Fiscal Year:	FY 2022	**Task Last Updated:**	FY 03/16/2022
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		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	77058	**Congressional District:**	22
Comments:			
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Start Date:	05/15/2019	**End Date:**	12/31/2024
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	2	**Monitoring Center:**	NASA JSC
Contact Monitor:	Whitmire, Alexandra	**Contact Phone:**	
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Flight Program:			
Flight Assignment:	NOTE: End date changed to 12/31/2024 per A. Beitman/JSC (Ed., 1/20/23) NOTE: End date changed to 5/14/2023 per S. Huppman/HRP and NSSC information (Ed., 3/3/2020)		
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. 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.
	The first Virtual Intelligent Task Assistant (VITA) study was a pilot laboratory study to determine techniques for use in the second study, to be conducted in the NASA Human Exploration Research Analog (HERA) Campaign 6 (C6). This pilot study was completed in June 2021. Restrictions going onsite NASA Johnson Space Center (JSC) due to COVID-19 were lifted this year. This enabled us to conduct pilot sessions in the Human Factors Engineering Laboratory (HFEL) onsite at JSC using subjects from the Human Test Subject Facility (HTSF). A total of 16 participants performed a session with VITA. For these sessions, the participant performed tasks from electronic procedures on a tablet or tasks provided by VITA in a HoloLens 1 display. The second VITA study being conducted in HERA Campaign 6 started in September 2021. The HERA study has four participants per mission and there will be four missions in Campaign 6, for a total of 16 participants. At the current time, the VITA sessions for two missions in HERA C6 are complete. We worked with our HERA Experiment Support Scientist (ESS), Michael Merta, 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 crewmember about his/her experience using VITA during the

mission. Data collection and analysis for the VITA study in HERA C6 was started in Year 3 as well. We report preliminary results from the Pilot study and HERA C6 Mission 1 (C6M1) below.

Findings on Gaze-activated Control

Multi-modal interaction when using the VITA augmented reality software in a HoloLens includes visual presentation of task cues, hand gestures, and gaze-activated control. To improve support for hands-free operation, we are investigating the use of gaze to interact with the VITA user interface, including advancing to the next instruction, returning to a prior instruction, and recording data.

The operator uses gaze to mark instructions done and advance to the next instruction. Gaze is also used to zoom closer to or away from the VITA display, and to rotate a 3D model of the rover.

Gaze-activated controls are investigated as a means to reduce workload during assembly tasks by enabling interaction with the VITA intelligent agent without moving the user's hands away from the assembly task. Subjective feedback from subjects on gaze-activated controls indicates such controls can increase workload, if not properly designed. If button response is too sensitive to user gaze, buttons can be accidentally activated, causing the user additional work to "undo" unintended actions. If button response is not sensitive enough to user gaze, repeated gaze actions and extended gaze times can be required, making it difficult to activate these controls and frustrating the user.

In response to feedback from the pilot study, a number of design changes were made to the gaze-activated controls in VITA. In the initial VITA design, buttons used to navigate through task instructions were located below the textual cue, to be near the bottom of the virtual field of view and closer to the user's line of sight during assembly. However, this location appeared to possibly contribute to accidental button activations as the eyes moved during assembly, so the navigation buttons were moved above the task cue to be further away from the user's line of sight when assembling the rover. The time that a user must gaze at a control button to activate it (called dwell time) was also increased to 250 msec. Navigation buttons were modified to blink briefly when activated, to improve user awareness of button activation. Finally, accidental activation of critical controls (like marking a task done and moving to the next task) is prevented by using an "arm-and-fire" design that requires two button activations to take an action.

Even with these changes, subjective feedback from the first mission of HERA Campaign 6 indicates that users felt gaze-control was slow and not sensitive enough. The HoloLens 1 tracks head direction but does not track eye movement. This reduced the precision of gaze direction, which can make it harder to activate buttons.

Task Progress:

Findings on Placement of Virtual Cues

The VITA user interface arranges virtual task cues and gaze-activated controls in a planar layout. By default, this plane is placed at eye-level when the head is raised and looking forward. The user can use hand gestures to adjust the placement of this plane relative to head position and focal length.

During the pilot study, users were trained how to adjust the placement of this plane. Some subjects found it difficult to make this adjustment. Initially, many users intuitively placed the plane near their hand position when assembling the rover. Eventually, most users moved the plane above their hands and to one side, to prevent accidental activation of gaze-controlled buttons. If the plane was placed too far away, however, users had to move their heads more to see task cues.

During HERA C6M1, placement of virtual cues continued to be challenging for users. Some crew mentioned that shifting the focal plane between virtual task cues and the rover can be tiring over time.

Preliminary findings indicate that additional study of the placement of virtual cues with respect to the focal plane of the task is merited. The user interface design should make it easy to adjust placement of virtual cues relative to the location of task components. The user interface design should also try to minimize shifts in focal length between the physical task and the virtual task cue, as frequent shifts can cause visual fatigue. Designs should be investigated that simplify aligning the focal length of the virtual cues with the focal length of the task components, even when virtual cues are not placed near the task components.

Results

The VITA study is investigating workload when using only gaze-activated control, which earlier studies do not address. Subjective response to gaze-activated control has been mixed, with some users preferring it while others suggest using gesture or voice control. The reliance on gaze for all interaction with VITA makes it more likely that users may experience some visual fatigue, which is substantiated by observations during both the pilot study and HERA C6M1.

Observations from the pilot study and HERA C6M1 indicate that procedure information may need to be organized differently than in the tablet display for more effective use in virtual space. Currently, figures are associated with specific instructions. Users can easily glance at an earlier figure, when using a tablet to view the procedure. When using VITA, however, access to prior figures requires navigating back one instruction at a time. A number of users observed that the effort to go back using VITA discouraged them from looking at figures that would have helped with the current instruction.

Some participants in the pilot study and in HERA C6M1 reported discomfort when using the HoloLens 1 continuously for over 50 minutes. These reports are consistent with a study of simulator sickness. Gaze control was reported as fatiguing to some users in the pilot study. One participant in HERA C6M1 reported that having more than one session with an augmented reality headset in a day made symptoms worse, even when using different headsets (HoloLens 1 in one session, HoloLens 2 in another session). We are investigating in the HERA C6 study whether users adapt to this with repeated use.

We submitted a paper entitled "Lessons on Developing an Augmented Reality Interface to a Virtual Intelligent Task Assistant" to the Human Factors and Ergonomics Society annual meeting to be held in Atlanta, GA, on October 10 - 14, 2022. This paper reports preliminary results from the VITA pilot study and the first two missions in HERA Campaign 6.

Bibliography Type: Description: (Last Updated: 03/25/2025)

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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. Special Issue on Human Factors and Ergonomics in Space Exploration. 2022 Jan 28:187208211060978. https://doi.org/10.1177/00187208211060978 ; PMID: 35089111 , Jan-2022