EFFECTS OF LUNAR MISSION GRAVITATIONAL TRANSITIONS ON FINE MOTOR TASK PERFORMANCE. K. Holden[1], [1]Leidos, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX, kritina.l.holden@nasa.gov

Introduction: Space travelers will endure many challenges as they embark on future long-duration missions beyond low Earth orbit. They will face isolation, confinement, a closed environment, space radiation, and long-duration microgravity. We know that the human body is impacted by the deleterious effects of spaceflight, and ISS research over the last fifteen years has led to a basic understanding of these effects, as well as the efficacy of mitigations. One lessor studied area of spaceflight performance is fine motor skills. Fine motor skills will be critical for interacting with hardware and software-based controls to perform a variety of tasks such as information access, just-in-time training, subsystem maintenance, and medical treatment, among others. Fine motor skills are also critical for tasks involving hand controllers – flying a space vehicle, or teleoperating a robotic arm. When crew land on Mars after a long journey, they must be able to accurately safe the vehicle, command the rover, and startup the habitat and their spacesuits without high error rates.

ISS Research: Holden, Greene, Cross, and Feiveson [1] completed a research investigation on the ISS, measuring fine motor skills of seven astronauts preflight, inflight over the course of a six-month mission on ISS, and postflight out to 30 days after landing. This investigation had two primary aims: 1) determine the effects of long-duration microgravity on fine motor performance, and 2) determine the effects of different gravitational transitions on fine motor performance. The study used a Fine Motor Skills Test Battery [2] to measure performance. Crew performed the task four times preflight as a baseline, two times in the first week onboard ISS, every week for the first three months of the mission, and then every fourteen days for the remainder of the six-month mission. Post-flight data collection was accomplished twice on landing day, and then on post-landing days 1, 3, 5, 15 and 30. Ground subjects matched to each crewmember on the basis of age, education, vision, hearing, and fitness level completed test sessions on the same schedule as their crewmember match – lagged by two weeks.

Fine Motor Skills Test Battery: The Fine Motor Skills test battery consists of four fine motor tasks: Pointing, Dragging, Shape Tracing, and Pinch-Rotate (see Figure 1). In the Pointing task, squares are tapped in order, either clockwise or counter-clockwise, depending on the instructions. In the Dragging task, the small square is dragged to the distant rectangle and dropped in the rectangle; then repeated in other opposite direction. Dragging is horizontal or vertical, depending on instructions. In the shape tracing task, a circle or square is traced in a continuous motion in either a clockwise or counter-clockwise direction. In the Pinch-rotate task, the outer shape is "grabbed" with the thumb and pointer finger, and the shape is rotated and pinched until it aligns with (lies on top of) the inner shape. All tasks were performed both with a stylus and finger (per onscreen instructions), with the exception of the pinch-rotate task, which was only performed with a finger.

Figure 1. Fine Motor Skills Test Battery (available on Apple app store)

Results: There were no significant decrements in performance during the mission, for the seven crew participants, and small but significant decrements at the gravitational transition points. Pointing, Dragging, and Shape-tracing task performance showed significant decrements during the first week on ISS, as compared to the ground controls. Performance then recovered, and gradually improved over the mission. Soon after landing, Pointing and Shape-tracing task performance again showed significant decrements compared to the ground controls. At 30 days post-landing, performance on the Pointing task was still significantly worse than the ground controls. These results indicate that there is a fine motor performance decrement whenever astronauts go through a gravitational transition. The decrements are small, but from a human factors perspective, what matters is that these results indicate astronauts may be unable to maintain stable, accurate performance after going through gravitational transitions. Moore, Dilda, Morris, Yungher, MacDougall, and Wood [3] also investigated the effects of gravitational transitions on motor performance. Results showed ISS standard duration crew had significant decrements, compared to preflight, in the ability to operate simulated vehicles within 24-hours of landing. Piloting performance and a rover-docking maneuver were also compromised, and there was a 10% decline in subject manual dexterity on landing day.

Critical Proving Ground: Lunar surface missions will serve as critical proving grounds for future deep space missions, and an ideal opportunity to extend the

Fine Motor Skills research. Results from a lunar mission will provide new data to refine conclusions with respect to the current concerns related to spaceflight effects on fine motor skills. The unique opportunity afforded is the ability to measure: 1) effects of transition from microgravity to lunar surface gravity, 2) effects of transition from lunar surface gravity back to microgravity, and finally, 3) effects of transition from microgravity back to Earth gravity. This type of investigation would provide much needed data regarding performance decrements after planetary gravitational transitions. Performance decrements would suggest that crew's ability to accomplish planetary surface tasks with accuracy upon landing could be at risk.

Proposed Lunar Investigation: A research study similar to the Fine Motor Skills studies performed on ISS is recommended. The Fine Motor Skills Test Battery, and a subset of hand controller tasks similar to the Robotic on-Board Trainer (ROBoT) are recommended. ROBoT is a laptop-based Space Station Remote Manipulator System (SSRMS) that is used to perform robotic arm proficiency training for crewmembers. Fine motor skills are required to accurately acquire targets in this task.

Fine Motor Skills test battery measures and hand controller measures will be taken at the gravitational transition time points below:

- pre-flight
- upon arrival to Gateway
- prior to lunar descent
- after landing on the lunar surface
- prior to ascent to Gateway
- after arrival on Gateway
- prior to landing
- post-landing on Earth

Results from this type of study will be critical for judging risk for future missions, and will help determine the need for mitigations for any performance decrements. For example, perhaps concentrated practice on fine motor tasks will provide a buffer against decrements, or perhaps special interfaces will need to be developed if we confirm that fine motor capabilities will be impacted.

This investigation would require the following estimated resources:

- Crew time across entire mission: two crew, approximately 15 test sessions, 15 min per session, postflight survey
- Upmass: tablet computer, laptop computer, hand controller

Conclusion: There is some evidence from ISS that shows fine motor performance decrements associated with gravitational transitions; but currently, we do not have all the knowledge needed to gauge risk and embark upon deep space missions with confidence. Crewmembers must be able to accurately interact with computer-based controls to accomplish safety-critical mission objectives when they land on a planet's surface. Testing these capabilities on a lunar mission is the logical next step in assessing fine motor performance risks in spaceflight.

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References: [1] Holden, K., Greene, M., Cross, E.V., and Feiveson, A. (2018). *Effects of Long-duration Microgravity on Fine Motor Skills*. Presentation at the Human Research Program (HRP) Investigator's Workshop, Galveston, TX, [2] Thompson, S., Holden, K., and Sándor, A. (2015). *Validation of the Fine Motor Skills Application using the 9-Hole Peg Test*. NASA internal report, [3] Moore S. Dilda V. Morris T. Yungher D. MacDougall H. Wood S. (2018). *Effects of Long-Duration Spaceflight on Post-Landing Operator Proficiency*. Presentation at the Human Research Program Investigator's Workshop, Galveston, TX.