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PI Name:	McGregor, Heather Ph.D.		
Project Title:	Investigating Plantar Somatosensory Noise as a Countermeasure for Balance and Locomotion Impairments in Simulated Lunar and Martian Gravity		
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Program/Discipline--Element/Subdiscipline:	TRISH--TRISH		
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Comments:			
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Contact Monitor:		**Contact Phone:**	
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Key Personnel Changes/Previous PI:			
COI Name (Institution):	Seidler, Rachael Ph.D. (MENTOR: University of Florida, Gainesville)		
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Task Description:	POSTDOCTORAL FELLOWSHIP The vestibular system in our inner ear is key to our sense of orientation and balance. However, in space, the vestibular system does not function normally and the brain cannot interpret its signals. The brain gradually reinterprets vestibular signals to adapt to microgravity, but when astronauts re-encounter gravity post-flight, they have difficulty maintaining their balance while standing and walking. This is because the brain needs time to readjust to normal vestibular signals in gravity. Astronauts require days or even weeks to regain their full sense of balance in gravity. This is problematic for missions to the Moon and Mars as poor balance may impair spacecraft evacuation or result in falls during extravehicular activities. While their vestibular system is dysfunctional, astronauts can use other sources of sensory information for maintaining balance in gravity. Indeed, research suggests that astronauts rely on somatosensory cues – derived from their sense of touch and body position – for maintaining stable upright stance following spaceflight. For example, the brain can use somatosensory information such as the angle of the ankle joint and the sensation of pressure between the foot sole and the ground to help maintain balance. If astronauts rely on somatosensory signals from the feet for maintaining balance after spaceflight, could enhancing those somatosensory signals improve their balance? The primary goal of my proposed study is to address this question. In this ground-based study, I will use a body weight support system to mimic gravity on the Moon and Mars. Participants will perform balance and walking tests in Earth's gravity, in simulated Moon gravity, and in simulated Mars gravity. During a subset of the tests, I will enhance somatosensory inputs from the feet using vibrating shoe insoles. I will test if insole vibration can improve stability while standing and walking in simulated partial gravity. The secondary goal of my proposed study is to characterize how reduced gravity and insole vibration change how the brain processes sensory inputs from the feet. I will measure the brain's response to foot sensory inputs using electroencephalography (EEG). The brain's response to sensory inputs will be measured in Earth gravity, simulated Moon gravity, and simulated Mars gravity, both with and without insole vibration. I will test if reductions in gravity alter how the brain processes sensory inputs from the feet. Moreover, I will assess if insole vibration augments the brain's response to sensory inputs from the feet. If insole vibration indeed enhances balance, locomotion, and the brain's sensory processing in simulated Moon and Martian gravity, this method of sensory enhancement will warrant further investigation. In addition to contributing to our fundamental understanding of the contribution of somatosensory inputs to human balance and locomotion, the findings of this research will test if insole vibration could be an effective countermeasure for post-flight balance and locomotor impairments for future deep space exploration missions.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	We have successfully developed vibrating insoles. Behavioral testing will determine if delivering subsensory insole vibration can speed up adaptation of balance and locomotor control after gravitational transitions (i.e., Earth to simulated Martian gravity, and from simulated Martian gravity back to Earth gravity). Behavioral tests and analyses will examine whether and how subsensory insole vibration impacts sensory reweighting once adapted to the different gravity levels. If we find that subsensory insole vibration is indeed effective in speeding up adaptation of balance and locomotor control following gravity transitions, insole vibration will warrant further investigation as a potential countermeasure for balance and locomotion impairments during future space travel. If effective, vibrating insoles could help improve crewmember performance shortly after landing on the Moon or Mars. Since this is a subsensory, imperceptible countermeasure, it would not imposing additional cognitive demands on astronauts. Vibrating insoles would be a small, light-weight, simple and cost-effective means of providing sensory augmentation during deep space exploration missions. Insoles and tactors are easily customizable, reusable, and could be easily integrated into the boots of existing spacesuits. Behavioral tests and analyses of sensory reweighting and following adaptation to different gravity levels will contribute to fundamental knowledge for future studies developing somatosensory and proprioceptive countermeasures for post-flight balance and locomotion impairments.
	1. PROJECT AIMS/OBJECTIVES: Original: Aim 1: Determine if insole vibration improves adaptation of postural stability during standing balance in simulated Mars gravity and during re-adaptation to Earth (1 g) gravity. Aim 2: Determine if insole vibration improves adaptation of stability during locomotion in simulated Mars gravity and during re-adaptation to Earth (1 g) gravity. Aim 3: Determine if adaptation to simulated Mars gravity alters early somatosensory processing of lower limb afferent inputs during upright stance. I will also test if changes in somatosensory cortical processing are associated with changes in balance and locomotion performance during adaptation to partial gravity. Aim 4: Determine if insole vibration during upright stance augments early cortical processing of lower limb somatosensory inputs. Update: Somatosensory evoked potentials (SEPs), collected using electroencephalogram (EEG), were intended to probe changes in early cortical processing of lower limb somatosensory inputs. We have been encountering noise issue with the EEG system in the lab. We can only acquire SEPs if everything in the lab is unplugged. When we plug in the treadmill and/or the tactors embedded in the insoles, the SEPs are just noise and unusable. We have purchased troubleshooting equipment, sought assistance from collaborators and other researchers in the department, reached out the EEG system company, and changed EEG systems. Nothing has been able to resolve the issue. Changing rooms is not feasible as we need at least 13-foot ceilings and exposed i-beams to hold the body weight system. It has not been feasible to collect SEPs in this study. Instead, I can adapt the study to use a subset of my existing EEG experimental setup (i.e., electrical stimulations applied to foot sensory nerves) and measure changes in subjects' perceptual sensitivity to lower limb sensory inputs. This can be done by gradually increasing the intensity of foot sensory nerve stimulation and having the subject report when they begin to detect stimulation. As indicated in the Main Findings section (b), this method examining perceptual changes to lower limb somatosensory inputs can be used to detect sensory changes associated with adaptation following gravitational transitions.

Task Progress:

Aim 1 (unchanged): Determine if insole vibration improves adaptation of postural stability during standing balance in simulated Mars gravity and during re-adaptation to Earth (1 g) gravity.

Aim 2 (unchanged): Determine if insole vibration improves adaptation of stability during locomotion in simulated Mars gravity and during re-adaptation to Earth (1 g) gravity.

Aim 3: Determine if adaptation to simulated Mars gravity alters subjects' perceptual sensitivity to lower limb afferent inputs during upright stance. I will also test if changes in somatosensory perceptual sensitivity are associated with changes in balance and locomotion performance during adaptation to partial gravity.

2. KEY FINDINGS

We have acquired pilot data from 1 pilot participant who was run through the experimental group protocol. Subsensory insole vibration was applied while the pilot participant adapted their balance and locomotor control to simulated Martian gravity (simulated using a body weight support system), and also while readapting to Earth gravity (i.e., no body weight supported). These preliminary findings are discussed in the Main Findings section. Briefly, we see:

a) Transient impairments in standing balance when reintroduced to Earth gravity after adapting to simulated Mars gravity.

b) Changes in subjects' perceptual sensitivity to sensory stimulation applied to the lower limbs in simulated Mars gravity, and during readaptation to Earth gravity. The pilot subject showed increased sensitivity to somatosensory inputs during the simulated Martian gravity condition. Then, immediately after transitioning back to Earth gravity condition, we see transient reductions in sensitivity followed by gradual increases in sensitivity throughout readaptation.

c) Changes in multi-sensory weighting after adapting to each of the 3 different gravity conditions, with down weighting of both proprioceptive and vestibular inputs and upweighting visual inputs after adaptation to simulated Martian gravity.

3. IMPACT

Additional data from both the experimental and control groups are required to test the study hypotheses, but these preliminary data show promise of balance adaptation, somatosensory perception changes, and multisensory reweighting.

4. PROPOSED RESEARCH PLAN FOR THE COMING YEAR

Progress in year 1:

- I learned to use the body weight support system and inertial measurement units.

- I hired and trained a research assistant, and obtained IRB approval for the study.

- I selected, ordered, and purchased all required equipment and troubleshooting supplies.

- I troubleshooted SEP collections as noted above, and have adapted the study as noted above.

- Institutional Review Board (IRB) amendments are in progress.

- I have collected pilot data and have preliminary data analysis protocols set in place.

Plans for year 2:

- Data collection will begin in August 2022.

- Data collection is anticipated to take approximately 4 months for all 24 participants.

- Following data collection, data analyses will be performed over 2 months.

- Findings of this study will be presented as the 2023 NASA Human Research Program (HRP) Investigators' Workshop (IWS) meeting, at the Society for Neural Control of Movement (NCM) meeting, and the International Society for Posture and Gait Research (ISPGR) meeting.

- Based on critical feedback from these meetings, I will begin to draft manuscripts for publication.

Bibliography Type:	Description: (Last Updated: 01/12/2023)
Awards	McGregor H. "Society for Neural Control of Movement (NCM) scholarship, July 2022." Jul-2022