STIMULUS FACTORS IN MOTION PERCEPTION AND SPATIAL ORIENTATION

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INTRODUCTION

The Malcolm horizon (Malcolm, et. al., 1975) utilizes a large projected light stimulus (PVHD) as an attitude indicator in order to achieve a more compelling sense of roll than is obtained with smaller devices. The basic principle is that the larger stimulus is more similar to visibility of a real horizon during roll, and does not require fixation and attention to the degree that smaller displays do. Succesful implementation of such a device requires adjustment of the parameters of the visual stimulus so that its effects on motion perception and spatial orientation are optimized. With this purpose in mind, the present paper reviews the effects of relevant image variables on the perception of object motion, self motion and spatial orientation.

Stimulus size:

The PVHD differs from other attitude indicators primarily in that it subtends a substantially greater extent of the visual field. For this reason it might be anticipated that the variable of stimulus size exerts significant influences on motion perception and spatial orientation responses.

The influence of size on motion sensitivity was examined by Johnson and Scobey (1980), who varied the length of moving line stimuli both at the fovea and 18 degrees in the periphery. Increases in line length improved motion sensitivity for peripheral, but not foveal viewing. The improvement, however, was obtained only with increases of line length up to a degree in subtense. Further increases did not alter sensitivity for object motion perception.

A different response measure commonly used to investigate the influence of visual scenes on spatial orientation is vection, or the apparent self-motion which results when a sufficiently large stimulus moves relative to an observer. In general, increases in the size of the moving surround produce consistantly larger influences on perceived orientation in both roll vection (about the line of sight; Held, et. al., 1975) and circular vection (about the vertical axis; Brandt, et. al., 1973). It is this finding that perhaps forms the basis for the more automatic sensation of roll when the PVHD is employed. Results obtained with other measures of spatial orientation are consistant with those for vection. Postural stability is enhanced by the visibility of large, rather than small stimuli and reflexive eye movements termed optokinetic nystagmus (OKN) are elicited primarily by the motion of large stimuli. In general, the importance of stimulus size for these orientation measures is consistant with reports concerning the PVHD.

Retinal eccentricity:

As the size of the roll stimulus is increased by use of the PVHD, the retinal eccentricities which are stimulated are neccesarily altered at the same time. It is therefore important to determine the contributions of different retinal eccentricities to motion perception and spatial orientation.

Although it is sometimes asserted that peripheral vision is specialized for the detection of motion, sensitivity to movement actually decreases with increasing retinal eccentricity. If acuity and motion sensitivity measures are obtained at various retinal eccentricities in the same observers (see e.g., Johnson, et. al., 1976), the ratio of motion sensitivity to acuity values is roughly constant throughout the visual field. That is, motion sensitivity decreases with increasing retinal eccentricity about the same amount as acuity does. A perceptual effect which is perhaps related to the decreased sensitivity for threshold motion in the periphery is that the perceived velocity of peripheral moving targets is also decreased (Tynan and Sekuler, 1982).

With regard to spatial orientation responses, the contribution of different retinal regions is somewhat unclear. Although there are some reports that vection is elicited more easily from the periphery (Brandt, et. al., 1973), the differences are small and may be reversed depending on the manner in which stimulation is restricted to a region of the field (Held, et. al., 1975). Unlike vection, optokinetic nystagmus is clearly dependent on eccentricity of stimulation. Both the frequency and gain of these movements are greatest with perifoveal stimulation and decrease systematically as eccentricity is increased (Post, et. al., 1983). Similarly, preliminary postural stability measures indicate that for this orientation response the central visual field contributes to a greater degree than stimulation of an equally large portion of the periphery.

Stimulus luminance:

Luminance is another stimulus feature to be considered in the implementation of a PVHD, as it would be desirable for the device to be intense enough to be effective, yet not so bright as to degrade the visibility of other detail in the cockpit. The influence of luminance on motion sensitivity was examined by Johnson and Scobey (1980) in both central and peripheral vision. The results revealed an apparently greater influence of luminance on peripheral motion sensitivity than on foveal motion sensitivity. The effect is restricted, however, to a relatively small range of luminances, about one log unit above the threshold for detection of moving detail. That is, for most of the range of luminances tested, there was no benefit to motion detection from increasing the luminance of the moving stimulus.

Studies of the effects of luminance on orientation responses are similar in that there are either small effects or no effects of decreased luminance on these behaviors. Leibowitz, Rodemer and Dichgans (1979) report that vection is undisturbed with reductions of luminance to near-threshold values. Similarly, the localization of visual detail and optokinetic nystagmus are not influenced by changes in luminance (Leibowitz, et. al., 1955; Grüttner, 1939).

Image quality:

Image quality is a fundamental and limiting variable for foveal visual resolution. There are also typically large and variable refractive errors in peripheral vision. It is therefore of interest in the present context to determine the influence of these peripheral refractive errors on motion sensitivity. Correction of these errors has been found to improve peripheral motion sensitivity (Johnson and Leibowitz, 1974), although the effects are small and limited to threshold motion sensitivity, or the finest possible movement that can be detected (Post and Leibowitz, 1981).

Image quality is apparently not a significant determinant of the adequacy of orientation responses, either. The addition of refractive errors does not alter the magnitude of vection responses (Leibowitz et. al., 1979) the radial localization of seen detail (Post and Leibowitz, 1980) or the gain of optokinetic nystagmus responses. Apparently the loss of fine detail does not alter the performance of orientation systems, and exerts little influence on the detection of motion.

Summary:

The literature concerning the effects of stimulus variables on motion perception and spatial orientation responses has been reviewed in order to determine the potential relevance of selected stimulus variables on the

Malcolm horizon. The following tentative conclusions are possible:

1.) Increases of stimulus size serve to increase the contribution of stimuli to spatial orientation sensations and responses. For this reason, a horizon display might be expected to be more effective the greater its angular subtense.

2.) The existing literature does not permit a conclusion as to the contributions of different retinal eccentricities to orientation responses, although motion detection is systematically degraded at greater eccentricities.

3.) The luminance and optical clarity of stimuli, except near threshold values, exert very little influence on either the ability to detect motion or the influence of stimuli on spatial orientation. For this reason, the luminance of the horizon display might still be effective although adjusted to a perceptually dim intensity.

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