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| **Fiscal Year:** | FY 2021 | **Task Last Updated:** | FY 02/25/2021 |
| **PI Name:** | Gao, Wei Ph.D. | | |
| **Project Title:** | A Multimodal Wearable System for Deep Space Monitoring of Stress and Anxiety | | |
| **Division Name:** | Human Research | | |
| **Program/Discipline:** | | | |
| **Program/Discipline--Element/Subdiscipline:** | TRISH--TRISH | | |
| **Joint Agency Name:** | | **TechPort:** | Yes |
| **Human Research Program Elements:** | None | | |
| **Human Research Program Risks:** | None | | |
| **Space Biology Element:** | None | | |
| **Space Biology Cross-Element Discipline:** | None | | |
| **Space Biology Special Category:** | None | | |
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| **Zip Code:** | 91125 | **Congressional District:** | 27 |
| **Comments:** | | | |
| **Project Type:** | GROUND | **Solicitation / Funding Source:** | 2020 TRISH BRASH1901: Translational Research Institute for Space Health (TRISH) Biomedical Research Advances for Space Health |
| **Start Date:** | 04/01/2020 | **End Date:** | 03/31/2022 |
| **No. of Post Docs:** | 1 | **No. of PhD Degrees:** | 0 |
| **No. of PhD Candidates:** | 2 | **No. of Master' Degrees:** | 0 |
| **No. of Master's Candidates:** | 0 | **No. of Bachelor's Degrees:** | 0 |
| **No. of Bachelor's Candidates:** | 0 | **Monitoring Center:** | TRISH |
| **Contact Monitor:** | | **Contact Phone:** | |
| **Contact Email:** | | | |
| **Flight Program:** | | | |
| **Flight Assignment:** | | | |
| **Key Personnel Changes/Previous PI:** | | | |
| **COI Name (Institution):** | Yue, Yisong Ph.D. ( California Institute of Technology ) | | |
| **Grant/Contract No.:** | NNX16AO69A-T0501 | | |
| **Performance Goal No.:** | | | |
| **Performance Goal Text:** | | | |

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| **Task Description:** | The goal of this project is to develop a holistic hardware/software solution based on a multimodal wearable sensing platform to achieve dynamic deep space stress and anxiety assessment. Sweat could serve as an excellent candidate for non-invasive stress response monitoring as it contains rich physiological information. The hypothesis is that sweat analyte levels monitored continuously along with the key vital signs, when coupled with machine learning approach, will provide accurate and dynamic stress and anxiety assessment. The approach is to simultaneously monitor the molecular analytes in human sweat including stress hormones (i.e., cortisol, adrenaline, and noradrenaline), glucose, lactate, sodium, potassium, pH, sweat rate, and key vital signs (i.e., skin temperature, blood pressure, heart rate, and heart rate viability) using the wearable multimodal sensing platform. Based on a combination of the physical/molecular data and machine learning model, a more comprehensive stress assessment system with significantly higher accuracy and robustness can be achieved. |
| **Rationale for HRP Directed Research:** | |
| **Research Impact/Earth Benefits:** | Despite the urgent need for the real-time monitoring of stress, current approaches for stress assessment are largely limited to questionnaire-based scales or self-reported measures, which can be very subjective and cumbersome to implement in the space. To our knowledge, this work will be the first dynamic stress assessment using a single wearable sensing patch to continuously collect both physical vital signals and molecular data from the human body. While most other designs target single, specific sensing modalities, the proposed platform is explicitly multimodal with capabilities to simultaneously monitor glucose, lactate, Na+, K+, pH, stress hormones, sweat rate, pulse waveform, and skin temperature, with opportunities in future research to incorporate many more modalities. Large data sets of molecular data collection from human trials coupled with modern machine-learning model approaches will generate an optimal algorithm to assess stress levels dynamically. Such non-invasive dynamic multimodal monitoring technology also enables numerous other fundamental investigations to address the performance, mental health, and protection of astronauts in deep space environments.<br>As COVID-19 became a major challenge for us over the past year, the SARS-CoV-2 RapidPlex, developed based on target-specific immunoassays built off laser-engraved graphene, could be used for rapid and remote assessment of COVID-19 biomarkers (i.e., nucleocapsid protein, anti-spike protein IgG and IgM, and C-reactive protein). The SARS-CoV-2 RapidPlex has the potential to quickly and effectively triage patients and track infection progression, allowing for the clear identification of individuals who are infectious, vulnerable, and/or immune. Modification of our platform design may allow for rapid viral antigen and antibody panel testing such that COVID-19 infection could be clearly distinguished from non-specific symptoms of seasonal respiratory infections such as influenza. Additionally, the wireless telemedicine diagnostic platform, when coupled with emerging wearable biosensors to continuously monitor vital signs and other chemical biomarkers, could provide comprehensive information on an individual's health status during the COVID-19 pandemic. |
| **Task Progress:** | The original goal of this project is to develop a holistic hardware/software solution based on a multimodal wearable sensing platform to achieve dynamic deep space stress and anxiety assessment. Sweat could serve as an excellent candidate for non-invasive stress response monitoring as it contains rich physiological information. The hypothesis is that sweat analyte levels monitored continuously along with the key vital signs, when coupled with machine learning approaches, will provide accurate and dynamic stress and anxiety assessment.<br>During Year 1, we have successfully developed most of the individual sensors with high performance (including glucose, lactate, Na, K, pH, blood pulse wave, temperature, galvanic skin response (GSR)) for continuous monitoring. With materials and chemistry innovation, we have made major progress to improve the long term stability of our wearable chemical sensors (most of these sensors now have stable performance during multiple-day in vitro operation). We also developed a portable cortisol sensor for rapid stress hormone analysis in human sweat. Our engineering development in Year 1 paves the way for an integrated multimodal system and now we have integrated all these sensors into one multimodal wearable system for physical and chemical sensing on human subjects. We are trying to simultaneously monitor the molecular analytes in human sweat including stress hormone, glucose, lactate, sodium, potassium, pH, and key vital signs (i.e., skin temperature, pulse wave, GSR) using this wearable multimodal sensing platform. In the coming year, we plan to mainly focus on system validation and human studies -- evaluating the multimodal sensor performance in human subjects under different stressors and we will use machine learning to classify the stress levels based on the data collected. Based on a combination of the physical/molecular data and machine learning model, we anticipated that a more comprehensive stress assessment system with significantly higher accuracy and robustness can be achieved.<br><br>As COVID-19 became a major challenge for us over the past year, we have also developed, partially supported by the Translational Research Institute for Space Health (TRISH), an ultrasensitive and low-cost telemedicine platform, the SARS-CoV-2 RapidPlex, based on target-specific immunoassays built off laser-engraved graphene for rapid and remote assessment of COVID-19 biomarkers (i.e., nucleocapsid protein, anti-spike protein IgG and IgM, and C-reactive protein). We successfully demonstrated the platform's applicability using COVID-19-positive and COVID-19-negative serum and saliva samples. The SARS-CoV-2 RapidPlex has the potential to quickly and effectively triage patients and track infection progression, allowing for the clear identification of individuals who are infectious, vulnerable, and/or immune. |
| **Bibliography Type:** | Description: (Last Updated: 07/11/2023) |
| **Articles in Peer-reviewed Journals** | Lukas H, Xu C, Yu Y, Gao W. "Emerging telemedicine tools for remote COVID-19 diagnosis, monitoring, and management." ACS Nano. 2020 Dec 22;14(12):16180-93. https://doi.org/10.1021/acsnano.0c08494 ; PMID: 33314910; PMCID: PMC7754783 , Dec-2020 |
| **Articles in Peer-reviewed Journals** | Min J, Sempionatto JR, Teymourian H, Wang J, Gao W. "Wearable electrochemical biosensors in North America." Biosens Bioelectron. 2021 Jan 15;172:112750. Epub 2020 Oct 26. https://doi.org/10.1016/j.bios.2020.112750 ; PMID: 33129072 , Jan-2021 |

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| **Articles in Peer-reviewed Journals** | Song Y, Min J, Yu Y, Wang H, Yang Y, Zhang H, Gao W. "Wireless battery-free wearable sweat sensor powered by human motion." Sci Adv. 2020 Sep 30;6(40):eaay9842. https://doi.org/10.1126/sciadv.aay9842 ; PMID: 32998888; PMCID: PMC7527225 , Sep-2020 |
| **Articles in Peer-reviewed Journals** | Torrente-Rodríguez RM, Lukas H, Tu J, Min J, Yang Y, Xu C, Rossiter HB, Gao W. "SARS-CoV-2 RapidPlex: A graphene-based multiplexed telemedicine platform for rapid and low-cost COVID-19 diagnosis and monitoring." Matter. 2020 Dec 2;3(6):1981-98. Epub 2020 Oct 5. https://doi.org/10.1016/j.matt.2020.09.027 ; PMID: 33043291; PMCID: PMC7535803 , Dec-2020 |
| **Awards** | Gao W. "American Chemical Society Nano Rising Star Lecture, May 2020." May-2020 |
| **Awards** | Gao W. "Biocom Life Science Catalyst Award, December 2020." Dec-2020 |
| **Awards** | Gao W. "Chemical Society Review 2020 Emerging Investigator, June 2020." Jun-2020 |
| **Awards** | Gao W. "Highly Cited Researcher 2020 by Clarivate Web of Science, December 2020." Dec-2020 |
| **Awards** | Gao W. "Institute of Electrical and Electronics Engineers (IEEE) Engineering in Medicine & Biology Society Early Career Achievement Award, June 2020." Jun-2020 |
| **Awards** | Gao W. "Institute of Electrical and Electronics Engineers (IEEE) Senior Member, August 2020." Aug-2020 |
| **Awards** | Gao W. "MINE 2020 Young Scientist Award (by Microsystems & Nanoengineering), July 2020." Jul-2020 |
| **Awards** | Gao W. "World Economic Forum Young Scientist, May 2020." May-2020 |