Fiscal Year:	FY 2019	**Task Last Updated:**	FY 05/02/2019
PI Name:	McLaughlin, Anne Ph.D.		
Project Title:	Creating a Taxonomy of Variables Affecting Cognitive Aid Design via an Investigation of Hybrid Aids		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Space Human Factors Engineering		
Joint Agency Name:		**TechPort:**	No
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 (2) **Medical Conditions**:Risk of Adverse Health Outcomes and Decrements in Performance Due to Medical Conditions that occur in Mission, as well as Long Term Health Outcomes Due to Mission Exposures		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:			
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:	08/09/2016	**End Date:**	02/01/2019
No. of Post Docs:	0	**No. of PhD Degrees:**	1
No. of PhD Candidates:	3	**No. of Master' Degrees:**	1
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	1
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NASA JSC
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Flight Program:			
Flight Assignment:	NOTE: Extended to 2/1/2019 per NSSC information (Ed., 9/5/18) NOTE: Element change to Human Factors & Behavioral Performance; previously Space Human Factors & Habitability (Ed., 1/19/17)		
Key Personnel Changes/Previous PI:	June 2017 report: Dr. Aniko Sandor, the original co-Investigator, left her position at KBRWyle in late 2016. We have been working with substitute co-Is and currently are working with Vicky Byrne, a specialist in medical human factors, who is now listed as Co-Investigator.		
COI Name (Institution):	Byrne, Vicky M.S. (KBRWyle/NASA Johnson Space Center)		
Grant/Contract No.:	NNX16AP91G		
Performance Goal No.:			

Performance Goal Text:	
Task Description:	This proposal addresses the NASA Research Announcement for Human Exploration Research Opportunities (HERO), NNJ15ZSA001N-FLAGSHIP Appendix A, Interactive Cognitive Aids. Onboard crewmembers, similarly to operators from other industries, complain about using current checklist-like procedures. Issues include procedures having too much or too little detail and poor usability. Due to these, mistakes still occur and time to accomplish procedures is misestimated. NASA crew presently use static paper or electronic “cue cards” (PDFs) and procedures that provide guidance on both nominal and off-nominal tasks. Existing tools may not account for the lack of recent training, may not be optimized for the task, may not be optimized for the number of users, and may not be resilient to resumption after interruption. A more interactive cognitive aid can overcome the limitations of these cue cards and procedures by matching task, individual, team structure, and environment. This project addressed the Risk of Inadequate Critical Task Design of the Human Research Program (HRP), specifically the SHFE-TASK-02 gap: What model-based HF (human factors) tools can assist with the design and evaluation of spacecraft systems and task procedures. A toolkit is needed to support dynamic task design, particularly for design by non-programmers who would be making the procedures. There exists no taxonomy of cognitive aid design and task type nor standards for interactive cognitive aids to drive development. A cognitive aid should provide guidance to support efficiency and success while minimizing cognitive workload, but it was not yet clear what attributes, such as adaptability, the aid should contain. The project also addressed the HRP’s Risk of Performance Errors Due to Training Deficiencies, specifically the TRAIN-03 gap: We need to develop guidelines for effective onboard training systems that provide training traditionally assumed for pre-flight. (Previously: SHFE-TRAIN-03 - How can onboard training systems be designed to address Just in Time (JIT) and recurrent training needs for nominal and off nominal scenarios?). To contribute to the closure of this gap, we investigated cognitive aids for non-expert operators. Our goals in this project were two-fold: The first goal was to investigate a new form of cognitive aid that incorporates the beneficial attributes of static, adaptable, adaptive, and dynamic aids into a hybrid aid. We see the benefit of this hybrid aid to be: 1. a technology able to be immediately deployed (unlike augmented reality or other heavily technology-dependent advances), 2. a technology able to be used by non-programmers as they design aids for crewmembers (the audiences would be procedure designers and scientists creating procedures for in-flight experiments), 3. a form of aid that offers the beneficial attributes of a dynamic aid that responds to each step in a procedure with the security of a static or adaptable aid that does not require functioning sensors for performance. We designed a prototype of a hybrid aid for medical equipment maintenance tasks, while at the same time building a library of tools to create similar aids for other procedures. Second, developed a taxonomy of cognitive aid design that considers the most important variables affecting performance with aids: user knowledge and experience, time pressure on performance, task criticality, and the number of operators expected to interact with the aid.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The results of the project provide guidelines for the development of cognitive aids in any number of areas, including aviation, automobiles, manufacturing, nuclear power plants, and medical procedures. Reducing error rate in many of these circumstances can save lives. Reducing duration spent on the task could reduce costs. A system that is no longer cumbersome or distracting will encourage adherence, one of the major flaws of current procedures and checklists. Our Hybrid Aid toolkit is a prototype of an innovative cognitive aid technology that is designed to support non-expert operators in complex tasks, while also offering tools to the procedure designers and the operators themselves as they perform the task.
	Project Aims, Objectives, or Hypothesis To contribute to the closure of these gaps, the research focused on investigating cognitive aids for non-expert operators. Our goals were two-fold: The first goal was to investigate a new form of cognitive aid that incorporates the beneficial attributes of static, adaptable, adaptive, and dynamic aids into a hybrid aid. We see the benefit of this hybrid aid to be: - a technology able to be immediately deployed (unlike augmented reality or other heavily technology-dependent advances), - a technology able to be used by non-programmers as they design aids for crewmembers (the audiences would be procedure designers and scientists creating procedures for in-flight experiments), - a form of aid that offers the beneficial attributes of a dynamic aid that responds to each step in a procedure with the security of a static or adaptable aid that does not require functioning sensors for performance. The second goal was to develop a taxonomy of cognitive aid design that considers the most important variables affecting performance with aids: user knowledge and experience, resources demanded by the task and sub-tasks, time pressure, and the number of operators expected to interact with the aid. Hypotheses were that a hybrid aid would have the following benefits: - a technology able to be immediately deployed (unlike augmented reality or other heavily technology-dependent advances), - a technology able to be used by non-programmers as they design aids for crewmembers (the audiences would be procedure designers and scientists creating procedures for in-flight experiments), - a form of aid that offers the beneficial attributes of a dynamic aid that responds to each step in a procedure with the security of a static or adaptable aid that does not require functioning sensors for performance. Specific Questions Addressed The following specific research questions were addressed across four experiments, a validation study, and an integrative literature review. All experiments and studies focused on capable but non-expert operators using a cognitive aid.

Task Progress:	First, how does the sensory modality of the aid interact with the demands of the task being aided? Is it better to avoid cognitive resource conflict or to consider the task and aid as an integrated system that might benefit from matching the resources needed for each? Second, how does the method of interaction (manual, voice) affect use of the aid in various sensory modalities? Third, how do teams of two operators differ from single operators in how they utilize the cognitive aid and perform the task? Does this interaction change when under time pressure? Fourth, how do individual differences in ability needed for the task (e.g., spatial ability) affect use of a cognitive aid? Is there a benefit to providing aid from perspectives that do not require mental rotation? Fifth, using the information gained from the literature review and experiments, can we create an aid that supports significantly better performance from space-experienced operators at Johnson Space Center compared to a traditional procedure? Connection to the NASA Human Research Roadmap : The overall project addresses Risk of Inadequate Critical Task Design of the Human Research Program (HRP), specifically the SHFE- TASK-02 gap: What model-based HR tools can assist with the design and evaluation of spacecraft systems and task procedures? A toolkit is needed to support dynamic task design, particularly for design by non-programmers who would be making the procedures. There exists no taxonomy of cognitive aid design and task type nor standards for interactive cognitive aids to drive development. A cognitive aid should provide guidance to support efficiency and success while minimizing cognitive workload, but it is not yet clear what attributes the aid should contain. The experiments included in this project are examining the variables of aid modality, number of team members, and support for off-nominal procedures. The first experiment, reported here, will draw conclusions about the importance of reducing sensory modality conflict between the cognitive aid and the task. The project also addresses the HRP's Risk of Performance Errors Due to Training Deficiencies, specifically the TRAIN-03 gap: We need to develop guidelines for effective onboard training systems that provide training traditionally assumed for pre-flight. Last, Risks not included in the original proposal (but discovered to be applicable to the current project) were: - Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions: Med-05: We do not know how to train crew for medical decision making and medical skills to enable extended mission or autonomous operations. Cognitive aids can provide just-in-time training and job support; - Risk of Inadequate Human-Computer Interaction and HCI-06: We need guidelines to ensure operators receive all of the information required to accomplish necessary tasks in a timely fashion, even when operating autonomously. (Previous title: SHFE-HCI-06). Discovering the best way to design cognitive aids for previously unstudied scenarios (e.g., non-expert operators, numbers of operators) results in guidelines for the cognitive aids of the future. As projected, the overall project addressed the Risk of Inadequate Critical Task Design of the Human Research Program (HRP), specifically the SHFE- TASK-02 gap: What model-based HR tools can assist with the design and evaluation of spacecraft systems and task procedures? A toolkit was created to support dynamic procedure design. Further, the literature review and taxonomy provides a structure and boundary conditions for the development of new cognitive aids, even those using unexplored technologies (e.g., Augmented or Virtual reality). One of the main take home messages from the literature review was the lack of research on supporting non-expert operators and a lack of focus on broad generalized knowledge of cognition that can be applied to all cognitive aids. The project also addressed the HRP's Risk of Performance Errors Due to Training Deficiencies, specifically the TRAIN-03 gap: We need to develop guidelines for effective onboard training systems that provide training traditionally assumed for pre-flight. All of the studies performed used non-expert operators and provided information on how to create aids that assist with just-in-time training. Another risk addressed was the Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions: Med-05: We do not know how to train crew for medical decision making and medical skills to enable extended mission or autonomous operations. Again, our focus on supporting non-expert operators applies to this risk, under the assumption that crewmembers may be called upon to perform medical tasks for which they are not fully trained. Last, we addressed the Risk of Inadequate Human-Computer Interaction and HCI-06: We need guidelines to ensure operators receive all of the information required to accomplish necessary tasks in a timely fashion, even when operating autonomously. Cognitive aids, as was shown in the literature review and taxonomy, require study both of how the aid supports cognition in the task and how cognition must be supported in using the aid itself. Discovering the best way to design cognitive aids for previously unstudied scenarios (e.g., non-expert operators, numbers of operators) resulted in guidelines for the cognitive aids of the future. [Ed. note October 2020--HRP gaps have been changed since this report in May 2019]
Bibliography Type:	Description: (Last Updated: 07/10/2023)
Articles in Peer-reviewed Journals	Pryor M, McLaughlin AC. "Developing video or multimedia instructions for older adults." Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2018 Sep;62(1):1739-43. (62nd Annual Meeting of the Human Factors and Ergonomics Society, Philadelphia, Pennsylvania, October 1–5, 2018.) https://doi.org/10.1177/1541931218621394 , Sep-2018
Articles in Peer-reviewed Journals	McLaughlin AC, Byrne VE. "A fundamental cognitive taxonomy for cognition aids." Hum Factors. 2020 Sep;62(6):865-73. Epub 2020 May 21. https://doi.org/10.1177/0018720820920099 ; PMID: 32436740 , Sep-2020