Fiscal Year:	FY 2023	**Task Last Updated:**	FY 03/14/2023
PI Name:	Schreckenghost, Debra M.E.E.		
Project Title:	HCAAM VNSCOR: Enhancing Situation Awareness of Automated Procedures Using Adaptive Multimodal Augmented Reality Displays		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture		
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Space Biology Special Category:	None		
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Zip Code:	77058	**Congressional District:**	22
Comments:			
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No. of Post Docs:	0	**No. of PhD Degrees:**	0
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No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Whitmire, Alexandra	**Contact Phone:**	
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Flight Program:			
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Key Personnel Changes/Previous PI:	March 2022 report: There are no key personnel changes.		
COI Name (Institution):	Holden, Kritina Ph.D. (NASA Johnson Space Center) Dory, Jonathan B.S. (NASA Johnson Space Center)		
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Task Description:	This task is part of the Human Capabilities Assessments for Autonomous Missions (HCAAM) Virtual NASA Specialized Center of Research (VNSCOR). Future deep space missions will present new challenges for crew, and increased risks to human performance due to the stress, fatigue, radiation exposure, and isolation that characterizes these missions. In addition, crew will no longer be able to depend on timely support from Mission Control due to distance from the Earth, but will have to work autonomously, while maintaining high performance. Mission Controllers may not be available to answer questions, check system status, assist with procedures, monitor for errors, or troubleshoot problems. Greater crew autonomy will increase dependence on automated systems, and design of these automated systems must be driven by sound human-system integration standards and guidelines in order to ensure mission success. Historically, crew have had very limited dependence on automated systems, thus crew will be faced with a new way of working that may put situation awareness (SA) at risk. We must develop methods for promoting good situation awareness in the automated systems that will most certainly be part of future deep space vehicles and habitats. Procedure automation is a promising technology for reducing crew workload. We define procedure automation as technology that automates the selection or execution of procedural tasks. Structuring the work of automation according to human procedures should improve the transparency of automation actions. This approach provides a means for establishing common ground about ongoing tasks to improve operator understanding of automation behavior. New technologies such as adaptive, multimodal, augmented reality displays can offer the benefits of information presentation tailored to meet the needs of each crewmember, taking into consideration the current state of that crewmember (e.g., sleep-deprived, high workload), as well as the current state of his/her environment and ongoing activities (e.g., emergency situation, time-critical operations). We propose to combine technology for procedure automation with technology for augmented reality multi-modal (ARMM) user interfaces using Microsoft Hololens head-mounted display to provide a virtual task assistant to assist crew in performing procedural work. This virtual task assistant will be capable of identifying which procedures should be performed, performing actions in crew procedures, and summarizing actions taken by the human-automation team to assist crew in preparing for tasks and taking over tasks from other team members. Four studies are planned to evaluate the effects of a virtual task assistant combining procedure automation with augmented reality multi-modal (AARM) user interfaces on human task performance. These studies will achieve the following aims: Aim 1. Determine best methods to improve situation awareness and improve crew autonomy when using a virtual task assistant to prepare for and perform manual maintenance. Aim 2. Determine best methods to improve situation awareness and reduce workload when a virtual task assistant is used to handover maintenance tasks between users. Aim 3. Determine best methods to improve situation awareness and reduce workload when using a virtual task assistant to help manage concurrent manual and automated tasks. Aim 4. Determine best methods for display of procedural work to improve crew autonomy and satisfaction The proposed work addresses a number of gaps in the Human Research Program Human Factors and Behavioral Performance risks. This project will provide guidelines for designing effective human-automation systems and evaluate human-automation performance for exemplar procedure automation systems. This project also will provide guidance for the application of multi-modal and adaptive displays and control to Human-Computer Interaction (HCI) design for long duration operations.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Technologies for virtual task assistance are increasingly available in everyday life. One of the most common is voice enabled assistance, like Siri and Alexa, that aid some activities of daily living. And augmented and virtual reality technologies are becoming mainstream, with the introduction of new devices such as Microsoft HoloLens 2, and improved standards such as the WebXR standards (https://) for accessing virtual and augmented reality devices. The Virtual Intelligent Task Assistant (VITA) project is leveraging augmented reality platforms and new WebXR standards to develop a virtual task assistant that can be used to assist users with procedural task work on the job. Our technical approach is innovative in that new procedural tasks can be supported without custom software development. Our experimental research is distinguished by investigating effective task assistance for maintenance or assembly tasks where hands-free operation of task assistance is beneficial. For the first year we are investigating best techniques for using augmented reality task assistance when assembling small devices that are held in the hands during assembly. This technology and associated research findings have potential benefit to NASA for the assembly, maintenance, and repair of aircraft, spacecraft, habitats, and robotics. This technology and associated research findings also have broader potential benefit for any organization performing assembly and maintenance procedural work. This includes assembly and maintenance of drilling equipment for the oil and gas industry, equipment used in chemical processing plants, and maintenance and repair of commercial aircraft.
	Preliminary Findings for HERA Campaign 6 Missions 1-3 The Virtual Intelligent Task Assistant (VITA) study to be conducted in HERA Campaign 6 started on September 2021. At the time this report was submitted, the VITA sessions for three missions in the NASA Human Exploration Research Analog (HERA) Campaign 6 (C6) were completed, and the fourth mission was in progress. We worked with our HERA Experiment Support Scientists (ESSs) Michael Merta and Reinhold Polvilaitis to prepare for each mission. Prior to each mission, we train the crew on how to interact with the VITA. After each mission, we debrief each crew member about their experience using VITA during the mission. Data collection and preliminary data analysis for the VITA study in HERA C6 were performed on data from the first three missions during the reporting period as well. We met with Millenia Young, the NASA biostatistician working on VITA, to define statistical analysis that will be performed once data from C6 Mission 4 is available.

Task Progress:

We report preliminary results from 12 participants in HERA C6 Missions 1-3 in the remainder of this section.

Situation Awareness (SA)

Two types of situation awareness data are collected, situation awareness during performance of the task and situation awareness after completion of the task. We report preliminary descriptive statistics for each.

Situation Awareness during the Task

Two assessments are collected for each session, one mid-way through the task (interim) and one near the end of the task (final). Each assessment consists of the user indicating their situation awareness as a value ranging from 1 (lowest SA) to 7 (highest SA). Users are given the following definition of situation awareness to help make this assessment:

Situation awareness is the perception, understanding, and anticipation of factors impacting the effective completion of the tasks. • Are you getting the information that you need to do the task? • Do you understand what you are doing? • Do you have a good feel for what is coming next?

The descriptive statistics for situation awareness during the task by condition for three HERA C6 missions indicate the Team Tablet condition received the highest SA ratings (M = 6.14, 6.33), followed closely by the Solo Tablet (M = 6.04) while HoloLens was rated lower (M = 5.04).

Situation Awareness after the Task

The second type of SA data was collected using a questionnaire administered at the end of the task. This questionnaire uses the Situation Awareness Rating Technique (SART) to measure SA. The SART questionnaire has 10 questions grouped into the following categories:

• Task Demand. The amount of attention needed to perform the task and the task complexity and dynamics that affects this. A lower number indicates a less demanding task. • Supply of Crew Resource. Crew alertness, spare mental capacity, and the ability to focus on the task. A higher number indicates more crew resource is available for the task. • Availability of Information for Crew Understanding. How much information is provided to the crew, how easy it is to access this information, and the crew’s familiarity with the tasks. A higher number indicates a better task understanding.

The descriptive statistics for situation awareness after the task by condition for three HERA C6 missions indicate the task was considered the least demanding for the Team Reader (M=3.14) while other conditions were slightly more demanding. The crew resources available were slightly less when using Tablet (M=4.68) and slightly more for Team (M=5.02, 5.11). Crew resources for HoloLens condition were between Tablet and Team conditions. Crew information for understanding was the highest for the Team Reader (M=5.39) and the lowest for HoloLens (M=4.78).

Workload

The Bedford workload scale is used to assess the workload for each condition. Workload varies from 1 (least workload) to 10 (highest workload). Workload is measured at the end of each assembly session (condition). The descriptive statistics for workload by condition for three HERA C6 missions suggest that workload for HoloLens (M=5.58) is higher than other conditions, all of which have a mean workload of less than 3. A plot of the mean workload during missions 1-3 for each rover assembly procedure indicates the mean workload for HoloLens varies between a mean of 3-7 for the different rover assembly procedures.

Usability

The System Usability Scale (SUS) is used to assess usability of the different conditions. The SUS scale is rated from 1 (“Strongly Disagree”) to 5 (“Strongly Agree.”) Values are then scaled to be between 0 and 100. Usability is measured at the end of each rover assembly session.

For Campaign 6 Missions 1-3, preliminary descriptive statistics indicate the Team condition (M=80.42, 84.55) was considered the most usable, closely followed by the Tablet condition (M=77.29). The HoloLens condition (M=48.96) was considered less usable than other techniques.

Discussion of Preliminary Findings

Descriptive statistics for mean workload and usability for Missions 1-3 indicate the VITA augmented reality interface on the HoloLens 1 requires more workload and is less usable than either the Team or Tablet conditions. There are some observations about this augmented reality interface that might have affected these findings.

First, system reliability may have influenced the users’ ratings of augmented reality. Occasionally the HoloLens 1 would stop working and require a system restart. This would usually happen after 50 minutes or more of use and is suspected to be due to overheating. Our protocol required users to take a 5-minute break after 50 minutes of use to give the HoloLens time to cool. Even with this protocol, typically, one user per mission experienced a system crash. This system restart potentially affected both the users’ perception of the technology as well as the workload and SA measures during the session.

Second, the augmented reality system usability ratings may be affected by a few observations. First, most crew are not familiar with augmented technology, meaning it requires some users more practice to master. Additionally, some crew experienced fatigue when using the augmented reality headset. Also, gaze control was reported as fatiguing to some users.

Finally, the augmented reality system performance was observed to become less responsive at times. This likely was due to a combination of occasional slowness in the VITA software and intermittent network slowness due to loading.

To address some of these issues and improve the use of augmented reality in later VITA studies, the VITA augmented reality interface is being moved to the HoloLens 2 [https://] running Unity [https://] on the HoloLens 2 headset.

In addition to these findings based on data that were collected at the end of each condition (session), a questionnaire was administered after the final VITA session (called the end of mission questionnaire). This questionnaire was intended to collect crew's subjective assessment of the different techniques after they had used all of them.

	One question in this survey asked users to indicate whether they preferred figures or text instructions for rover assembly: “For all methods, to what extent did you rely on / prefer text vs. figure instructions to successfully complete the procedure actions?” Through Mission 3, most participants (N = 8) reported preferring figures to text instructions (N = 2), while only a few had no preference (N =2). Thus, in HERA Campaign 7, we will investigate a style of procedures that relies more on figures.
Bibliography Type:	Description: (Last Updated: 04/10/2024)
Abstracts for Journals and Proceedings	Schreckenghost D, Holden K, Milam T. "Enhancing situation awareness of automated procedures using adaptive multimodal augmented reality displays." 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 7-9, 2023. Abstracts. 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 7-9, 2023. , Feb-2023
Articles in Peer-reviewed Journals	Schreckenghost D, Holden K, Greene M, Milam T, Hamblin C. "Effect of automating procedural work on situation awareness and workload." Hum Factors. 2022 Jan 28;187208211060978. https://doi.org/10.1177/00187208211060978 ; PubMed PMID:35089111 , Jan-2022