Fiscal Year:	FY 2022	**Task Last Updated:**	FY 11/01/2021
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		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
Human Research Program Risks:	(1) **Sensorimotor**:Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks		
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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No. of PhD Candidates:	4	**No. of Master' Degrees:**	0
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	2	**Monitoring Center:**	NASA JSC
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Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	November 2021 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.
Task Progress:	In Year 1 of this project, we have made strides in several domains in preparation for our series of human subject experiments. First, Institutional Review Board (IRB) approvals have been obtained for the planned protocols at both Brandeis University and the University of Colorado-Boulder. This includes considerations for COVID-related safety protocols (at Brandeis the protocol is considered moderate risk with all potential hazards mitigated by appropriate safeguards). Second, the broader team has held a virtual kickoff meeting and intermittent virtual team meetings to discuss integrating project objectives, protocol choices, and planned analyses. Third, substantial progress has been made in integrating hardware and software and further defining our experimental protocols. Finally, we have successfully on-boarded new graduate students and post-doctoral fellows, who are becoming/have become more familiar with this research domain. At the University of Colorado-Boulder, we have developed and fully defined the “wave-like” motion profiles that we plan to use in our laboratory motion device (the Tilt-Translation Sled). Specifically, we analyzed representative buoy data near potential water landing sites, defining the frequency content, relative amplitudes, and coherence of tilt motion versus lateral translation. This informed developing a sum of sinusoids with 12 frequencies, each phase shifted, such that the motion is smooth, will appear random to the subject, and is representative of wave-like motion astronauts may experience in their capsule post-flight. These motion profiles have been implemented in the Tilt-Translation Sled, have undergone safety testing, and are approved for use with human subjects. 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 integration/modification with the head restraint). Further, we have developed and implemented software enhancements for the Tilt-Translation Sled to enable communication and provide motion information to the head mounted display through Unity, such that the visual orientation cues will be congruent with inertial motion. Finally, we as team, have refined our protocols for subjects reporting motion sickness using the Motion Sickness Questionnaire (i.e., the frequency of reporting, specific questions being asked, and protocol for operator-subject communication). Necessary improvements were made in the two-way auditory communication and visual monitoring systems within the Tilt-Translation Sled. With these updates, we have performed initial human subject pilot testing of the wave-like motion profiles, with the head mounted display, and the subject reporting motion sickness symptoms. In the remainder of the year, we intend to formally test a cohort of subjects in the control condition (no countermeasure). In addition, we have designed and begun implementation of a new structure for our Human Eccentric Rotator Device (HERD), which will enable the use of the hyper-gravity (e.g., 3gx) paradigm. This will serve as an analog for the gravity transition astronauts experience during return to Earth, and be performed prior to the wave-like motion on the Tilt-Translation Sled. In the coming months, we will complete construction and perform safety testing, in preparation for human subject testing. At Brandeis, the three proposed hardware elements have been fully prepared. The first is the subject chair which reclines

to orient the subject supine, to provide a visual reorientation illusion, while allowing Earth-horizontal plane head movements simulating the stimulus for space motion sickness. The chair can then quickly be reconfigured as an upright chair on a 6 DOF (degree of freedom) motion platform for the splashdown simulation configuration. The motion platform is the second hardware component ready for the project. The platform hydraulic servo control system has been tuned to follow the desired profiles of the load of the experimental equipment. The motion platform software is fully ready to provide a range of wave-like motions, which we are pilot testing for suitable provocativeness. We are assessing the provocativeness of a pattern consisting of a Rayleigh distribution of heave frequencies/amplitudes ranging from a 0.5 meter peak-to-peak at 0.1 Hz to 0.1 meter peak-to-peak at 1 Hz plus a phase-independent distribution of roll motion ranging from +/-15 degrees peak-to-peak at 0.1 Hz to +/-5 degrees peak-to-peak at 0.5 Hz. We hope to obtain feedback from the NASA Human Research Program about the best profile for simulating splashdown for further evaluation. The final hardware component that has been acquired and assembled is the head mounted display for creating virtual space flight and splashdown virtual environments. We have purchased an HVC VIVE Pro2 head mounted display system, because it has the capacity to track both the head motion relative to the 6 DOF platform and the platform motion relative to space, which are required for the space flight analog and splashdown analog environments, respectively. The tracking is currently operational and providing spatial compensation for a simple virtual visual scene. Our final software task is to create the virtual visual environments as well as the visual reference stimuli we propose to assess as motion sickness countermeasures.

While the beginning of the first year of this project has been dedicated to setting up equipment for our experiments, we are now prepared to begin our extensive human subject testing effort. Cohorts will be tested sequentially beginning with our control condition, adding the gravity transition analog, and then testing our countermeasure which provides congruent visual cues to help reduce sensory conflict.

Bibliography Type:	Description: (Last Updated: 12/01/2023)