THE EFFECTS OF DYNAMIC VISUAL STIMULATION
ON PERCEPTION AND MOTOR CONTROL

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Abstract — A set of research findings is described that deals with three principal laboratory measures of visual orientation (vection and postural and manual control). Two studies are highlighted, one of which compared the latencies of vection and visually induced postural change and the other of which investigated manual tracking under visually disorienting conditions. The first study showed that although vection and postural change are somewhat related to each other (for example, both were greater in response to roll and pitch as opposed to linear visual motion), the onset of vection is delayed by several seconds relative to the initiation of visually induced postural shifts. The second study showed that manual biases induced by visual roll motion are not overcome using a thumb-and-index (pyramidal) motor strategy, and may not be equivalent to the "giant hand" illusion that is believed to reflect the predominance of the vestibulospinal (extrapyramidal) motor pathways during extreme spatial disorientation. These and other findings indicate that various visual orientation effects may involve at least partially independent mechanisms.

Keywords — visual—vestibular; posture; vection; manual control.

Introduction

The overall objective of this research is to compare traditional laboratory measures of visual orientation such as vection (that is, illusory self-motion) and postural change with measures related more to the contexts in which spatial disorientation occurs in pilots. The major concern is that some of these traditional measures are not highly relevant for understanding the way visual orientation mechanisms interact with the pilot’s control of the stick in maintaining aircraft orientation. For example, vection is a delayed percept that does not involve a motor component and is believed to be cortically mediated; hence, it may not explain how preconscious motor reflexes momentarily overpower the pilot’s ability to orient via the cockpit instruments. Certainly, vection cannot account for visual orientation effects that are static in nature, such as a sloping cloud deck (leading to an erroneous roll percept) or a nighttime shoreline falsely perceived as the horizon (leading to an erroneous pitch attitude).

I will describe two studies, one of which compared the latencies and magnitudes of vection and visually induced postural change, and the other of which investigated manual tracking under visually disorienting conditions. These experiments were conducted in the Visual Orientation Laboratory at Brooks Air Force Base, Texas, a schematic diagram of which is contained in a recent report (1). The visual system presents a computer-generated, wide field-of-view, collimated image through a screen in front of the subject. The visual display is adjustable in height to allow for both manual testing in the seated position and postural testing in the standing position. The motor output of a force-stick is used to evaluate performance in the manual control task, while the instantaneous position of the body’s center-of-pressure is quantified in the postural task.
A Comparison of Visually Induced Postural Change and Vection

The first study (1) compared the magnitude and latency of postural change versus vection under a wide range of visual conditions. It is generally conceded that visually induced postural changes occur before the onset of vection, but it is not clear how these two measures relate to one another.

Twelve subjects viewed a pattern consisting of 100 variably sized white squares on a black background. The dimensions of the visual image were 85 degrees vertically and 95 degrees horizontally. The scene motion consisted of rotation in either roll or pitch at a velocity of 25°/s, or linear fore-aft stimulation (that is, an expanding and receding flow pattern). Each 50-second trial was preceded by a 10-second baseline interval. The postural record was sampled at 20 Hz while the subject viewed each scene. The magnitude of vection was rated on a 1 to 5 scale at the end of the trial, with “1” representing “little or no vection” and “5” representing “a great deal.”

Samples of the postural record under the six different visual motion conditions, as well as the eyes-open versus eyes-closed conditions, are contained in Figure 1. Viewing a stationary visual scene generally stabilizes sway, as shown in Figure 1a. But postural control becomes destabilized at least as much by a moving visual scene as when the eyes are closed, and the mean center-of-pressure is shifted away from baseline. The most consistent and robust postural changes are induced in the roll plane, with a strong postural deviation in the direction of stimulus motion accompanying an increase in the subject’s overall sway amplitude (Figure 1b). It may be presumed that a preconscious inference of falling opposite to the scene motion (as would be the case in everyday existence) is compensated for by allowing one’s vestibulospinal reflexes to push the body in the direction of the stimulus. At a conscious level, however, the subject typically experiences the self-tilt in the direction of the scene before the falling in the opposite direction (that is, vection) is experienced. It is interesting to note the roll asymmetry (that is, the greater postural deviation in the clockwise direction) shown by this subject and many others. A preliminary analysis based on data from the 12 subjects used in this study revealed that postural asymmetry in roll correlates well with turning tendencies on the stepping test (2). Perhaps an asymmetry in vestibulospinal reflex activity is responsible for both of these phenomena (2).

Postural changes created by a visual pitch scene were also robust (Figure 1c), although perhaps not quite as consistent across subjects as the visual roll effects. In this case, the compensatory postural bias is in the fore-aft plane, with the pitch-down stimulus typically creating a forward shift of the center-of-pressure and the pitch-up stimulus creating a backward one. Once again, these postural shifts presumably related to the perception of falling in the direction opposite to the scene motion. The postural asymmetry in pitch was much greater than in the case of roll, with the pitch-down stimulus being more effective overall. This strong asymmetry may be related to vestibulo-ocular, optokinetic, and other well-documented visual-vestibular asymmetries using pitch stimulation (3,4).

The visual motion stimuli that least affected postural control were the expanding and receding linear flow patterns. While some postural destabilization was created by these stimuli, at least half of the subjects showed little or no postural change in response to them. Moreover, the direction of the compensatory postural change was inconsistent across individuals; while some subjects tilted backward and forward to expanding and receding patterns, respectively (Figure 1d), others exhibited precisely the opposite effect. I believe that this discrepancy occurred because some subjects felt themselves moving against the radial flow (that is, they perceived forward self-motion in response to an expanding stimulus), whereas others perceived themselves moving with the stimulus. However, it is not clear why so many individuals exhibited no linear postural effects, whatsoever.

The effects of the various visual scene conditions averaged across all subjects are shown in Figures 2 and 3. The mean amplitude about
Figure 1. Postural sway produced under various visual conditions. (a) eyes-closed versus eyes-open (stationary visual input); (b) clockwise versus counterclockwise roll stimulation; (c) pitch-up versus pitch-down stimulation; and (d) expanding versus receding (fore–aft) linear visual flow stimulation.
The center of sway during each trial is shown in Figure 2, while the mean lateral and fore-aft deviations of the center of sway from baseline are shown in Figure 3. A significant increase in postural sway occurred in the eyes-closed condition relative to the eyes-open one (Figure 2), but the linear visual flow patterns produced very little additional effect. The greatest effects were in the clockwise and counterclockwise roll directions, and in the pitch-down condition. Pitch-up visual motion produced much less sway than pitch-down motion, although it did result in significantly more sway than was found in either the linear-receding or eyes-closed conditions.

The bias results revealed no overall lateral or fore-aft deviations in the two linear conditions, which reflected the fact that the direction of postural tilt was inconsistent across subjects in these conditions. Visual pitch created a large bias only in the fore-aft direction, although the bias was much greater in response to pitch-down stimulation. Visual roll stimulation resulted in large left-right lateral biases, which were significantly greater than in all other conditions. But the clockwise and counterclockwise roll motion also produced substantial tilt in the forward direction, for reasons that are unclear.

The vection magnitude ratings (Figure 4) somewhat paralleled the postural sway results.