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Vestibular Selection Criteria Development

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Technical Objectives

Our goal is to develop procedures for predicting an individual's susceptibility to motion sickness during orbital space flight. To this end we have been pursuing three interrelated directions of investigation: 1) determining what motion environments are particularly effective in eliciting motion sickness and finding the extent to which an individual's susceptibility in one motion environment correlates with his susceptibility in other, different motion environments, 2) trying to develop a brief and simple test for assessing susceptibility that will also be useful in determining the extent to which a subject can adapt to stressful motion, 3) identifying what forms of sensory conflict tend to elicit motion sickness. We are also extending an analysis of the literature on motion sickness that has already been prepared to deal also with the specific problem of selecting personnel for orbital flight.

Progress Since QPR 6/80

1) Experimental Elicitation of Motion Sickness

As mentioned in our last two progress reports, we have been developing a new test for assessing susceptibility to motion sickness. The test involves a Stille-Werner short arm centrifuge (Model CF-II) or a rotating chair surrounded by a striped cyclindrical enclosure. During an experimental session, the subject, with eyes covered, is accelerated at $15^{o}/sec^{2}$ to a constant clockwise velocity of $300^{o}/sec$ and maintained at this velocity for 30 seconds. The hydraulic brakes on the chair are then electrically activated and the chair is brought to a stop within 1.5 seconds. The subject then remains at rest for 30 sec while various physiological measures and symptoms of motion sickness are recorded. The experimental procedure is then repeated until the subject has reached a motion sickness endpoint or a total of twenty stops have been made with eyes closed. After the first twenty stops, the subject's blindfold is removed and the procedure is repeated while the subject attempts to maintain a straight-ahead gaze. Testing continues until either the motion sickness endpoint or twenty stops with eyes open has been achieved. If the endpoint has not been reached, then the direction of rotation is reversed and the test proceeds until either an endpoint or twenty additional stops have been achieved. In practice, only one subject has yet progressed this far without reaching an endpoint.

Three reports have now been completed and published on findings obtained with this technique. The first report provides a detailed description of the experimental device (Graybiel and Lackner, 1980a). The second report describes the relationship between developing symptoms of motion sickness and changes in heart rate, blood pressure, and body temperature during exposure to sudden stop stimulation (Graybiel and Lackner, 1980b). The experimental findings failed to show any systematic group or consistent individual relationship between any of these parameters and the appearance of symptoms of motion sickness. This lack of correlation suggests that biofeedback control of the physiological variables studied is not likely to prevent the expression of motion sickness symptomatology. The third report concerns the influence of vision on susceptibility to motion sickness during sudden-stop stimulation (Lackner and Graybiel, 1979a). This study showed that having one's eyes open during any part of the sudden stop assessment is more stressful than having them closed throughout. Copies of all three reports have been appended to this report.

We are continuing to evaluate subjects in the free-fall and the increased gravitoinertial phases of parabolic flight using the sudden-stop test. The findings, so far, are quite uniform; most subjects are more susceptible when tested aloft either in the free-fall or increased force phases of flight. In fact, our findings, to date, indicate that subjects are equally susceptible when tested in free fall and in high force phases of flight. These changes in apparent susceptibility have to be considered in relation to the subject's overall susceptibility in parabolic flight because the parabolas themselves constitute a highly stressful motion environment. We are currently testing more individuals in parabolic flight as well as on the ground to build up a sufficiently large body of experimental evidence to be able to draw systematic conclusions about how modifications in gravitoinertial force affect susceptibility to sudden-stop stimulation.

One finding that has emerged consistently from our parabolic flight experiments is a dependence of the gain of the vestibulo-ocular reflex (VOR) on gravitoinertial force level. Gain decreases markedly in free fall and increases markedly in high force phases of flight. The decrease in VOR gain in free fall likely accounts for the disorientation and dizziness sometimes experienced by astronauts when moving their heads in the early phases of orbital flight and again after splashdown. It is well known from studies involving slow rotation rooms that artificial modifications of the VOR are associated with motion sickness symptomatology. Accordingly, we may well have identified one of the major etiological factors in the elicitation of space motion sickness. A report describing our findings is forthcoming (Lackner and Graybiel, in press).

2) <u>Human Spatial Orientation in Free Fall</u>

In the course of our earlier experiments on susceptibility to motion sickness during Z-axis recumbent rotation (Graybiel and Lackner, 1977, 1979), we made a number of systematic observations on how touch and pressure cues affect apparent body orientation during such rotation (Lackner and Graybiel, 1978a,b). These studies have been extended to include evaluations in parabolic flight. On the basis of these observations we have shown that a sense of one's orientation is dependent on patterns of exteroceptive stimulation. In the absence of such inputs during the free-fall phases of parabolic flight, subjects lose all sense of body orientation and are aware only of the relative configurations of the different parts of their body. These findings also provide a way of understanding many of the postural and visual illusions experienced by astronauts in orbital space flight. (Lackner and Graybiel, 1979b).

Many of the subjects who have participated in our parabolic flight experiments have reported motion aftereffects following the flights. These aftereffects are of interest because related phenomena are experienced after being on shipboard and after orbital flight. During parabolic flight aftereffects, the body feels as if it is again undergoing periodic changes in force level because of motion of the substrate; strong apparent postural motion is accompanied by visual motion of the surroundings.

These aftereffects differ in frequency and amplitude from the inducing stimulus pattern, being always of much greater frequency and of lesser intensity; moreover at times, only fragments of aftereffects are experienced. Because of these differences, it seems unlikely that the aftereffects represent simple continuations of centrally generated "patterns of opposite sign," although they clearly represent the persistence of abnormal states of central activation. The existence of these abnormal states is expressed most often when the overall pattern and range of sensory stimulation of the body is diminished, such as when the subject is lying down quietly in a darkened room; that is, the expression of the aftereffects is most prominent against a relatively quiescent pattern of sensory activity. It is possible to attribute the decreased intensity of the aftereffects in relation to the intensity of the inducing pattern to the decay of a centrally-generated compensatory pattern but it is not possible to interpret the higher frequency of the aftereffects in like fashion or in terms of other known physiological mechanisms. Quantitative studies are necessary in which the frequency of the aftereffect is determined for a range of inducing stimulus frequencies before a plausible and physiologically consistent interpretation can be sought.

Of special interest is the general referral of the postural aftereffects to the surface on which the body is being supported. When a subject has a parabolic flight aftereffect, his apparent body motion is usually experienced as being due to motion of the substrate and the parts of his body in contact with the surfact of support are felt to undergo periodic changes in pressure related to the apparent motion of the substrate. Thus, the subject not only experiences a visual and postural illusion but also experiences pressure changes on his body surface such as would be present if the stationary substrate were, in fact, moving. The actual pressure pattern on the body is unchanging when the subject is prone or supine but, if he is standing, he may attempt to compensate by muscular adjustments for the apparent motion of the substrate. Such "compensation" can lead to disorientation and ataxia.

The present observations emphasize the complex processes involved in the computation and maintenance of sensory and postural stability. When a subject experiences strong body motion he also experiences visual motion in the same direction and perceives pressure changes on his body; in other words, compensation is being made for the change in apparent body position just as if it were a real change in position. The specific nature of the central changes induced by parabolic flight maneuvers which give rise to apparent body motion remains unclear; however, it should be noted that the inducing stimulation, the periodic variation in gravitoinertial force acting on the body, affects not only the vestibular receptor systems but also the touch, pressure, and kinesthetic receptor systems. Some contribution of the latter to the origin of the aftereffects should not be ruled out without systematic experimentation because their contribution to human spatial orientation has recently been shown to be much more important than previously thought (Lackner and Graybiel, 1978,a,b, 1979). A report describing these findings has appeared (Lackner and Graybiel, 1980).

3) Skeletal Muscle Vibration

We have found that illusions of continuous body tilt or rotation can be elicited by vibrating the appropriate postural muscles of subjects standing in the dark (Lackner & Levine, 1979). The illusory motion so elicited seems in many ways to be interpreted by the nervous system as if it were actual body motion. As mentioned in our last QPR, one of our concerns has been to determine whether illusory body motion invoked by muscle vibration will elicit symptoms of motion sickness. We still have found little evidence for such an influence but the patterns we have used have primarily involved constant velocity apparent motion rather than acceleratory apparent motion. Accordingly--since motion sickness is usually associated with acceleratory motion profiles rather than constant velocity ones--an adequate test has not yet been achieved. We are currently attempting to provide such a test. We are doing this by using "ramp" patterns of increasing or decreasing vibration frequency and alternately stimulating antagonistic muscles controlling body sway in the erect subject. Such stimulation leads to the subject experiencing a rocking motion of his body. Using these modified procedures we expect to be able to carry out a fair test of whether apparent motion of the stationary body will elicit motion sickness.

4) Motion Sickness and Sensory-Motor Adaptation

One aspect of a sensory-conflict theory of motion sickness is the notion that susceptibility gradually decreases because of adaptation to the conflict situation. Graybiel has shown in many extensive studies of adaptation to cross-coupled angular accelerations in slow rotation rooms that 1) initially head movements out of the axis of rotation elicit symptoms of motion sickness, 2) with continued exposure symptoms gradually abate, and 3) after rotation is stopped head movements again elicit symptoms until re-adaptation to the stationary environment is achieved. These studies provide an important potential way of pre-adapting subjects to the unusual patterns of vestibular stimulation they would encounter in free fall or orbital flight. Adaptation would be speeded up considerably if it were possible to use a passive exposure paradigm in which the subject's whole body were moved rather than just his head. This would avoid the fatigue that is associated with making large numbers of head movements actively.

However, before using passive exposure to cross-coupled angular accelerations we wished to compare the effectiveness of active and passive movements in generating adaptation to visual rearrangement. It has been claimed that adaptation only occurs with active, not passive, body movements (Held, 1965; Held and Hein, 1958) and this claim has been incorporated in recent models of the sensory conflict theory of motion sickness as a key element in adapting to sensory conflicts (Oman, 1980). Accordingly, we performed a series of experiments to reassess the role of active and passive movements in adaptation to visual rearrangement and in oculomotor pursuit tracking of the hand.

The results of these experiments were unequivocal. Adaptation was equally good with active and passive movements whenever exposure conditions differed <u>only</u> in whether active or passive movements were involved. Similarly, when conditions were carefully controlled oculomotor pursuit of the hand was equally good for active and passive movements. The results are presented in Mather and Lackner (1980a,b,c) copies of which have been appended. We conclude that it is practical to use passive movements in generating adaptation to sensory discordances, and that sensory conflict theories which are based on active movement paradigms are misguided.

5) <u>Development of Vestibular Selection Criteria</u>

A report was submitted earlier containing a critical analysis of recent motion sickness literature (Lackner, 1978). This report is being updated and literature specifically relevant to selecting personnel for orbital flight is being included.

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