The Effects of Encountered-Type Haptics on Immersion, Presence, User Experience and Task Performance in Virtual Control Panel Environments

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Abstract

Virtual Reality (VR) aims to immerse users in an experience that feels real. Passive haptic feedback enhances immersion, with users interacting with real-world analogues of virtual objects, as if directly encountered. Encountered-Type Haptic Displays (ETHDs) track users to dynamically provide this feedback, but cannot keep up with human movements, slowing them down, and negatively impacting the experience. Four experiments were conducted with the custom-built, high-speed, *Fast ETHD* system, to quantify its effects on aspects of the VR experience. The *VR Alien Shooter Game Experiment* entailed 25 participants shooting aliens, and answering modified versions of the Presence Questionnaire (PQ) and User Experience Questionnaire (UEQ), to answer *"What effects on immersion, presence and User Experience (UX) are observed in users as ETHD speed increases?"* Sentiment scores improved for the PQ aspects of *Possibility To Act*, *Quality Of Interface* and the UEQ aspect of *Efficiency*. Game performance improved in the *Total Aliens Hit, Aliens Hit by Normal and Double Shots, Aliens Hit by Laser and Big Shots, Alien Bullets Hit* and *Spaceship Damage* categories. The UEQ aspect of *Attractiveness* showed no effect on scores, with a decrease observed for *Dependability*. Participants had positive sentiments toward the system and experience, with average scores for *Perspicuity, Stimulation* and *Novelty* scales of the UEQ being 1.79, 2.27 and 1.33 respectively, the maximum of 3.00 being strongly positive sentiment. Users were not that sensitive to the speed profile range. Exposing users to more repetitions per speed, on a faster rig, would aid future studies. The *VR Fitts's Test Experiment* had novice users performing the ISO/TS 9241-411 multidirectional tapping task for different haptic conditions, answering *"What task performance is achieved with a high-speed ETHD and how does it compare to zero-delay conditions and previous studies?"* The ETHD Haptics Condition resulted in a throughput of 2.23bps for 27 subjects, the Table Haptics Condition 3.53bps for 26 subjects, and the No Haptics Condition 3.70bps for 23 subjects. The ETHD's lower throughput is attributed to the latency in the *Fast ETHD* system. A faster microcontroller, more optimised Computer Numeric Control (CNC) firmware, and incorporating predictive models for positioning is suggested to reduce latency, and training users to expert levels to improve throughput.