Fiscal Year:	FY 2023	**Task Last Updated:**	FY 11/02/2022
PI Name:	Clark, Torin K. Ph.D.		
Project Title:	A Non-Pharmacological Countermeasure Suite for Motion Sickness Induced by Post-Flight Water Landings		
Division Name:	Human Research		
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Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
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Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:	NOTE: PI moved to University of Colorado after NSBRI Postdoctoral Fellowship concluded in late 2015 (Ed., 9/1/17)		
Project Type:	Ground	**Solicitation / Funding Source:**	2019-2020 HERO 80JSC019N0001-HHCBPSR, OMNIBUS2: Human Health Countermeasures, Behavioral Performance, and Space Radiation-Appendix C; Omnibus2-Appendix D
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Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	November 2022 report: None.		
COI Name (Institution):	DiZio, Paul Ph.D. (Brandeis University) Lawson, Benton Ph.D. (Self) Oman, Charles Ph.D. (Massachusetts Institute of Technology)		
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Task Description:	To mitigate astronaut motion sickness during capsule water landings, we aim to assess the benefit of providing Earth-fixed, external visual references, and enabling active postural control to increase head and torso stability, in a series of ground-based laboratory experiments. Re-exposure to Earth gravity, combined with the passive motion of the capsule in the sea is expected to cause varying degrees of motion sickness in most astronauts. In our laboratory experiments, we will use sustained hyper-gravity centrifugation and a visual reorientation paradigm to mimic adaptive responses to gravity-transitions experienced by astronauts. Immediately following, we will use our motion simulators to expose subjects to passive motions relevant for those expected for a capsule at sea. With the standard Motion Sickness Questionnaire, we will first quantify the prevalence, severity, and time course of resulting motion sickness. Next, we will systematically evaluate approaches which have been reported, mostly anecdotally, to benefit terrestrial seasickness, theoretically by helping anticipate the incoming sensory information and reducing the resulting sensory conflict. This includes 1) providing external visual reference cues within the capsule and 2) requiring the subject to try to keep their head and/or torso upright during the passive simulated sea-motion. We hypothesize external visual references will help subjects anticipate inertial motion cues (e.g., vestibular) that are otherwise unpredictable in a closed capsule. Given the emerging relationship between posture and motion sickness, we hypothesize subjects with their head and torso unrestrained and required to maintain alignment with upright during the passive motion stimulation will again help reduce sensory conflict and thus mitigate motion sickness. While these approaches are anecdotally-promising and grounded in sensory conflict theory, they have not been systematically assessed for the scenario of post-flight water landings. Through our experimental evaluations, we will develop a better scientific understanding of the mechanisms of motion sickness induced by post-flight water landings. Our planned countermeasure approaches are readily implementable within the capsule (e.g., providing external visual cues with projection displays or virtual reality) and should have no side effects. In fact, we hypothesize our non-pharmaceutical approaches can lead to reduced dosages of anti-motion sickness medications (e.g., promethazine), which do have undesirable side effects. If successful, these approaches will have substantial significance in reducing astronaut motion sickness post-water landings, which can otherwise impair mission performance and egress.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	This project focuses on developing countermeasures to mitigate motion sickness experienced by astronauts during water landings post-flight. While our focus is on the unique combination of astronauts experiencing a gravity transition (microgravity to 1 Earth g) along with the passive motion of the capsule produced by ocean waves, our approaches are likely to translate well to terrestrial motion sickness scenarios (e.g., seasickness, carsickness). While terrestrial motion sickness does not include the gravity transition experienced by astronauts, the passive, ocean wave motion is similar to that which often causes some forms of terrestrial motion sickness. Thus, we anticipate that our most promising countermeasures may be effective in helping mitigate some forms of terrestrial motion sickness. To help assess this, we will perform testing with subject cohorts that are exposed to 1) the gravity transition analog, 2) the wave-like motion analog, and 3) the combination of both, which will help us disambiguate the relative contributions of each, but also evaluate the countermeasures during just wave-like motion without the gravity transition (which may be more applicable for terrestrial motion sickness). Since motion sickness is commonly experienced in cars, boats, airplanes, and other paradigms like virtual reality, countermeasures to mitigate motion sickness could have substantial terrestrial benefits.
	In Year 2 of this project, we have made substantial progress in our human subject evaluations at both experimental sites, as well as implementation steps towards future experiments. Programmatically, we have had intermittent virtual team meetings to discuss integrating project objectives, protocol choices, and planned analyses. The bulk of the effort has been on implementing, refining, and performing our human subject testing protocols to evaluate countermeasures effectiveness for mitigating motion sickness. We have also begun initial data visualization and analysis for these complex datasets. Further, we have made substantial progress in integrating hardware and software for later experimental efforts in Year 3. Finally, we have successfully onboarded new trainees, who are becoming/have become more familiar with this research domain. At the University of Colorado-Boulder, we have performed safety testing on two separate human-rated motion devices, enabling testing on real human subjects. We have safety tested the “wave-like” motion profiles on the Tilt-Translation Sled housed in our laboratory. These profiles are representative of buoy data near potential water landing sites in terms of frequency content, amplitudes, and coherence of tilt motion versus lateral translation. On our other device, the Human Eccentric Rotator Device (HERD), we have finished designing and now assembling a new centrifuge arm that positions the subject far off-axis in order to produce substantial and sustained centrifugal acceleration. We then performed a series of safety tests on this new hardware, spinning for our 1+ hour exposure of hyper-gravity, enacting the “sickness induced by centrifugation” (SIC) paradigm that mimics a gravity transition relevant for spaceflight. We iterated upon our design for how the participant was configured based upon pilot tests, transitioning from a “seated” posture to a “supine” or laying down posture, which we found to be more comfortable for participants during sustained x-axis centrifugation (i.e., “eyeballs in” g-forces). Next, we performed extensive preliminary testing for each of these paradigms in isolation. We tested 7 subjects that experienced just the “wave-like” motion, the Tilt-Translation Sled, in order to assess the propensity for our motion profile to induce motion sickness symptoms. This further allows us to capture the relative contribution toward motion sickness of the wave-like motion in isolation, as compared to conjointly with the SIC gravity transition analog paradigm. In summary, we found that while the majority of subjects were able to tolerate the entire wave-like motion exposure, the majority also experienced substantial levels of motion sickness. This is important to quantify as we proceed with evaluating countermeasures aimed to help mitigate/reduce motion sickness. This dataset will serve as a control condition for future experimental conditions. We then performed pilot testing with just the SIC gravity transition analog, as performed on our HERD human-rated motion device. We found in our pilot testing that the SIC paradigm was tolerable, and further, that immediately following, when the centrifuge was stopped, subjects reported illusory sensations, unsteadiness, and early symptoms of motion sickness (e.g., nausea). This is consistent with previous studies that have used the SIC paradigm on other centrifuges and suggests that we are able to mimic some of the motion sickness related to gravity transitions relevant for spaceflight. In one of our planned countermeasure conditions, we intend to provide congruent visual orientation cues to the subject during wave-like motion. The team decided to use a virtual reality head-mounted display to provide these cues, for ease of use in the laboratory, but also operational feasibility in a capsule (low mass, power, and volume). To do this in our experiments, we had to integrate our virtual reality headset into the Tilt-Translation Sled (including

Task Progress:	integration/modification with the head restraint). Previously, we developed and implemented software enhancements for the Tilt-Translation Sled to enable communication and provide motion information to the head mounted display programmed in Unity. In the last year, we have enhanced our implementation of the congruent visual cues in the virtual reality headset within the Tilt-Translation Sled. Specifically, our approach for driving the visual cues now allow for head-free motion within the Tilt-Translation Sled. This will be critically important for our “postural control” countermeasure condition, where the participant will be instructed to voluntarily move their head/body to remain aligned with perceived upright. These head/body movements are sensed in real-time and the visual cues in the virtual reality headset congruently depicts self-motion derived from both participant active head/body motions and wave-like whole-body passive motions. Finally, we preformed validation tests to confirm that the visual and inertial motion cues were precisely synchronized. Thus, we are now prepared to perform testing in each of our various countermeasure conditions (the control condition, visual cues, postural control, and the combination of both visual cues and postural control). With all of the technical implementation progress, we have proceeded with formal human subject testing of both the control condition and the visual cueing countermeasure condition. As of the time of writing this report, we have completed testing on 8 subjects (4 in the control condition and 4 in the visual cueing countermeasure condition). (We are testing 2-3 subjects per week, so our subject pool is changing rapidly). In brief, while subjects tend to become increasingly motion sick during the wave-like motion exposure, and then gradually recover after the wave-like motion ceases, the subjects which experience the visual cueing countermeasure appear to become less motion sick than subjects in the control group. Further, balance was substantially impaired in some of the control subjects after the wave-like motion but was unaffected in our subjects to date that were provided the visual cueing countermeasure. Pilot testing of additional countermeasure conditions is beginning. Specifically, we are exploring providing visual cues that are predictive of upcoming motions and their associated sensory signals. We hypothesize that this will enable the brain to produce between expectations of sensory cues, reducing sensory conflict and the associated motion sickness. Further, we are preparing to test the postural control countermeasure group, in which subjects are instructed to keep themselves upright, evoking postural control mechanisms that may be important for reducing motion sickness through active control. The Brandeis arm of this project employs a virtual rendition of the visual reorientation levitation illusion introduced by Howard (2000) to partially simulate orbital microgravity, and a six-degree-of-freedom Stewart motion platform to simulate a water landing sea state analog (heave ±42 cm centered on 0.17 Hz and roll ±10 degrees centered on 0.4 Hz). Pilot studies confirmed the validity of the microgravity (n=5) and sea state (n=5) analogs. Data collection is about 70% complete for three within-subject counterbalanced treatment conditions, with a target sample size of 15. All three sessions begin with the microgravity analog for 1 hour in which supine subjects make paced roll head movements in a fully articulated virtual room pitched back 90 degrees, followed by an immediate transition to the sea state analog of reorientation to the upright with head restraint and the onset of platform oscillation. For the next hour, subjects view either 1) a completely dark field (n=12), 2) a head-fixed single fixation point in a dark field (n=12), or 3) a virtual spatially stabilized horizon line (n=7). Motion sickness and anxiety self-ratings are prompted regularly through the entire session, and postural stability (stand on narrow beam eyes open/closed) is measured at the beginning and end. Preliminary statistics show the water landing simulation exacerbates motion sickness significantly more with a head-fixed target than in darkness.
Bibliography Type:	Description: (Last Updated: 11/26/2024)
Abstracts for Journals and Proceedings	Clark TK, Lonner T, Allred A, Drecksler S, Poole N, Oman CM, Lawson BD, Groen E, Lackner J, DiZio P "Development of a Countermeasure Suite for Motion Sickness Induced by Post-Flight Water Landings" 2022 NASA Human Research Program Investigator's Workshop, Virtual, February 7-11, 2022. Abstracts. 2022 NASA Human Research Program Investigators' Workshop, Virtual, February 7-11, 2020. , Feb-2022
Abstracts for Journals and Proceedings	Lonner TL and Clark TK "Evaluating Virtual Reality as a Countermeasure for Astronaut Motion Sickness during Post-Flight Water Landings" 2022 NASA Human Research Program Investigator's Workshop, Virtual, February 7-11, 2022. Abstracts. 2022 NASA Human Research Program Investigators' Workshop, Virtual, February 7-11, 2020., Feb-2022 , Feb-2022