Fiscal Year:	FY 2021	**Task Last Updated:**	FY 05/20/2021
PI Name:	Shelhamer, Mark Sc.D.		
Project Title:	Investigation of Partial-g Effects on Ocular Alignment		
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		
PI Email:	mshelhamer@jhu.edu	**Fax:**	FY
PI Organization Type:	UNIVERSITY	**Phone:**	410-614-5898
Organization Name:	Johns Hopkins University		
PI Address 1:	Otolaryngology - Head and Neck Surgery Department		
PI Address 2:	710 Ross Bldg, 733 N. Broadway		
PI Web Page:	https://		
City:	Baltimore	**State:**	MD
Zip Code:	21205-1832	**Congressional District:**	7
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2019 HERO 80JSC019N0001-FLAGSHIP & OMNIBUS: Human Research Program Crew Health. Appendix A&B
Start Date:	07/28/2020	**End Date:**	07/27/2022
No. of Post Docs:	1	**No. of PhD Degrees:**	
No. of PhD Candidates:	2	**No. of Master' Degrees:**	
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:	2	**Monitoring Center:**	NASA JSC
Contact Monitor:	Brocato, Becky	**Contact Phone:**	
Contact Email:	becky.brocato@nasa.gov		
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Schubert, Michael Ph.D. (Johns Hopkins University)		
Grant/Contract No.:	80NSSC20K1498		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	This project will provide information on binocular alignment as a measure of otolith asymmetry – more specifically as a measure of the neural compensation for asymmetry, which changes as a function of g level. This low-level function is easily and rapidly measured, and has been validated in vestibular patients and parabolic flight. The project draws on related Human Research Program (HRP) initiatives: Sensorimotor Assessment and Rehabilitation Apparatus (NNX10AO19G, 2010-2014) and Assessment of Otolith Function and Asymmetry as a Corollary to Critical Sensorimotor Performance in Missions of Various Durations (80NSSC19K0487, 2019-2027). Based on our previous studies, we anticipate a threshold of about 0.3 g, where there is a transition from ocular alignment that prevails in 1 g to that which is normal in 0 g (Karmali et al., J Vestibular Res 16:117-125, 2006). A subsequent model suggests a slightly higher (but not abrupt) transition at about 0.6 g (Beaton et al., Frontiers Syst Neurosci 9, 2015); thus, we predict a switching threshold in the range of 0.3 to 0.6 g.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The ability to evaluate vestibular (otolith) function, via simple and rapid testing with minimal apparatus, is useful in a variety of clinical settings. Clinical evaluation of our device and procedures is ongoing, for application to vestibular patients and military personnel with blast injuries.

Introduction (from grant proposal)
This project will provide information on binocular alignment as a measure of otolith asymmetry – more specifically as a measure of the neural compensation for asymmetry, which changes as a function of g level. This low-level function is easily and rapidly measured, and has been validated in vestibular patients and parabolic flight. The project draws on related Human Research Program (HRP) initiatives: Sensorimotor Assessment and Rehabilitation Apparatus (NNX10AO19G, 2010-2014), and Assessment of Otolith Function and Asymmetry as a Corollary to Critical Sensorimotor Performance in Missions of Various Durations (80NSSC19K0487, 2019-2027).

During g-level changes there are changes in torsional eye position, often markedly asymmetric. This change in torsional alignment is due to loss of compensation for otolith asymmetry in unusual g environments; normally the nervous system compensates for asymmetries in otolith properties, but in other than 1 g this compensation is inappropriate and yields torsional misalignment. Sudden changes in g level can also lead to differences in the vertical positions of the eyes. This is also thought to be a consequence of an asymmetry between the otolith organs, and has been demonstrated in our parabolic flight and laboratory studies.

In our assessment procedure, two line segments are presented on a computer display. The subject sees one segment with each eye, and adjusts them so that they appear to be aligned with each other (vertically or torsionally). Any actual misalignment of the segments reflects vertical or torsional skew of the eyes, which is a manifestation of uncompensated otolith asymmetry.

Background

Otolith asymmetry

During the g-level changes of parabolic flight there are changes in torsional eye position (Cheung et al. 1994). These changes can be markedly asymmetric (Markham & Diamond 1993, Markham et al. 2000) and are on the order of 1 deg. This change in torsional alignment may be due to loss of compensation for otolith asymmetry in unusual g environments; on Earth, the nervous system presumably compensates for natural asymmetries (e.g., unequal otoconial mass) in otolith properties (von Baumgarten & Thumler 1979), but in other than 1 g this compensation is inappropriate and produces torsional misalignment. A similar disconjugate change has been found during space flight (Diamond & Markham 1998), persisting throughout flights up to 180 days and for many days after flight. Torsional offsets seen in parabolic flight have been proposed as a predictive test for space motion sickness (Diamond & Markham 1991, Markham & Diamond 1993). Motion sickness in parabolic flight has likewise been correlated with differences in counterrolling with tilts to the right and left (Lackner et al. 1987); this is intriguing because it implies a link between motion sickness susceptibility in parabolic flight and in space flight, while other studies have not been able to establish this connection (Oman et al. 1986). More recently, a connection between such vestibular asymmetry and terrestrial motion sickness has also been postulated (Neupane et al. 2018).

Central neural compensation for such asymmetry becomes inappropriate in gravity fields other than 1 g, leading to potentially disruptive changes in ocular alignment (Karmali 2007). A mathematical model of the central compensating mechanisms for otolith asymmetry has been developed based on our findings in parabolic flight (Beaton et al. 2015a).

Vertical ocular alignment

Sudden changes in g level can also lead to small differences in the vertical positions of the two eyes, which can result in double vision (diplopia). This is also thought to be a consequence of asymmetry between the otolith organs on each side of the head, and has been demonstrated repeatedly in our parabolic flight and laboratory studies (Karmali et al. 2006, Karmali 2007). The effect is small but distracting, and would likely occur simultaneous with maximum piloting workload. We have quantified this g-related skew and resulting diplopia, and their adaptation, in parabolic flight (Beaton et al. 2017a).

Hypothesis

Based on our previous studies we anticipate a threshold of about 0.3 g between the response (binocular alignment) present in 1 g and that present in 0g, for a given subject (Karmali et al. 2006). A mathematical model suggests a slightly higher (not as abrupt) transition at about 0.6 g (Beaton et al. 2015a), Thus we predict a switching threshold in the range of 0.3 to 0.6 g.

Specific Aims

1. Evaluate modifications that permit use of our tablet-computer system in ambient lighting (current version requires darkness to eliminate binocular alignment cues).

2. Assess binocular alignment (vertical and torsional skew) in different g levels of parabolic flight.

3. Determine the nature of the function that relates the sensorimotor response of binocular alignment to instantaneous g level: continuous (with what slope) or piecewise-linear (with a threshold).

Task Progress:

References

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Progress since July 2020

This project is in the definition phase. Parabolic flights are tentatively planned for the fall of 2021. The study protocol has been submitted to the NASA Institutional Review Board (IRB) and is under review. A Reliance Agreement has been agreed to by Johns Hopkins University (JHU), to cede authority to the NASA IRB.

Most of the work in the initial grant period has been dedicated to refining our apparatus and procedures (Beaton et al. 2017b) for use in parabolic flight. One concern is that the tablet-computer version of the experiment requires complete darkness, in order for the subject to not see the edges of the computer screen, or other cues, for ocular alignment. In previous parabolic flights we used large shrouds that enclosed the subject's head along with the computer. This is viable but unwieldy, and can be uncomfortable. Hence, a team of students has been investigating two alternatives:

1. Optical magnification with a headset, so that the tablet-computer screen fills the entire field of vision, and peripheral cues are masked or distorted (and hence rendered unusable for ocular alignment).

2. Virtual reality (VR) implementation on an Oculus Quest, which has been completed and undergone initial testing in a clinical setting.

Analysis of the benefits and disadvantages of each implementation reveals the following:

Magnifiers - Pros: Compatible with existing VANTAN tablet technology; Data saved automatically; Adjustable magnification levels; Cheap, lightweight; Wireless; Less training required (don't need to learn VR control system); Can set up easily and quickly

Magnifiers - Cons: Have to hold tablet or velcro to wall; Some discrepancies between tests with prototype lenses vs. regular glasses; Varying degree of comfort; Somewhat unstable

VR - Pros: Software already developed, ready to use; Headset is comfortable and has only minor light leakage; Software is fast and intuitive

VR - Cons: Small light leakage ; May need to be plugged into laptop during trial to save data ; Software automatically exits after trial, needs to be restarted; Lines are not connected to each other; Headset can be uncomfortable with glasses; Takes time to set up; Multiple hardware components

A comparison of vertical-alignment results (VAN) between the original implementation (tablet-computer in darkness) and the magnifier implementation, for four subjects, shows that there are discrepancies, including much larger variability with the magnifier system.

Work in the next grant period will further investigate these two implementations. We are beginning to favor the VR implementation, which would require the following:

	• Reduction of light leakage; • Improvement of user interface (starting/stopping trials, entering user ID); • Moving stimulus line segments closer to each other; • Verifying compatibility with parabolic flight; • Checking for interference between multiple devices used in close proximity.
Bibliography Type:	Description: (Last Updated: 12/05/2024)