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PI Name:	Wood, Scott J. Ph.D.		
Project Title:	Sensorimotor Predictors of Postlanding Functional Task Performance		
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Joint Agency Name:		**TechPort:**	No
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Human Research Program Risks:	(1) **Sensorimotor**:Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks		
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Comments:	NOTE: PI returned to NASA JSC in January 2017. PI was at Azusa Pacific University from August 2013 – January 2017; prior to August 2013, PI was at NASA JSC.		
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No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
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Flight Program:			
Flight Assignment:	NOTE: End date changed to 09/30/2024 per C. Ribeiro/HHC (Ed., 10/2/23) NOTE: End date changed to 09/30/2023 per PI (Ed., 7/7/21)		
Key Personnel Changes/Previous PI:	Drs. Bloomberg, Reschke and Feiveson have retired. Dr. Bloomberg and Reschke have continued as unpaid collaborators.		
COI Name (Institution):	Bloomberg, Jacob Ph.D. (NASA Johnson Space Center--Emeritus) Clark, Torin Ph.D. (University of Colorado Boulder, Aerospace Engineering Sciences) Koppelmans, Vincent Ph.D. (University of Utah) Oddsson, Lars Ph.D. (University of Minnesota) Peters, Brian Ph.D. (KBR/NASA Johnson Space Center) Reschke, Millard Ph.D. (NASA Johnson Space Center) Seidler, Rachael Ph.D. (University of Florida) Theriot, Corey Ph.D. (University of Texas Medical Branch)		
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Task Description:	Spaceflight drives adaptive changes in healthy individuals appropriate for sensorimotor function in a microgravity environment. These changes are maladaptive for return to earth's gravity. The inter-individual variability of sensorimotor decrements is striking, although poorly understood. The goal of this study is to identify a set of behavioral, neuroimaging and genetic measures that can be used to predict early post-flight performance on a set of sensorimotor tasks. Astronauts are being recruited who previously participated in sensorimotor field tests and/or posturography soon after long-duration spaceflight. Behavioral tests include assessments of sensory dependency and adaptability. Visual dependency involves treadmill walking while viewing a moving virtual visual scene. Vestibular sensitivity is measured while seated with eyes closed during lateral translations. Proprioception dependency is measured during one-legged stance with eyes closed on a horizontal air-bearing surface. Ground assessment of adaptability is performed (1) during treadmill walking with a virtual linear hallway and a moving walking surface, and (2) during multiple trials of navigating an obstacle course while wearing reversing prisms. The neuroimaging tests will characterize individual differences in regional brain volumes (using Structural MRI) and white matter microstructure (using Diffusion Tensor Imaging) to serve as potential predictors of adaptive capacity. The genetic tests will utilize saliva samples to examine variations in four genes chosen because of their ability to differentiate sensorimotor adaptation ability in a normative population, including Catechol-O-methyltransferase (COMT), Dopamine Receptor D2 (DRD2), Brain-derived neurotrophic factor (BDNF) and the a2-adrenergic receptor. A subjective survey was introduced to obtain ordinal measures of how sensorimotor adaptation impacted tasks both early inflight and postflight, and the general timeframe that movements were restricted. This study will utilize data (n=6 astronauts) from a previous Predictors study (PI Mulavara, grant NCC 9-58-SA03801). Deliverables: Statistical models will use combinations of behavioral metrics, brain structure metrics and genomic polymorphisms to understand individual decrements in post-flight functional task outcomes. We expect that understanding the relationships between these sensorimotor biomarkers and post-flight functional task performance will improve both our understanding of the individual variability and our strategy to optimize sensorimotor countermeasures. Study Participants: This study will target recruitment of up to 30 astronauts who previously flew on ISS, including 6 obtained via the original Predictors study. Risk Characterization, Quantification, Evidence: This project was directed toward the risk titled “Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks.” This study is addressing gaps SM-101 (risk characterization of postural control and locomotion) and SM-104 (evaluate weightlessness-induced changes in sensorimotor/vestibular function with changes in other brain functions). This study will help quantify inter-individual variability of sensorimotor decrements. Countermeasure, Prototype Hardware or Software: The information derived from this study may be applied towards optimizing countermeasures based on preflight tests of sensorimotor biomarkers.
Rationale for HRP Directed Research:	The proposed works qualifies for directed research under the "Highly Constrained Research" category in the Human Research Program (HRP) Unique Processes, Criteria, and Guidelines. This project will utilize the findings from two previous studies (SM Predictors-Ground, SM Predictors-Retrospective) that were funded by the NASA Human Research Program (HRP) through a National Space Biomedical Research Institute (NSBRI) cooperative agreement. These studies have validated, in a non-astronaut ground population, a unique set of measures that were predictive of adaptation in response to exposure to novel sensorimotor environments. Predictors were evaluated in three categories, including: 1) behavioral tests to assess sensory bias and adaptability; 2) imaging to determine individual brain morphological and functional features; and 3) genotype markers for genetic polymorphisms that play a role in the neural pathways underlying sensorimotor adaptation. These two studies were conducted to help characterize the sensorimotor risk profile and design sensorimotor adaptability training countermeasures that may be customized for each crewmember’s individual characteristics. In addition to collecting data from ground subjects, the SM Predictors-Retrospective study gathered data from six crewmembers, and from three subjects who participated in a bed rest campaign in the past. While these data supported the validity of the tested measures, the small number of subjects in this part of the study limited the interpretation of the collected data, and logistical challenges (namely, the end of the NSBRI cooperative agreement) precluded recruiting additional astronaut subjects until now. Meeting HRP’s goal of addressing gap SM 24 requires collection of data from additional crewmembers who fit the recruitment criteria for this study (crewmembers for whom functional task performance data sets exists after previous spaceflight missions). This proposed effort will thus build-upon the findings from the previous studies, with the full data set (from both the prior study and the proposed one) used to build predictive models of postflight functional task performance capabilities. Since this study directly builds upon the two prior studies and data needs to be collected seamlessly, it requires the specific expertise that has been developed within the NASA Johnson Space Center Neurosciences Laboratory. Therefore, the work reflects "focused and constrained data gathering and analysis that is more appropriately obtained through a non-competitive proposal."
Research Impact/Earth Benefits:	The goal of this study is to identify a set of behavioral, neuroimaging and genetic measures that can be used to better understand the inter-subject variability in early post-flight performance on a set of sensorimotor tasks. We expect that understanding the relationships between biomarkers and post-flight functional task performance will improve our strategy to optimize sensorimotor countermeasures. These same biomarkers may also be useful for understanding individual variability in balance function in the general population, and predicting sensory compensation associated with aging and/or the onset of vestibular disease.
	A total of 27 of 30 long-duration astronauts have participated in this study to date, including 6 from this past year. The 27 participants include 21M, 6F and 17 veterans, and 10 first-time flyers with mean age of 52.6 ± 6.6 years. Their International Space Station (ISS) missions were 178.6 ± 30.5 days, mean ± std, in duration. The majority of the subjects returned on Soyuz; however, the inclusion of crewmembers returning on SpaceX, including three added this past year, is being pursued to complete our recruitment goals. The behavioral and genetic measures have been obtained 3.6 ± 3.8 years, mean ± std, following their last missions. Post-flight Outcome Measures: Computerized dynamic posturography on R+0/1 was performed in 26 of 27 participants. Field testing (recovery from fall and tandem walk) was performed in 24 of 27 subjects, although not consistently at the same time points. For this preliminary analysis, we are using the time points that occur following return to Johnson Space Center (JSC) (referred to as R+0c), given these are available for most participants and more closely match when

the posturography measures have been made. All of these measures continue to demonstrate high intersubject variability that is characteristic of postflight sensorimotor responses. The posture Sensory Organization Tests (SOT) use a continuous equilibrium score ranging between 0 – 100, with higher numbers representing better performance. These scores on R+0c ranged between 38 – 94 (median 83) for SOT-5 and 5 – 90 (median 57) on SOT-5M. A difference score (post-flight - pre-flight performance) was calculated, with more negative values representing greater deficits in performance relative to each individual's preflight baseline. The range of SOT-5 (head erect) post-pre differences was 7 to -29 (median = -3.8), while the range of SOT-5M (head moving) was 6 to -83 (median = -19.4). Thus, the SOT-5M ratio scores are more variable given the timeframe of these measures (>R+24hrs) and may be more sensitive to vestibular contributions to standing balance. The recovery from fall (RFF) used time to stability in sec, with lower numbers representing better performance, resulting in a median of 8.6s (range 4.4 – 21.4 s) on R+0c. Difference scores were also calculated using preflight - postflight, so more negative values would also represent greater deficits in performance relative to each individual's preflight baseline. The median in differences at R+0c was -3.0 (range 1.7 to -9.1). For reference, the median difference score for recovery from fall at the landing site (R+0a) was -9.4 (range -0.6 to -15.6). The tandem walk was performed with eyes open (TW-EO), and eyes closed (TW-EC), and scored as percent of correct steps ranging from 0 to 100. Note that for eyes open, only one subject scored less than a perfect 100 on this task preflight. TW-EC was more challenging, with a preflight median of 88.8 % (range 50 – 100%). Since higher numbers represent better performance, these difference scores were calculated using post-flight - pre-flight performance so more negative values would continue to represent greater deficits in performance across all outcome measures. For eyes closed, the median in differences in correct steps at R+0c was -44.8 (range -11.1 to -97.0). For reference the median difference score for tandem walk eyes closed at R+0a was -77.2 (range -34.8 to -97.0). For eyes open, the median in differences at R+0c was -10.0 (range 0 to -100.0). For reference the median difference score for tandem walk eyes open at R+0a was -59.6 (range -12.5 to -100.0). Not surprising, tasks with eyes open tend to exhibit fewer decrements by R+0c since visual compensation is one means of dealing with the postflight vestibular disruption. The relatively poor correlation between these postflight measures may reflect differences in how crewmembers utilize visual compensation. For example, the difference scores for eyes closed SOT-5 and eyes open RFF were negatively correlated (rho = -0.48, p = 0.02) and differences scores between TW-EC and TW-EO were poorly correlated 0.28 (p = 0.21).

Subjective ratings of both inflight and postflight adaptation continue to be captured using a Qualtrics survey to supplement the objective ratings. For both early inflight and postflight periods, crewmembers were asked to rate how severely adaptation impacted their ability to perform functional tasks, from 0 being no impact to 4, representing severe impacts, including not attempting tasks and/or deliberate restriction of motion. Based on the limited sample of responses received to date (n = 17 of 27), 70% of crewmembers rated postflight impacts to task performance (median = 2, range 0 - 4) higher than inflight impacts (median = 1, range 0 - 3). A different question asked how long they restricted movements, from 0 = no impact or restriction of movements to 4 representing more than 3 days. Fourty-seven percent of crewmembers indicated they needed to restrict movements over a longer period postflight (median = 2, range 0 - 4) than inflight (median = 2, range 0 – 3) while only crewmembers reported restricting movements longer inflight. The survey also included open questions to capture what recommendations they had for enhancing adaptation based on their own experience, e.g., closing eyes during parachute opening, initially restricting then incrementally increasing movements, prophylactic medication, and allowing for sleep.

Task Progress:

Sensory Dependency Measures: Sensitivity to visual motion was measured during treadmill walking while viewing a moving (virtual hallway) visual scene. The dependent variable was lateral torso translation during scene oscillation (amplitude at 0.3 Hz scene motion). Vestibular sensitivity involves a perceptual direction-recognition task while seated with eyes closed during lateral translations. The dependent variables (threshold and bias) were derived from psychometric curve fit. The ability to balance using proprioception is assessed by monitoring medial-lateral center of pressure (COP) during a one-legged stance on a horizontal air-bearing surface (eyes open and eyes closed). Measures include both range and root mean square (RMS) COP of medial-lateral and anterior-posterior directions from the force plate. Based on the current data set, there do not appear to be any significant correlations of these single dependency measures with the postflight outcome measures. Future statistical analysis will explore combining these dependency measures with others to increase predictive power. For example, visual dependency during treadmill walking is significantly correlated with the adaptive Functional Mobility Test (aFMT) scores (rho = 0.4, p = 0.039), and therefore a combination of both measures may be a more robust measure of visual dependency.

Sensory Adaptability Measures: The Adaptive Functional Mobility Test (AFMT) measured the time to complete navigating an obstacle course while wearing up/down reversing prisms over 5 trials. While the performance continued to improve on average throughout the 5 trials, the variability in performance was greatest during the first trial (range 65 – 422 sec to complete the course). There was a clear adaptive change across trials and the time constant from a single exponential fit using all subjects was 1.4 trials. To capture adaptability over the 5 trials, we calculated a cumulative time-to-complete (cTTC) score. For two subjects with similar trial 1 TTC measures, a lower cumulative TTC will reflect the improved performance on later trials and is therefore interpreted as having greater adaptability. The trial 1 TTC and the cumulative TTC are highly correlated (rho 0.9, p<0.001), although we plan to use the cumulative TTC as our primary adaptability measure. Interestingly, based on the data collected to date, the cTTC is most negatively correlated with eyes closed conditions, e.g., posturography SOT-5 (rho = -0.41, p = 0.038) and the tandem walk (rho = -0.53, p = 0.009). Adaptability is also being assessed with the Treadmill Sensory Discordance Test. Changes in both stride frequency and reaction time to an auditory cue while walking with a virtual linear hallway on an oscillating treadmill are recorded after 1 and 4 minutes of walking on the oscillating treadmill. These scores are normalized with respect to the baseline walking period, with scores of 1 being equal to baseline performance and scores greater than 1 representing longer reaction time and higher stride frequency. On average, subjects tend to take 25% longer on the reaction time and walk with a 10% higher stride frequency during the initial minute of exposure to the sensory discordance. While both reaction time and stride frequency trend lower towards baseline over the 5 minute exposure, one would not necessarily expect a similar stride frequency as adopted without the surface perturbation. Therefore, increases in stride frequency relative to baseline are not necessarily maladaptive during the treadmill oscillation, and it is challenging to derive an "adaptability" metric from this data set.

Neuroimaging measures: Further neuroimaging analysis has been on hold pending the completion of all data collection. The preflight neuroimages to be used for this analysis have been obtained and will be processed in the coming year.

Genetic measures: Variations in four genes have been analyzed from saliva samples, including Catechol-O-methyltransferase (COMT), Dopamine Receptor D2 (DRD2), Brain-derived neurotrophic factor (BDNF), and the a2-adrenergic receptor. The distribution of the different alleles were within expected range. There does not appear to a clear pattern of alleles in any of the four genes that predict post-flight performance.

	Summary of Preliminary Findings: There is considerable variability among the post-flight performance outcomes for the 27 participants to date. Based on a partial sample using an ordinal scale survey, 70% indicated their ability to perform functional tasks was more impacted postflight relative to inflight with 50% indicating they needed to restrict movements for a longer period postflight relative to inflight. While there is a strong association within tests obtained at different R+0 timepoints, by R+24 hr performance on one post-flight test does not necessarily correlate with performance on other post-flight tests. There are apparent relationships between individual measures and specific post-flight outcome measures, e.g., the cumulative time to complete during the aFMT is negatively correlated with the pre-to-post-flight changes in tandem walking with eyes closed. Preliminary statistical analysis indicates combining biomarkers will increase predictive power and this will be explored with future analyses. Our preliminary findings underscore the importance of a comprehensive post-flight test battery including different types of tasks with varying sensory feedback. We expect that understanding the relationships between these sensorimotor biomarkers and post-flight functional task performance will improve both our understanding of the individual variability and our strategy to optimize sensorimotor countermeasures.
Bibliography Type:	Description: (Last Updated: 04/29/2024)
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