control Mechanisms at Portland, Oregon in May 1992. A conference paper has been published in Posture and Gait: Control Mechanisms, Vol. I, M. Woollacott and F. Horak (eds.) University of Oregon Books, pp. 272-5, 1992. (Copy of paper attached.)
- A poster titled "Response characteristics of the human torsional vestibulo-ocular reflex" was presented at the Conference on Sensing and Controlling Motion; Vestibular and Sensory Motor Function at NASA-Ames Research Center, Moffett Field, CA in July 1991. A conference paper has been published in Sensing and Controlling Motion, Vol. 656, Annals of the New York Academy of Sciences, pp. 877-9, 1992. (Copy of paper attached.)