Display Reading Performance Under Lateral Whole-Body Vibration Due to 12-Hz Thrust Oscillation

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NASA's Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (MPCV) Programs recently revealed that solid-rocket-booster thrust oscillation (TO) during launch will cause astronauts to experience narrowly focused ~12-Hz lateral (side-to-side) vibration during launch. TO vibration raises concern because of its potential impact on crew ability to visually monitor vehicle systems. Due to the absence of comparable spaceflight experience and relevant data in the literature, we conducted a laboratory investigation to address this concern by examining the effects of lateral vibration on the visual performance of semi-supine observers in order to support SLS and MPCV establishment of new TO limits.

In the experiment, twelve participants (8 M / 4F, age range: 23-42) performed a number-reading task while undergoing lateral (g_y), single-frequency (12-Hz), whole-body vibration superimposed on a chest-to-spine 1-G_x bias via a semi-supine seating configuration. In addition, a strap snugged tightly across the forehead served as a surrogate for the elevated G_x-loading experienced during launch thereby ensuring continuous head contact with the seatback. The task, which is identical to the one we employed under axial (chest-to-spine) vibration in support of requirements development for NASA's Constellation Program, involves viewing an Orion-inspired high-density numeric display format on a liquid-crystal display (LCD) panel, and locating and determining whether a specified three-number string comprises a monotonic sequence. [1],[2] Thus the task tests both visual acuity and cognitive processing.

Trials were grouped into blocks, with each block presenting a constant vibration amplitude ranging between zero (control condition) and 0.7 g (zero-to-peak), bracketing recent estimates for TO-driven lateral vibration to the crew. Identical vibration blocks were repeated on separate days, with a 10-pt font-size version of the task presented on one day and 14.5-pt on the other. Objective measures of task performance (error rate and average response time) and participants' subjective ratings of the workload as well as the visual and cognitive impact of vibration were obtained for each block.

The subjective ratings indicated statistically significant differences between the highest vibration level, 0.7 g, and the zero-vibration control condition for both font sizes. Both objective measures, however, did not demonstrate a significant impact of vibration at any study level, with median error rates remaining below 5% for all conditions, consistent with expected "finger error." High-speed video recordings of eye-in-space motion, which could be successfully analyzed from only five of the study participants, revealed that eye position was minimally affected by vibration in the 12-Hz band, with corresponding average gaze deflections rising by only ±0.2 mm (~±1 pixel) at the LCD plane. This limited eye-in-space response when compared with the ±1.2 mm lateral seatback motion adjacent to the head at 0.7-g vibration suggests the absence of significant objectively measured performance effects may be due to the observers' eye-head system being largely decoupled from lateral chair inputs at 12-Hz despite the head restraint strap.

REFERENCES

[1] Adelstein, B.D., et al. (2009a). NASA/TM 2009-215385. [2] Adelstein, B.D., et al. (2009b). NASA/TM 2009-215386.