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| <b>Fiscal Year:</b>                               | FY 2023  | <b>Task Last Updated:</b>             | FY 06/29/2023  |
| <b>PI Name:</b>                                   | Tavakkoli, Alireza Ph.D.   |                                       |  |
| <b>Project Title:</b>                             | A Non-intrusive Ocular Monitoring Framework to Model Ocular Structure and Functional Changes due to Long-term Spaceflight                          |                                       |  |
| <b>Division Name:</b>                             | Human Research   |                                       |  |
| <b>Program/Discipline:</b>                        |  |                                       |  |
| <b>Program/Discipline--Element/Subdiscipline:</b> |  |                                       |  |
| <b>Joint Agency Name:</b>                         | <b>TechPort:</b>   | Yes                                   |  |
| <b>Human Research Program Elements:</b>           | (1) <b>HHC:</b> Human Health Countermeasures   |                                       |  |
| <b>Human Research Program Risks:</b>              | (1) <b>SANS:</b> Risk of Spaceflight Associated Neuro-ocular Syndrome (SANS)   |                                       |  |
| <b>Space Biology Element:</b>                     | None   |                                       |  |
| <b>Space Biology Cross-Element Discipline:</b>    | None   |                                       |  |
| <b>Space Biology Special Category:</b>            | None   |                                       |  |
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| <b>Zip Code:</b>                                  | 89557-0001   | <b>Congressional District:</b>        | 2  |
| <b>Comments:</b>                                  |  |                                       |  |
| <b>Project Type:</b>                              | GROUND   | <b>Solicitation / Funding Source:</b> | 2019 HERO 80JSC019N0001-FLAGSHIP & OMNIBUS: Human Research Program Crew Health. Appendix A&B |
| <b>Start Date:</b>                                | 08/27/2020   | <b>End Date:</b>                      | 02/28/2023   |
| <b>No. of Post Docs:</b>                          | 0  | <b>No. of PhD Degrees:</b>            | 1  |
| <b>No. of PhD Candidates:</b>                     | 2  | <b>No. of Master' Degrees:</b>        | 3  |
| <b>No. of Master's Candidates:</b>                | 2  | <b>No. of Bachelor's Degrees:</b>     | 0  |
| <b>No. of Bachelor's Candidates:</b>              | 0  | <b>Monitoring Center:</b>             | NASA JSC   |
| <b>Contact Monitor:</b>                           | Stenger, Michael   | <b>Contact Phone:</b>                 | 281-483-1311   |
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| <b>Flight Program:</b>                            |  |                                       |  |
| <b>Flight Assignment:</b>                         | NOTE: End date changed to 02/28/2023 per C. Ribeiro/JSC (Ed., 6/2/22)<br>NOTE: End date changed to 08/26/2022 per NSSC information. (Ed. 10/26/21) |                                       |  |
| <b>Key Personnel Changes/Previous PI:</b>         | N/A  |                                       |  |
| <b>COI Name (Institution):</b>                    | Webster, Michael Ph.D. ( University of Nevada, Reno )  |                                       |  |
| <b>Grant/Contract No.:</b>                        | 80NSSC20K1831  |                                       |  |
| <b>Performance Goal No.:</b>                      |  |                                       |  |
| <b>Performance Goal Text:</b>                     |  |                                       |  |

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|  | <p>Unique neuro-ocular structural and functional changes affect a subset of astronauts who have completed prolonged spaceflight missions and due to its unique pathology, a new case definition was proposed and the condition was renamed Spaceflight Associated Neuro-ocular Syndrome (SANS). In this project we investigate two interconnected computational frameworks to develop a diagnostic system as well as a mapping mechanism to assist NASA scientists and clinical experts to more comprehensively study the SANS phenomenon and predict the risk of its development in prolonged spaceflight. Therefore, the first aim (Aim 1) of this project is to develop novel computational tools to establish mappings between the observed ocular structure and visual function, pre-, in-, and post-flight, in order to provide NASA scientists and clinicians with better means to investigate SANS etiology and its progression. The second aim (Aim 2) of this project is to integrate Contrast Sensitivity (CS), Visual Fields (VF), and our novel distortion assessment mechanism into a validated and compact diagnostic tool to better measure ocular function (SANS 301 : Laboratory development of mechanical countermeasures).</p> <p>We will focus our efforts in each aim on a sub-set of functionalities that allow for the establishment of the interconnected computational framework enabling the pursuit of long-term research to predict the risk of development of SANS and monitor its progression.</p> <p>Omnibus Aim 1: Structure-Function Mapping</p> <p>Research Task-1.1: Design a novel mapping between Optical Coherence Tomography (OCT), Magnetic Resonance Imaging (MRI), Contrast Sensitivity (CS), and Visual Fields (VF) perimetry.</p> <p>Research Task-1.2: Conduct studies on retrospective data from NASA Lifetime Surveillance of Astronaut Health (LSAH) and Life Sciences Data Archive (LSDA) on the three populations (astronauts, head-down-tilt bed rest, and idiopathic intracranial hypertension (IIH)) patient.</p> <p>These findings will be significant in two ways:</p> <ol style="list-style-type: none"> <li>(1) They will allow us to predict measures within a smaller sample set, if a larger analog sample set has known structure-function maps.</li> <li>(2) They will enable us to design predictive mechanisms to study disease progression both in astronauts and in terrestrial analogs terrestrial analogs.</li> </ol> <p>Expected Outcomes: (1.i) understanding how OCT/MRI correlates with VF, (1.ii) translational parametrization of mappings across cohorts, and (1.iii) ability to predict the risk of development of SANS and monitor its progression by utilizing the proposed mappings.</p> <p>Omnibus Aim 2: Address SANS 301 Knowledge Gap</p> <p>Research Task-2.1: Integrate VF and CS assessments into a VR-mediated framework.</p> <p>Research Task-2.2: Validate VR-based VF/CS on the terrestrial analog populations.</p> <p>Expected Outcomes: (2.i) a novel Virtual Reality (VR)-based VF/CS assessment and (2.ii) a compact diagnostic tool.</p>  |
| <p><b>Rationale for HRP Directed Research:</b></p> <p><b>Research Impact/Earth Benefits:</b></p> | <p>During the previous year of the project, our team has made contributions on the two aims as follows:</p> <p>Aim 1- The first aim (Aim 1) of this project is to develop novel computational tools to establish mappings between the observed ocular structure and visual function, pre-, in-, and post-flight, in order to provide NASA scientists and clinicians with better means to investigate SANS etiology and its progression (SANS 1).</p> <p>Contributions: 1- Design a novel mapping between OCT, MRI, CS, and VF. 2- Conduct studies on retrospective data from NASA Lifetime Surveillance of Astronaut Health (LSAH) and Life Sciences Data Archive (LSDA) on the three populations.</p> <p>Technical Details: In order to establish a comprehensive mapping between different ophthalmic domains we started by designing a conditional generative adversarial network (GAN) to map across the publicly available data we had at our disposal, i.e., fluorescein angiography (FA) and fundus photographs. The GAN comprises of two generator modules and four discriminator modules to take fundus photographs and produce anatomically accurate FA images inferred from the fundus images.</p> <p>Impact: We have shown novel deep architectures in ophthalmic applications could improve diagnostic accuracy, that attention maps can improve transferability of learned models across datasets, and deep architectures could effectively extract shared feature representations across ophthalmic image modalities to translate from one domain to another. These discoveries have paved the way for our team to tackle the main problem of mapping between the domain of ocular structure to the visual function.</p> <p>Significance: (1) Understanding how ocular structure correlates with visual function. (2) Parametrization of mappings. (3) Predict the risk of SANS.</p> <p>Aim 2- The second aim (Aim 2) of this project is to integrate CS, VF, and our novel distortion assessment mechanism into a validated and compact diagnostic tool to better measure ocular function (SANS 3).</p> <p>Contributions: 1- Integrate VF/CS assessments into a VR-mediated framework. 2- Validate VR-based VF/CS on the terrestrial analog populations.</p> <p>Technical Details: We present a methodology that comprises a calibration step, four different visual function tests that measure different aspects of user perception, and then a composite pipeline that simulates the modeled deficits for validation. In order to properly utilize the virtual assessment, the environment would need to be calibrated at the beginning of each session. Simple calibrations such as adjusting lens distance, interpupillary distance, and headset adjustments are done at the start. After these adjustments, the fixation and tracking capabilities of the eyes are tested, first binocularly and then monocularly. These performance metrics are saved alongside the user demography information. After the calibration phase, the user's visual assessment can commence. Visual acuity (VA), contrast sensitivity (CS), and visual distortions are assessed through a variety of procedures. For VA, binocular distant VA as</p> |

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|  | <p>well as dynamic VA is measured under mesopic (natural light) conditions. Instead of using images of conventional charts, we render individual characters in front of the user at predetermined distances and scale it based on user response. The results are reported in logMAR scale among others. The contrast sensitivity is measured using gabor patches as stimuli. In this test, the user gaze follows a gabor patch that alters its contrast and spatial frequency based on user performance. At the end, the contrast sensitivity expressed in logCS among other contrast sensitivity units. The amsler grid test is adapted to VR to measure the perceptual distortions in age-related macular degeneration (AMD) patients. At the start of the exam, the amsler grid is displayed in front of both eyes. While looking at a fixation point in grid, if the straight grid lines appear to be distorted the user emulates the metamorphopsia of the deficient eye on the healthy eye. This grid manipulation is modeled as a gaussian mixture of different scotoma parameters. The results are reported as the image of the altered amsler grid.</p> <p>Impact: In addition, we have developed a new approach mediated by advances in virtual reality (VR) for better assessment of metamorphopsia to enable remote monitoring of the progression of AMD \cite{zaman2020mixed}. These findings in conjunction with the findings of Aim 1 motivate and inform the objectives of this project, by allowing our team to maintain a correspondence between how the ocular structural changes could impact visual function assessments.</p> <p>Significance: (1) A novel VR-based VF/CS assessment. (2) A compact diagnostic tool.</p> |
| Task Progress:                         | <p>We have shown novel deep architectures in ophthalmic applications could improve diagnostic accuracy, that attention maps can improve transferability of learned models across datasets, that generative models are effective in segmenting certain anatomical features from ophthalmic images, and that deep architectures could effectively extract shared feature representations across ophthalmic image modalities to translate from one domain to another. These discoveries have paved the way for our team to tackle the main problem of mapping between the domain of ocular structure to the visual function.</p> <p>In addition, we have developed a new approach mediated by advances in virtual reality (VR) for better assessment of metamorphopsia to enable remote monitoring of the progression of age-related macular degeneration (AMD). In addition, we have developed several techniques to evaluate other visual functions including gravitational transition visual effects, multi-modal function, and visual acuity, as well as other effects of microgravity on the human body. These findings in conjunction with the findings of Aim 1 motivate and inform the objectives of this project, by allowing our team to maintain a correspondence between how the ocular structural changes could impact visual function assessments.</p>   |
| Bibliography Type:                     | Description: (Last Updated: 04/25/2024)   |
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| Articles in Peer-reviewed Journals     | <p>Waisberg E, Ong J, Masalkhi M, Zaman N, Kamran SA, Sarker P, Lee AG, Tavakkoli A. "Generative Pre-Trained Transformers (GPT) and space health: A potential frontier in astronaut health during exploration missions." Prehosp Disaster Med. 2023 Jun 2;1-5. <a href="https://doi.org/10.1017/S1049023X23005848">https://doi.org/10.1017/S1049023X23005848</a> ; PubMed PMID: 37264946 , Jun-2023</p>   |
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