Fiscal Year:	FY 2010	**Task Last Updated:**	FY 09/14/2010
PI Name:	Oman, Charles M. Ph.D.		
Project Title:	Advanced Displays for Efficient Training and Operation of Robotic Systems		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Sensorimotor Adaptation Team		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **SHFH**:Space Human Factors & Habitability (archival in 2017)		
Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture (2) **Sensorimotor**:Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	02139-4301	**Congressional District:**	7
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2007 NSBRI-RFA-07-01 Human Health in Space
Start Date:	09/01/2007	**End Date:**	08/31/2011
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	6
No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Young, Laurence (Massachusetts Institute of Technology) Natapoff, Alan (Massachusetts Institute of Technology) Liu, Andrew (Massachusetts Institute of Technology) Tomlinson, Zakiya (NASA Johnson Space Center)		
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Task Description:	The long term objectives of this 4 year NSBRI Sensorimotor Team project address three specific aims related to astronaut performance during space telerobotics training. We are collaborating with the JSC Robotic Systems Training Group (DX-2). The project is in its third year. Astronaut robotics trainees vary significantly in their initial performance, ability, learning rate, and level of mastery. Because the process of training astronauts to be qualified robotics operators is so long and expensive, NASA needs tools to predict performance and customize training. Our scientific goal has been to understand how individual differences in spatial and manual control abilities impact learning and performance. Aim 1. Astronaut candidates currently take an "Aptitude for Robotics Test" (ART) and those selected proceed to Generic Robotics Training (GRT). Using a logistic modeling approach we investigated how well an astronaut's ART scores and an additional set of mental rotation, perspective taking and visualization tests predicted spatial performance in subsequent training. We found ART was not a reliable predictor and proposed changes in ART metrics to improve the predictive power. These were implemented and used in the current round of astronaut testing and GRT training. During the coming year we plan to re-evaluate ART using this new data. Logistic regression analysis of mental rotation and visualization scores allows us to predict who will achieve a top score in qualification evaluations, but not those who fail (partly because very few do). Model predictions are reliable enough to use in customization of regular and remedial training, but not to make career defining decisions. Additional GRT and spatial ability data is also being obtained for analysis this year, in collaboration with the JSC Robotics Training Branch. Aim 2: Our second objective has been to study performance and learning in a controlled laboratory setting using a space telerobotics training simulator at MIT. The simulator recreates the BORIS training environment used in GRT, and also the ISS environment. In a series of three previous experiments, we consistently found that a trainee's early performance and learning in relatively simple GRT-like "fly-to" and pregrapple tasks correlate with their spatial abilities. We believe this is because mental rotation and visualization abilities are important for integrating the multiple video camera views used when performing robotics tasks. This year we completed two more experiments. In our prior research, camera configurations were controlled by the experimenter. In reality, cameras are selected by the primary or secondary operator. In the first experiment (n=21) we found that while acting as a secondary operator, camera selection performance and ability to identify arm clearance issues was also correlated with the individual subject's (Vandenberg) mental rotation, (Purdue Spatial) visualization, and (Kozhevnikov 2D) perspective taking ability. A second experiment (n=20) studied the effects of spatial ability, handedness, and joystick configuration on "fly-to" performance requiring multi-axis movements. Like spacecraft, the Shuttle and ISS robotic arms are always controlled using a 3 DOF rotational controller in the right hand, and a 3DOF translational controller on the left. Current hand preference theories (e.g. Guiard) suggest that right handed astronauts should be at a particular advantage with this physical hand controller arrangement. As in our prior experiments, we found that spatial ability scores predicted task performance. However to our surprise we found no large or consistent effect of handedness (Edinburgh questionnaire), or whether the RHC was in the dominant or non-dominant hand, even in the early stage of training. As when using an "Etch-A-Sketch", robotics operators must learn to must parse different spatial axes to different hands. (Happily for left handed astronauts), right handed operators apparently have no significant advantage in this regard. Aim 3: So far our MIT experiments have studied performance only during the first 1-2 days of training while operators perform relatively simple fly-to, camera selection, and clearance monitoring tasks. Are spatial abilities as important during the later phases of GRT and more advanced training? Based on discussions with the Robotics Training Branch, this year we developed a new series of training protocols and performance metrics in order to study performance during more advanced tasks. New experimental scenarios developed include grapple, loaded-fly-to, autosequencing and free-floating payload track-and-capture. (With the impending retirement of ISS, astronauts must be able to capture drifting HTV logistic supply vehicle.) We have also developed a side task to assess workload. Trainees are able to perform complete sequences of robotic tasks, and the more realistic protocols will allow us to study the process of complex skill acquisition under multi-day advanced training scenarios, and quantify spatial ability effects. Also, in a companion study being initiated this year (NSBRI project NBPF02001) we plan to assess the effects of fatigue and sleep deprivation.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Our goal is to improve the efficiency of robotic training via improvement of current pedagogies and development of new teaching tools. Improved training methods provide a framework for designing future in-flight training procedures during long duration missions. The project will also demonstrate how individual differences in spatial and manual control skills affect performance of critical operational skills, including complex robotics tasks associated with post-Shuttle era ISS operations
Task Progress:	Overall our project is running ahead of original schedule. All members of our MIT scientific team have taken part or substantially all of the JSC GRT course. One (Tomlinson) completed her graduate work at MIT, and joined the JSC DX2 group as a robotics trainer. Aim 1: Completed logistic model analysis of spatial ability and JSC-ART data on 40 NASA astronauts to predict GRT scores. Results presented at NASA HRP-BIW and ASMA, and manuscript submitted. ART scoring changes implemented by JSC. Over the past 10 months we have received a partial data set for the 14 astronauts in the 2009 class : ART data is complete, 10 with spatial ability data, 3 with GRT data (most have completed GRT - data coming). Aim 2: Developed MIT robotic skills trainer, developed several new BORIS and ISS tasks, and completed 5 experiments (n=121). This year completed two new experiments: a) effects of spatial skills on secondary operator camera selection performance (n=20) and b) effects of spatial ability, joystick configuration and subject handedness during fly-to tasks. Both experiments confirmed strong spatial ability effects. Results are described in a Master's Thesis (June 10) and in articles in preparation. To our surprise, we found no reliable effects of handedness and joystick arrangement (left vs right hand). Camera selection results were presented at ASMA (May 10 poster and abstract). Our MIT Robotic Skills Trainer was demonstrated at the NSBRI booth at ASMA. We have advised two other NASA-HRP projects (PIs Steven Moore and Angelia Sebok) on metrics and robotics simulation platforms. At the request of the Boston Museum of Science we recently developed a stand-alone version of our robotic skills training software for an upcoming (late 2010) museum exhibit. Aim 3: So far our MIT experiments have addressed performance only during the early stages of training, and while trainees perform relatively simple fly-to, camera selection, and clearance monitoring tasks. The relationship between early performance and individual spatial ability metrics has been consistently demonstrated. Based on discussions with

	the Robotics Training Branch this year we developed training protocols and new performance metrics to study complex skill development during more advanced phases of training, including grapple, loaded-fly-to, autosequencing and free-floating payload track-and-capture. We are also incorporating a side task workload metric. These protocols will allow us to quantify spatial ability effects on ultimate performance on advanced tasks. We also plan to leverage these developments by incorporating them into a new collaborative study - initiated this year - on the effects of fatigue on robotics performance. We may also be able to incorporate our performance metrics into JSC training and even onboard ISS robotic software as a training aid.
Bibliography Type:	Description: (Last Updated: 01/02/2024)
Abstracts for Journals and Proceedings	Oman CM, Liu AM, Natapoff A, Tomlinson ZA, Pontillo TM. "Influence of spatial abilities and fatigue on space telerobotics operator performance." Aerospace Medical Association 81st Annual Meeting, Phoenix Ariz., May 10, 2010. Aviat Space Environ Med 2010 Mar;81(3):214. , Mar-2010
Abstracts for Journals and Proceedings	Pontillo TM, Oman CM, Liu AM, Natapoff A, Tomlinson ZA. "Role of spatial ability in camera selection for space teleoperation tasks." Aerospace Medical Association 81st Annual Meeting Phoenix, Ariz., May 13, 2010. Aviat Space Environ Med 2010 Mar;81(3):255. , Mar-2010
Articles in Peer-reviewed Journals	Liu AM, Oman CM, Natapoff A. "Predicting space telerobotic operator performance from human spatial ability assessments." Human Factors, Submitted, 2009. (not yet published as of September 2010--ed.) , Sep-2010
Dissertations and Theses	Pontillo TM. "Spatial ability and handedness as potential predictors of space teleoperation performance." Dissertation, Massachusetts Institute of Technology, June 2010. , Jun-2010