This is Your Brain on Mars

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Synopsis

In this talk we describe an experiment where six participants spent a full week in simulation at a Mars analog in the Utah desert, living and working together as a crew. They took part in multiple extravehicular activities (EVAs) each day that involved complex decision making while equipped with functional-near infrared spectroscopy (fNIRS) and other sensors. In this talk we outline the steps involved in collecting quality fNIRS data on Mars, present our fNIRS results, and we describe how this dataset is merged with larger lab-based datasets to train machine learning models to predict key decision-making states in the real-world.

Background

We envision a not-too distant future in Human-AI Teaming where non-invasive brain measurement is used to inform neuroadaptive systems that are designed to support people working in isolated, confined, and extreme (ICE) environments. Recent advances in physiological and behavioral sensing have expanded the set of tools available for inferring task-relevant cognitive states. Modalities such as fNIRS have demonstrated utility in characterizing constructs central to real-world performance, including trust, cognitive workload, and situation awareness, across both human-human and human–agent teams. As these technologies mature, their use is increasingly viable in naturalistic task contexts, reducing reliance on highly constrained laboratory paradigms where data and resulting models may not generalize. This study looks at one of these naturaltic ICE envioronments; space exploration. First we detail preliminary efforts to prepare such an environment. Then we detail our field experiment where we collect naturalistic physiological and behavioral data on crews at the Mars Desert Research Station (MDRS) in the Utah Desert, as they undergo complex decision-making and navigation tasks in the presence of contested information.

Methods

Pilot Studies. To inform training and mission operations, we conducted two pilot studies in advance of the data collection missions. During these pilots, the research team traveled to the data collection site in Utah and tested the sensors while wearing full spacesuits on EVA. This included in-field pilot testing, mapping areas of WiFi connectivity and deadzones, event-related design considerations, spatial registration of optodes in the field, and cable management and spacesuit integration. After our pilot studies, we opted to use Artinis fNIRS PortaLites rather than NIRX Sport2 fNIRS devices due to its light footprint and ease of use.

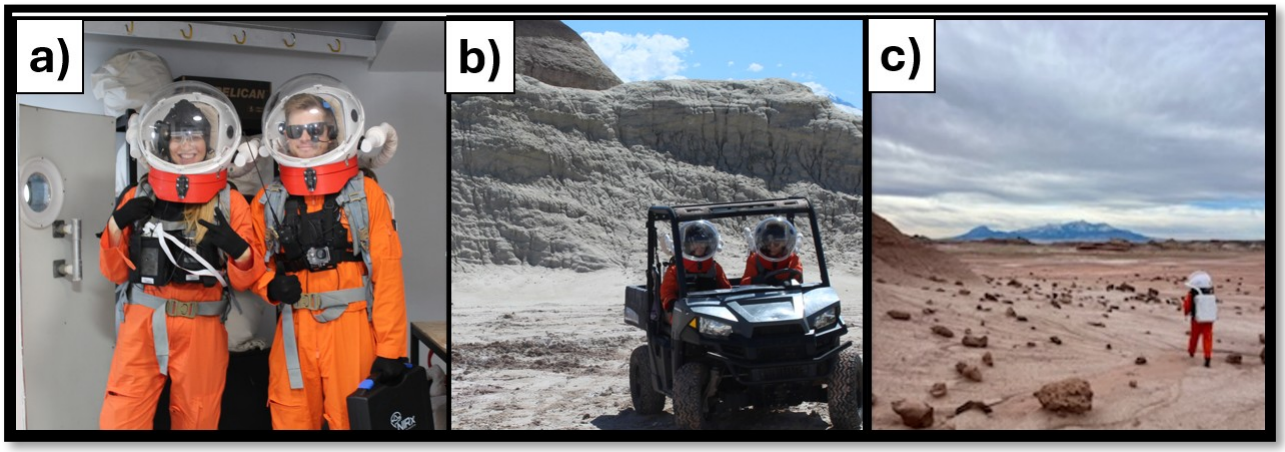

Figure 1. A dyad heads out on EVA while equipped with fNIRS. a) Dyad wearing fNIRS in the Habitat, b) heading out on EVA, and c) on foot navigation tasks to locate items of interest.

Field Experiment. We conducted a mixed methods study to investigate factors affecting team decision making in environments with sparse and conflicting information. We collected data from six crew members across one analog spaceflight mission at the Mars Desert Research Station MDRS; participants lived and worked at MDRS for one week Crews were selected to represent astronaut teams, two co-commanders, one crew scientist, one crew engineer, one green habitat officer, and one medic.The analog experience was designed to elicit stressors associated with spaceflight missions. In particular, external communication was limited to a two-hour window each evening. Crews lived in the MDRS habitat, which features individual sleeping quarters and a shared living area and kitchen. Crew members could not leave their habitat except while on their scheduled EVA wearing spacesuit simulators (Allred et al. 2025). Participants completed EVAs multiple times per day in dyads to complete a reconnaissance mission. Each EVA condition featured a unique objective, narrative, and destination that are designed to span a gradation of ecological validity (Crum et al. 2024). Participants wore physiological and behavior sensors during the EVA, including fNIRS, eye-tracking, heart rate, microphones, a location tracker. To maintain immersion in the analog simulation, it was critical that crew members were physically separated from the research team throughout the duration of their mission. Thus crews were trained to don, operate, and doff all research equipment independently.

Results & Analysis

To quantify data quality across deployments, we generated scalp coupling index (SCI) values per channel, per EVA, per participant for pilot fNIRS data (Sport 2) and field data (Artinis). Preliminary results show that usable fNIRS data can be collected with both the NIRX and Artinis devices in this operational deployment. At the conference, we will report SCI summaries and present event-related constrasts aligned to EVA task structures that are designed to isolate the neural mechinsm of key event-driven cognitive states of interest. Finally, to support predictive modeling, the data collected “on Mars” will be combined with additional fNIRS data collected in the lab (Sport 2) and in fMRI scanners (concurrent fMRI-fNRIS with NIRX Borealis), where participants complete the same EVA tasks via a simulation platform; these datasets are used to build models to predict key mental states of interest.

Discussion

Our findings suggest that with the right amount of planning, pilot testing in the field, and creation of custom suits to house/support the sensors, it is possible to get quality fNIRS data from ecological and naturalistic environments that are isolated, confined, and extreme. We have a number of lessons learned from the study, which can inform other fNIRS researcher designs in the wild. A key lesson from this deployment is that obtaining high-quality fNIRS data in

researcher-isloated naturalistic ICE settings depends as much on operational design as on signal processing. When crews must self-equip and troubleshoot, protocols should be redundant across media forms, training should include multiple guided opportunities for independent practice embedded within the broader mission checklist, and troubleshooting should be explicitly standardized to discourage improvisation and to preserve an interpretable record of what was attempted. For multimodal paradigms, securing the full field hardware configuration well in advance is essential to identify and resolve practical integration constraints, so that robust troubleshooting procedures for newly discovered hardware-software interactions can be built, and to establish contingency donning methods and data handling plans before deployment. Finally, designating clear points of contact, both a crew member responsible for sensor equipping and component-level experiment leads, streamlined operations. We will present these lessons learned along with the modeling and analysis results at the conference.

References

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