VISUALLY INDUCED SENSATIONS OF MOTION

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As early as 1875, Mach noted that under appropriate visual conditions, a large visual field, moving uniformly around a subject, could produce a sensation of self-rotation or self-translation which can be extremely powerful, and nearly indistinguishable from body motion. These phenomena, often referred to as Circularvection (CV) and Linearvection (LV), have subsequently been studied by a number of different investigators.

From the point of view of flight simulator design, it has been generally found that appropriate visual scenes can be used to influence subjective spatial orientation, and minimize the actual linear and angular motions required.

In the past year, our laboratory has been conducting a collaborative research program with the Department of Neurology in Freiburg, Germany. and the Psychology Department at M.I.T. Our work has been specifically aimed at modelling the visual and vestibular information integration process in humans, and determining the implications of these models with respect to requirements for flight simulation. This paper reviews our findings with respect to visually induced motion sensation.

Working with a subject seated on a rotating chair inside a cylindrical, closed, rotating drum whose inner walls were painted with vertical alternating black and white stripes, Dichgans and Brandt (1972) found that subjects were not able to distinguish rotation of the drum at constant velocity from rotation of the chair at the same rate but in the opposite direction. The strength of the stimulus to the peripheral retina appeared to be of primary importance in determining the strength of apparent rotation. Brandt and Dichgans (1972) showed CV strength to be essentially independent of the stimulus strength to the central retina (± 20 degrees), and also independent of the strength and direction of optokinetic nystagmus, such as might be generated by a separate display in the central portion of the field of view.

Dichgans, Held, Young, and Brandt (1972) have shown that an analogous effect can be produced for CV about horizontal as well as vertical axes. They found that a rolling visual field produced tilts of the apparent vertical up to 40 degrees, depending on the angular velocity of the visual roll stimulus. Subjects report feeling the paradoxical sensation of being tilted at a constant angle, but continuing to experience a sensation of roll angular velocity, due to the continuing stimulus. Apparently, this is due to the inherent conflict of the visual information with that from the otolithic gravireceptors. Presumably, this conflict is not present when CV is produced about an earth vertical axis. Some of our recent studies using the projection system in the NASA Langley Dual Maneuvering Simulator indicate that CV can also be produced in pitch, although apparent tilt responses induced appear somewhat smaller than in roll. Occasionally, vertical linearvection is also experienced simultaneously, possibly because the axis of rotation of the scene is less visable. The Langley studies indicated that the strength of the apparent tilt induced in pitch and roll was substantially increased when the subject's head was tilted.

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With respect to design of displays for flight simulation, it is particularly interesting to note that Dichgans and Brandt (1972) have found that head movements about horizontal axes by a subject experiencing CV about a vertical axis elicit perceptual effects (such as apparent tilt and nausea) subjectively indistinguishable from the well known Coriolis Phenomenon (Guedry and Montague, 1961) - even though the body is *not* undergoing actual rotation. Our attempts to elicit this phenomenon with CV about non-vertical axes in the Langley simulator have so far been equivocal, however.

More recently, our efforts have been specifically aimed at studying the interaction between visual CV effects and vestibular responses. Young and Henn (1973) have found that CV produces a short term direction specific habituation of nystagmus response to vestibular stimuli. Tang (1973) has studied the combined effects of body tilt and roll CV using an appropriately modified Link GAT-1 simulator, and has found that the effects of tilt and CV seem additive, at least for the small tilt angles studied thus far. Using the same device with CV and actual cab rotations ocurring about a vertical axis, Young, Dichgans, Murphy, and Brandt (1973) found that CV in a given direction produced a corresponding rise in subject's angular acceleration thresholds. Magnitude estimates of angular velocity showed the effects of a CV induced offset, which were increased slightly by vestibular responses in the same direction, and decreased markedly for vestibular responses in the opposite direction. However, rapidly occuring conflicts between visual and vestibular sensation, especially those involving direction disparities, resulted in a precipitous decline in CV and temporary domination by the vestibular response.

Current efforts are aimed at optimizing display configurations appropriate for simulation; extending current studies to include linearvection effects; continuing investigations of the visually induced "pseudocoriolis" effect; attempting to incorporate these results into a hierarchical model for visual and vestibular interaction; and the application of this model to the simulator design process.

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FLIGHT-TEST EXPERIENCE WITH A SNAP-SHOOT DISPLAY

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ABSTRACT

This paper will report on some of the flight test experience with a heads-up pursuit tracking display proposed several years ago (Gilbert, Preyss, and Wills, 1969 Conference on Manual Control). The primary advantages of this display over conventional lead angle computing displays was thought to be a better allocation of tasks between man and machine: the man should be able to perform a more accurate prediction of target motion, whereas the computer is able to do the rote ballistic computations. Although the display has an inherent delay of one time of flight, the pilot should, nevertheless, be able to predict the convergence of the impact point and the target. The flight test data confirm these hypotheses, in general. Problems associated with timing cues, pilot-computer interactions, dynamic bore sighting, symbology, tracking problems, learning experience and contradictory simulation results will be discussed.