POSTURAL CONTROL SHIFTS WITH SENSORY DISCORDANCE

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Introduction: The perception of instability can be elicited by both physical and visual motion. We have examined postural responses to separate and concomitant concordant and discordant visual, vestibular, and proprioceptive inputs to determine how multimodal environmental disturbances are resolved.

Methods: Two healthy subjects (24 and 26 yrs) were tested standing still in the dark, with the platform and visual scene moving alone, or with the scene moving in the opposite (in sync) or same direction (out of sync) as the platform. The platform was translated sinusoidally (0.1 Hz, 12 cm/s) in the a-p direction. A virtual environment (VE) produced 0.1 Hz fore-aft motion of the visual scene at 4 velocities (4, 7, 14, and 28 cm/s). In addition, seven healthy (25-31 yrs) and one labyrinthine deficient (LD) adult (34 yrs) were tested with sinusoidal a-p platform translations (0.25 Hz, 32 cm/s). Then a VE produced 0.1 Hz, 38 cm/s sinusoidal fore-aft motion of the visual scene. Platform and scene motions were then presented concurrently. Three-dimensional kinematic data of the head, trunk, and ankle were collected at 100 Hz with active markers (Optotrak, Northern Digital) positioned over the left eye socket, meatus of the ear, C_7, acromion process, iliac crest, and lateral malleolus. Angular displacements, FFT phase values of each segment, the scene, and the platform, and power of the response at each stimulus frequency were calculated. Repeated measures ANOVA and post-hoc comparisons ($p < 0.05$) were performed on area under the power curve, and amplitudes of center of pressure (COP), and kinematic data from the head, trunk, and lower limb.

Results: In sync motion of the platform and scene (0.1 Hz) produced negligible segmental displacements and scattered low frequency power spectra similar to that of standing still in the dark. Peak segmental power emerged around 0.02 Hz; peak power of the COP was at 0.1 Hz. Subjects' reported that they did not perceive the platform moving when in sync with the scene. When platform and scene were out of sync, peak excursions of the COP were greater than when in sync. When the scene moved alone, head, trunk, and ankle were ~180° out of phase at the highest velocity; only ankle phases shifted 45°-90° at lower velocities. All segments were 0° to 45° out of phase when the platform moved alone. All segments were <45° out of phase with both inputs when in sync. When out of sync, segments were <90° out of phase with the platform and close to 180° out of phase with the scene. At the highest velocity, however, all segments shifted to 90° out of phase with both the platform and the scene.

Different platform and scene frequencies increased segmental and COP response amplitudes over time, and both frequencies were present in the power spectra. Power across time when exposed to both inputs was significantly greater for the head and trunk at the visual frequency than to either input presented alone. This increase could not be obtained by a simple summing of the responses to single frequency inputs. Power across time in the ankle was the same for the platform and the scene when both moved. Segmental amplitudes of the LD subject were smaller than in healthy subjects, but the power spectra still demonstrated responses of each segment at both relevant frequencies.

Discussion and Conclusions: Our results suggest that mechanical disturbances of the body or large visual velocities must occur for responses of instability to emerge. The postural response reflected both input frequencies, but the strength of the response to each input was manifested differently in each segment of the body. With discordant input frequencies, subjects became more in tune with the visual frequency over time. These data suggest the possibility of multiple levels of sensorimotor control during the postural task. Instability in patients with labyrinthine deficit may be due to a change in the way they process multi-modal inputs which may lead to an error in the continuous regulation of the postural response in a dynamic environment.