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ELECTROENCEPHALOGRAPHY (EEG), ELECTROMYOGRAPHY (EMG) AND EYE- TRACKING FOR ASTRONAUT TRAINING AND SPACE EXPLORATION

Abstract

The ongoing push to send humans back to the Moon is giving rise to a wide range of novel technical solutions in support of prospective astronaut expeditions. Crew capsules for long-duration travel, prospective lunar surface habitats, and extravehicular activity (EVA) suits are a few of the advanced systems set to underpin future human lunar explorations. Such systems are in need of efficient human-machine control mechanisms and interaction interfaces that would ensure optimal work performance, while safeguarding astronaut's physical and mental wellbeing. Against this backdrop, the European Space Agency (ESA) has recently launched an investigation into unobtrusive interface technologies as a potential answer to such challenges. In theory, the application of these technologies could enable future crews to initiate actions without requiring any form of manual manipulation, resulting in a more intuitive, safe, and flexible control mechanism in numerous situations. Potential examples range from the control of robotic arms and rovers, to the interaction with virtual and augmented reality applications.

Three particular technologies have shown promise in this regard: EEG - based brain-computer interfaces (BCI) provide a non-invasive method of utilizing recorded electrical activity of a user's brain, electromyography (EMGs) enables monitoring of electrical signals generated by the user's muscle contractions, and finally, eye tracking enables, for instance, the tracking of user's gaze direction via camera recordings to convey commands.

Beyond simply improving the usability of prospective technical solutions, our findings indicate that in particular EEG and eye-tracking could also serve to monitor and assess a variety of cognitive states, including attention, cognitive load, and mental fatigue of the user. Such capabilities may well turn out to be important enablers for the success of future lunar expeditions. Indeed, monitoring cognitive states could, for instance, help guide adaptive automation, improve crew mental health and concentration via neurofeedback, indicate training success, or help astronauts optimize the timing of their actions during future missions.

In this paper, we elaborate the key strengths and challenges of these three enabling technologies, and in the light of ESA's latest findings, we reflect on their applicability in the context of human space flight. Furthermore, a timeline of technological readiness is provided. In so doing, this paper feeds into the growing discourse on emerging technology and its role in paving the way for a human return to the Moon.