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QUANTIFYING PERFORMANCE IN HUMAN-ROBOTIC INTEGRATED OPERATIONS FOR SPACEFLIGHT APPLICATIONS: A MISSION-DRIVEN APPROACH

Abstract

As the global space exploration community moves towards the exploration of the Moon and beyond, so must the preparation of crew operations. Given the distinct operational requirements of human lunar exploration scenarios compared to the on-going ISS operations, the study of human-robotic integrated operations (HRIO) is key in the endeavour of mankind's return to the Moon and enabling a sustainable exploration strategy. Moving beyond qualitative performance assessments of HRIO, one particular issue for exploration destinations is regarding time-delay conditions, and therefore the step must be made towards quantifying performance in these operations such that both crew and system designs can be prepared accordingly.

Based on the pilot study previously presented in Hosseini et al. 2017, the current paper presents a mission-driven experiment campaign set up to study human performance regarding the ESA-led HERACLES mission, a proposed sub-scale tele-operated demonstrator mission aiming to prepare international partners for human lunar missions. A targeted geological site in a lunar crater is set up in an analogue environment indoors at ESA allowing a rover to be tele-operated. The knowledge gap in HRIO is challenged in this study, since reaching this level of human-robotic partnership requires an unprecedented understanding of the interaction between the human and robotic system.

The approach to fill this gap is to quantify objectively the HRIO performance for spaceflight applications, by studying human and robotic elements as two separate yet cooperating systems. 40 participants were instructed to drive the rover through an obstacle course using a controller and camera as interface to the rover. Three mission-driven time-delay conditions were applied to simulate different control configurations, i.e. 3.5s, 0.5s, and 0s representing control from Earth, cis-lunar space, and lunar surface, respectively, assuming the rover is driving on the lunar surface.

The experiment is set up such that human performance metrics are acquired following a neuroergonomics approach, focusing on the cardiovascular activity to infer participants' mental workload, and ocular behaviour, to measure attentional abilities. In parallel, robotic metrics are acquired through the hardware and software output of the rover.

Studying human and robotic data output recorded in parallel allows quantification of the level of mental workload under the delay conditions and the resulting effects on the HRIO performance. This approach is believed to advance the level of detail and understanding of HRIO as known to date, subsequently identifying the key elements to prepare astronauts for future missions.