SUPERPOSITION OF OPTIMAL SUBMOVEMENTS IN FEEDBACK-CONTROLLED REACHING

Kevin A. Rider, Bernard J. Martin
University of Michigan; email: riderk@umich.edu, web: www.humosim.org

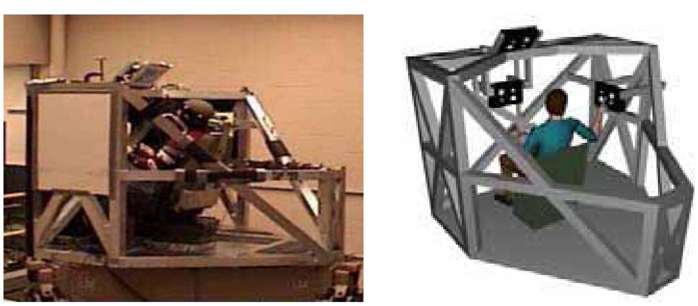
INTRODUCTION

The inverse relationship between speed and accuracy of rapid target-directed movements is a result of the combined use of visual and somatosensory feedback systems by the central nervous system (CNS). Feedback loops allow for comparisons between the desired movement plan and actual execution in discrete intervals [1]. Optimal rapid movements have been shown to exhibit bell-shaped speed profiles [2], although speed profiles exhibit multiple peaks due to compensatory adjustments made when the movement is perceived to no longer satisfy the desired goals. Composites of superimposed optimal speed profiles of submovements were generated and compared with actual speed profiles of rapid, three-dimensional reaching tasks under stationary and random whole-body vibration.

METHODS

Participants (N=20) performed rapid pointing tasks under stationary and motion conditions to targets presented on three touchpanel displays. A ten-camera VICON motion capture system recorded trajectories of reflective marker placed on the participants' torso, head, and arms. Fingertip trajectories were extracted and averaged to determine participant's optimal path for each motion condition [3]. Speed profiles were generated from the tangential velocity of the fingertip marker.

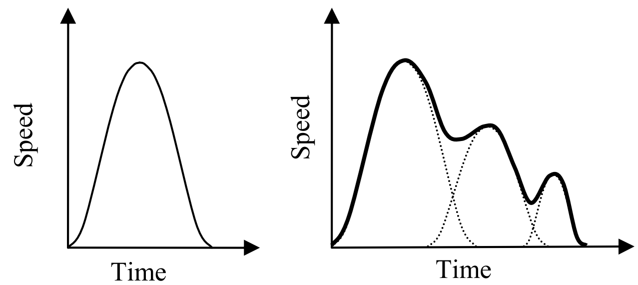
Random six degree-of-freedom (6DOF) ride motion was recorded from a High Mobility Multi-Wheeled Vehicle (HMMWV). Motion conditions (Roll, Pitch) were extracted, each with dominant vehicle acceleration about the longitudinal and lateral axes respectively. These motion files were simulated on a 6-DOF Ride Motion Simulator (RMS) (Figure 1a). Three touchpanel displays were mounted to the RMS to display targets and record endpoint locations (Figure 1b).



a) b)

Figure 1. The RMS (left) configured with three touchpanel displays and depicted in simulation (right).

Modeling began with an optimal bell-shaped speed profile of the fingertip, initially generated based on the time and magnitude of the peak tangential velocity (Figure 2a). As the fingertip deviates from the optimal path, a compensatory submovement is made with a sensorimotor delay of 100 ms. Submovements were assumed to have optimal bell-shaped profiles. The optimal path was then adjusted using a decreasing gradient in the vector of radial deviation to create a new optimal path, from which the continuing trajectory of the fingertip was evaluated. This recursive process continued until task completion. Submovements were superimposed to form composite speed profiles (Figure 2b).



a) b)

Figure 2. a) Optimal open-loop bell-shaped speed profile and b) Closed-loop profile with superimposed submovements.

RESULTS AND DISCUSSION

Composite speed profiles compared favorably with actual fingertip speed profiles in the latter portion of the movement, when the fingertip entered the field-of-view. Our results suggest that the initial phase of movement is to accelerate away from the origin without specific accuracy requirements. It is possible that somatosensory feedback is used only for movement planning and not for feedback control. It is unclear whether the CNS does not discern initial deviations from the optimal path, or if comparisons are weighted more heavily toward the destination. Reaches performed without ride motion did not have observable movement corrections, rather near-optimal speed profiles. This may be due to corrections that were either imperceptible or not present. These and other discrepancies between composite and actual speed profiles may be due to additional movement strategies such as non-linear trajectories, time-varying goals (lift-off vs. landing phases), and biodynamic responses to the vibration stimulus.

REFERENCES

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3. Faraway J. Proceedings of SAE Digital Human Modeling Conference, Report, 2000.

ACKNOWLEDGEMENTS

Thanks to the Automotive Research Center (ARC); a collaboration between the University of Michigan and the US Army. Special thanks to Charles Woolley and additional support of the HUMOSIM Laboratory for their time in setting up the displays and data acquisition systems used.