Fiscal Year:	FY 2020	**Task Last Updated:**	FY 01/04/2021
PI Name:	Kozlowski, Steve Ph.D.		
Project Title:	Team Cohesion Monitoring Badge: Development of Galvanic Skin Resistance Modality		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **Team**:Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	33620	**Congressional District:**	12
Comments:	I moved from Michigan State University to the University of South Florida in August 2020.		
Project Type:	Ground	**Solicitation / Funding Source:**	2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus
Start Date:	08/25/2016	**End Date:**	07/31/2020
No. of Post Docs:	0	**No. of PhD Degrees:**	1
No. of PhD Candidates:	1	**No. of Master' Degrees:**	2
No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Williams, Thomas	**Contact Phone:**	281-483-8773
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Flight Program:			
Flight Assignment:	NOTE: Changed end date to 7/31/2020 per D. Risin/JSC (Ed., 5/27/2020) NOTE: New end date is 5/15/2020 per L. Juliette/HRP (Ed., 2/19/2020) NOTE: New end date is 12/31/2019 per NSSC information (Ed., 5/29/19) NOTE: New end date is 12/31/2018 per NSSC information (Ed., 3/14/18) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/18/17)		
Key Personnel Changes/Previous PI:	June 2017 report: Co-Investigator Chu-Hsiang (Daisy) Chang's leave assignment to serve as NSF Science of Organizations Program Officer has been extended an additional year. August 2016 report: Co-Investigator Chu-Hsiang (Daisy) Chang started a one-year leave in July 2016 to assume the role of NSF (National Science Foundation) Science of Organizations Program Officer.		

COI Name (Institution):	Biswas, Subir Ph.D. (Michigan State University) Chang, Chu-Hsiang Ph.D. (Michigan State University)
Grant/Contract No.:	NNX16AR52G
Performance Goal No.:	
Performance Goal Text:	
Task Description:	This proposal is for ground-based, technology development research designed to address: PRD (Program Requirements Document) Risk: Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team. IRP (Integrated Research Program) Gap – Team2: We need to identify a set of validated measures, based on the key indicators of team function, to effectively monitor and measure team health and performance fluctuations during autonomous, long duration, and/or distance exploration missions. Collaboration, cooperation, and coordination are essential underpinnings of effective teamwork. This is especially the case for “high reliability” action teams, such as long duration space flight crews, that will have to perform in isolated, confined, and extreme environments. For such teams, effective teamwork is critical for minimizing errors and supporting team performance, and it is reflective of good psycho-social adaptation by the team to the rigors and stresses of long duration space missions. In previous research, the project team developed a team interaction sensor (TIS) technology platform – a wearable body sensor array – that assesses the frequency, duration, and quality of collaborative interactions between team members as they work together to accomplish team tasks, as well as physiological metrics (i.e., heart rate [HR]; heart rate variability [HRV]). That prior research demonstrated that the high frequency interaction data streamed by the badges is reliable and valid. In addition, experimental evidence indicated that positive and negative affective reactions to specific team member interactions could be predicted from TIS data. This research was designed to build on the previous findings; to extend technology development to add an additional sensor – galvanic skin response (GSR) – to the TIS to improve reliable detection of crew anomalies using badge data streams. Specifically, the research (1) extended technology development of the sensor platform to integrate a GSR sensor, develop relevant software, and redesign the badge casework, and (2) validated the utility of the GSR sensor for improving discrimination of positive and negative affective states. The technology was successfully developed and transferred to the NASA Wearable Electronics Application and Research Lab (WEAR Lab). Experimental evaluation of the GSR sensor did not yield compelling evidence that the addition of the GSR sensor provided useful predictive information beyond HR and HRV. Although no one research study is definitive, we conclude that the GSR sensor did not demonstrate a useful addition to the TIS technology platform.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Team cohesion is not just a critical factor for astronaut teams and ground crews; cohesion is important to the effectiveness of all teams and especially those that operate in critical, high reliability setting. Of the many team process factors that support team effectiveness, team cohesion is the most studied with over a half century of research. Yet, remarkably, very little is known about the characteristics that promote its development and maintenance. For example, we know that experience working together is associated with cohesion formation and maintenance, but what are the mechanisms? Teams that do not cohere replace problematic members or disintegrate so experience reveals only those teams that survive, but that does not tell us why or how. This research, which will create technologies to monitor team cohesion and guide interventions to restore it, has the potential for wide utility in aviation, military, medical, industrial, and other environments where society depends on the effective performance of high reliability teams.
	Collaboration, cooperation, and coordination are essential underpinnings of effective teamwork. This is especially the case for “high reliability” action teams, such as long duration space flight crews, that have to perform in isolated, confined, and extreme environments. For such teams, effective teamwork is critical for minimizing errors and supporting team performance, and it is reflective of good psycho-social adaptation by the team to the rigors and stresses of long duration space missions. This project was an extension of work previously funded by NASA. That research had two primary research foci: (1) benchmarking the variability, cycles, and fluctuation of team cohesion in a range of isolated, confined, and extreme (ICE) mission analogs and (2) developing a team interaction sensor (TIS) technology platform – a badge - designed to unobtrusively measure team interactions and physiological reactions in real time as a means to assess potential stressors to team cohesiveness. The first research focus, which is concluded, used Experience Sampling Methods (ESM; daily assessments) to benchmark team functioning in ICE environments. The research was designed to quantify the expected range of variation in key teamwork processes (e.g., cohesion, conflict), identify shocks that influence variation, and assess effects on team functioning. Findings, across a range of ICE environments and mission durations (i.e., 6 weeks to 1 year in Antarctica; 1 month to 12 months in dedicated space mission simulations), indicated that team psycho-social functioning during long duration missions was challenged. These challenges were particularly apparent for simulation teams on missions longer that 6 months. Specifically, such teams evidenced destabilization and decline of social cohesion – the psychological glue that bonds members to the team as an entity. This evidence makes clear the need for a means to help team members assess their teamwork interactions and to take necessary steps to maintain it in the face of persistent mission stressors. This is relevant to the goal of the second research focus. The second research focus is the development of an unobtrusive technology platform (i.e., a wearable wireless sensor package) – the TIS – to assess the dynamics of team cohesion. The technology is designed to assess the frequency, duration, and quality of collaborative interactions between team members as they work together to accomplish team tasks, as well as physiological metrics (i.e., heart rate [HR]; heart rate variability [HRV]). The high frequency interaction data streamed by the badges are highly reliable and valid. In addition, experimental evidence indicated that positive and negative affective reactions to specific team member interactions could be predicted from badge data. Specifically, interactions between team members that involved a cognitive stressor were associated with negative affect and performance failures for the stressed team member. HR predicted both affective states (activation). However, negative affect (valence) was predicted by a significant interaction between HR and HRV. This was considered a very

promising finding, because it indicated that the psychosocial status of team members could be inferred analytically from interaction metrics (who was interacting) combined with HR and HRV (who had a negative affective reaction) data streams that are monitored by the badges.

Although this was considered a promising finding, the current project was predicated on adding an additional sensor – galvanic skin response (GSR) – to the TIS array. The purpose was to improve reliable detection of crew anomalies using TIS data streams. Detecting affective states using HR and HRV is complicated, because they reflect the activities of the autonomic nervous system (ANS). The ANS consists of sympathetic and parasympathetic branches, which are associated with activation and relaxation, respectively. Importantly, different indicators of ANS activity reflect different branches. GSR predominantly reflects sympathetic activity, HR reflects a combination of sympathetic and parasympathetic activities, and HRV is linked to parasympathetic activity. Research suggests that combining multiple indicators of ANS activity increases sensitivity to distinguish affective valence and activation, which is essential for discriminating positive and negative affective states. Distinguishing and classifying these states is critical to the effectiveness of the TIS system to detect anomalies in team cohesion. Thus, the purpose of this project was to extend technology development of the TIS system and to evaluate the utility of the additional GSR sensor to improve discrimination of positive and negative affective states.

Task Progress:

Technology Extension

The sensor platform had evolved from an early prototype in which the sensors and processing components were housed in a cardboard box (Version 1.0) to a subsequent package utilizing a 3D printed case (Version 2.0) to a more robust hardened 3D printed case (Version 2.5). Technology development was predicated on maintaining the form factor, robust casework, and good battery life (approximately 12-16 hours of continuous usage) of the TIS badges.

Technology development devised the hardware, embedded software, and storage software components for adding GSR as an additional sensing modality to the existing badge platform. The design was system-wide backward compatible in that the usability and prior functions of the TIS platform were maintained. The GSR sensor was designed to be pluggable to the badge using a wired interface. Upon detection, the badge and base station software self-configures to sense, collect, and store GSR data following the standard protocols employed for the other sensing modalities. The design was implemented such that the wired interface could be replaced by a Bluetooth (BT) interface.

The following components were designed and developed:

• GSR Hardware Integration: An off-the-shelf GSR sensor was used. Interface hardware was developed so the sensor connects to the badge processor using a wired interface. Functions of this hardware include signal conditioning, filtering, and Analog to Digital conversion.

• Driver Software: TinyOS driver software for GSR signal acquisition and integration with the existing badge to base station networking software was developed.

• Base Station Software: Software for integrating GSR data with existing sensor data streams was developed, providing a seamless integration of this new modality with the existing dashboard.

• Sensor Post-processing Software: Data processing software was developed to properly scale GSR data for integration within the existing data framework.

• Case Design: The 3D-printed badge casework was redesigned so the additional GSR-hardware could be packaged without a significant increase in the badge form-factor.

Technology Transfer to NASA: During 2017-2018, the engineering team led by Dr. Subir Biswas worked closely with the NASA Wearable Electronics Application and Research (WEAR) Lab to transfer TIS hardware and software capabilities developed by the Michigan State University research team to NASA. The WEAR Lab has been engineering a new hardware and software platform that replicates the capabilities of the TIS that was developed by this research stream.

GSR Sensor Rationale: Prior phased validation evidence demonstrated that the badge technology (1) is a highly reliable and accurate instrument for capturing team member interaction characteristics. Moreover, (2) a time pressure manipulation designed to differentially induce stress on interactions between teams (i.e., experimental vs. control) was significantly detected by badge heart rate (HR) metrics and ratings of affect following stressed interactions. Furthermore, (3) a cognitive test (CT) manipulation designed to stress interactions was shown to yield increases in HR mean and HR variance (HRV; controlling for baseline HR and HRV) and CT yielded increased negative affectivity (NA) and decreased positive affectivity (PA). Importantly, additional findings indicated that HR and HRV were predictive of NA and PA. Specifically, HR (arousal) was associated with NA and PA, HRV was positively related to NA, and the interaction of HR and HRV predicted NA (i.e., high HR and high HRV predicted high NA).

In this phase 4 validation experiment, we adapted and extended the prior phase 3 validation design to evaluate the efficacy of the GSR sensing modality as part of the TIS sensor array. The effectiveness of the GSR sensor as a predictor of affective responses to stressed interactions was examined. In particular, the research was primarily focused on its ability to add to the prediction of affect beyond the HR and HRV metrics that were previously validated. The validation experiment was designed to create differential degrees of stress across conditions by using a strong CT (i.e., similar to phase 3 validation which yielded a 78% failure rate) versus a moderate CT (i.e., an easier CT with a target failure rate of approximately 50%). This allowed an evaluation of the sensitivity of the GSR sensor to different degrees of stress. In addition, interactions within conditions were differentially stressed (i.e., resource exchanges with CT versus without CT) which allowed an examination within individuals.

GSR Sensor Evaluation

Research Task and Experimental Design: The laboratory task was adapted from a task we had successfully used in past validation phases. It was an adaptation of the NASA Space Flight Resource Management task “Moon Base” to serve as the simulation for collaborative interaction among members. To provide an appropriate research platform, the simulation was redesigned to provide a task context that necessitated frequent structured interactions to facilitate the validation efforts.

The validation sessions consisted of 3-person teams in which members were assigned the role of Alpha, Bravo, or Charlie. We introduced a manipulation between team members to selectively stress interactions (moderate vs. difficult).

	We used a short cognitive test that was delivered prior to selected resource exchanges to induce stress. Approximately 73% of stressed interactions in the difficult test condition and 49% of stressed interactions in the moderate test condition failed the cognitive test. The final sample included 72 teams of three team members each (n = 216). Findings and Conclusion: Heart rate had more consistent relationships with the key study variables (PA, NA, cognitive testing) than GSR. GSR only related to NA, and its relationship was redundant with information conveyed by HR alone. As previously discussed, HR is indicative of both sympathetic and parasympathetic nervous system activity, whereas GSR is solely an indicator of the sympathetic nervous system. It is interesting and perhaps consistent with this conceptualization that GSR only related to NA; however, given the literature, we had anticipated that GSR would aid in the prediction of NA for this reason. Although HR may simply be a more effective physiological measure, there are alternative reasons why this result may have occurred. The GSR sensors used may simply be less precise than the more established HR sensors that were utilized. It is also possible that GSR and HR may not be sufficiently “in phase.” That is, if galvanic skin responses occur more slowly than HR responses, the interaction-level analyses would not effectively capture the relevant information from the GSR metrics; recall the failure of GSR SD to relate to any of the key study variables. However, previous research has shown that GSR and HR responses tend to occur on the same timescale. It was also plausible that skewness within physiological data affected the analyses. To address that possibility, all the analyses were replicated using log-transformed data. The relationships between GSR / GSR SD and key study variables were unchanged. On balance, we conclude that GSR using the sensors employed in this research does not offer incremental validity for the TIS badge. Although there is sufficient ambiguity to note that these findings are not definitive, the research described in this report does not support a GSR sensor as a strong prospect for improving the TIS technology.
Bibliography Type:	Description: (Last Updated: 07/05/2023)
Articles in Peer-reviewed Journals	Van Fossen JA, Olenick J, Ayton J, Chang C-H, Kozlowski SWJ. "Relationships between personality and social functioning, attitudes towards the team and mission, and well-being in an ICE environment." Acta Astronaut. 2021 Dec 1;189:658-70. https://doi.org/10.1016/j.actaastro.2021.09.031 , Dec-2021