Fiscal Year:	FY 2009	**Task Last Updated:**	FY 09/15/2009
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
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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:			
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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)		
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Task Description:	The long term objectives of this 4 year NSBRI Sensorimotor Team project address three specific aims related to human performance during space telerobotics training. We are collaborating with the JSC Robotic Systems Training Group (DX-2). The project is in its second year. Aim 1. Our goal is to improve NASA teleoperation training efficiency by scientifically customizing remedial training based on the measured spatial abilities of individual astronauts. 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 robotics performance prior to training. NASA's existing "Aptitude for Robotics Test" (ART) had not been statistically validated. Using a logistic modeling approach we investigated how well an astronaut's ART scores predicted their spatial performance in subsequent evaluation testing (either Shuttle PDRS or Generic Robotics Training). ART was not found to be a reliable predictor. Based on our data analysis, we proposed changes in ART performance metrics to improve the predictive power. These have now been implemented and are being used in the current round of astronaut candidate testing. We expect to re-evaluate the modified ART dataset in year 4. Also, as described in a paper recently submitted to J. Human Factors, we tested the mental rotation and perspective taking spatial abilities of 40 active astronauts who had completed at least one robotics training course. We found logistic regression models that predicted who would achieve the top score in qualification evaluations. The model predictions appear reliable enough to be used to customize regular and remedial training, but not to make career defining decisions. The models could not reliably predict who would completely fail, because so few did. We have proposed improvements in GRT scoring methodology that should improve prediction reliability. At JSC's request, we are also evaluating whether GRT scores could be used to predict performance in later training (e.g. SSRMS), or under operational conditions on ISS. Aim 2: Our second major objective is to perform experiments using a space telerobotics training simulator at MIT to quantify how a trainee's individual spatial and manual control abilities, use of camera views, and hand controller reference frame impacts learning and final level of performance as both primary and secondary robotics operator. This aim was the main focus of our activity this year. We hypothesized that individual ability to manipulate the arm and integrate camera views correlates with 3 subcomponents of spatial intelligence: spatial visualization (SV), mental rotation (MR) and perspective taking (PT). In particular, PT (the ability to imagine an object from another viewpoint) was thought to be important for integrating camera views. This year we completed three different experiments using MIT's Dynamic Skills Trainer, a virtual space telerobotic training system similar to that used at NASA JSC: In the first experiment, 19 subjects were trained to manipulate a robotic arm using a pair of hand controllers in a virtual environment almost identical to that in NASA's Basic Operational Robotic Instruction System (BORIS), used in NASA's introductory "Generic Robotics Training" course. Over 18 "fly to" trials, the disparity between the arm's control frame and the cameras was varied between low (< 90 degrees) and high (> 90 degrees) conditions. We used the Cube Comparisons (CC) test to assess SV, the Vandenberg Mental Rotations Test (MRT) to assess MR, and the Purdue Spatial Visualization of Views Test (PSVT) and a Perspective Taking Ability (PTA) test to assess PT. We showed that subjects with high PSVT scores moved the arm more directly to the target and were better at maintaining the required clearance between the arm and obstacles, even without a direct camera view. The subjects' performance degraded under the high disparity condition. Our second experiment addressed trainee performance as both primary and then secondary (monitoring) operator. Twenty subjects were trained to manipulate the arm during 6 trials in a BORIS environment and then acted as a secondary operator observing an additional 32 trials in an ISS-like environment. We recorded which of three display monitors the trainee was looking at. The MRT, PSVT, and PTA were used to assess spatial abilities. Though the primary operator task was slightly different than that used in Experiment 1, we prospectively confirmed many results of the first experiment. Subjects with high PTA scores took less time, moved the arm more directly to the target, and moved the arm more fluidly, especially under the high disparity condition. High scorers on the PSVT and PTA were better at maintaining required clearance. Low PTA scorers looked from monitor to map more often. Prior experience with the arm didn't significantly improve task performance, and performance as primary operator didn't reliably predict performance as a secondary operator. However, subjects with high PSVT scores had better overall secondary operator performance and high PTA scorers were better at detecting problems before they occurred. These two experiments are the Master's thesis of Ms. Z. Tomlinson, and have so far been presented in two conference abstracts and posters. Aim 3: Our third major goal is to identify and develop new interfaces and tools to support future in-space and lunar surface teleoperation and teleoperation training. Our original 2007 plan was to develop an adjunct spatial situation display and a scheme for switching camera views using operator gestures. We plan to focus on bimanual control skill assessment this year, while acquiring the necessary tracking hardware and address gesture control or spatial situation displays during Year 4.
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 bimanual control skills affect performance of a critical operational skill and provide initial designs of controls, displays and procedures that better match the operator's cognitive skills with task demands.
	Overall the project is running ahead of the original schedule. Aim 1: Completed logistic model analysis of spatial test and JSC-ART data on 40 NASA astronauts to predict GRT scores. Manuscript submitted to Journal of Human Factors. Results presented at NASA HRP-BIW and ASMA. Changes in ART scoring proposed and have been implemented by JSC for next round. Reevaluation planned for year 4. GRT scoring methodology changes suggested. Aim 2: Modified MIT dynamic skills trainer, developed new BORIS and ISS SSRMS tasks, developed IRB protocols and completed 3 series of experiments (n= total 60) on effects of spatial skills on primary and secondary operator performance and gaze patterns during simulated teleoperation training. Preliminary results of first two experiments presented at NASA HRP-BIW (Feb 09). Complete results in ASMA (May 09) poster and abstract and Master's Thesis (February 09). Articles in preparation. Aim 3: Discussions with the Robotics Training Branch suggested that we should also focus our research attention on the

Task Progress:	control and display issues associated with their newest challenge: training crews to use the ISS arms to successfully grab and dock ISS logistics supply vehicles such as ATV and HTV, which may be slowly drifting. Although the task does require spatial skills, it particularly demands that the operator develop a high degree of skill in bimanual control, so the end of the robotic arm can follow a three dimensional arc, all the while maintaining proper angular alignment with the docking pin. Arm translations are controlled with the left hand, and rotations with the right, so the operator must be able to instinctively decompose a 6 DOF movement into the corresponding 3DOF tasks for each hand. (The task feels a bit like to learning to draw smooth lines using a children's Etch-a-Sketch tablet, except using rate rather than position control, and with six degrees of freedom, not just two.) Some individuals acquire much more proficiency than others. High performance normally requires extensive training and sustained practice. Relatively little is known about acquisition and retention of asymmetric coordinated bimanual control skills, or the origins of individual differences. The bimanual control literature largely addresses human computer interface tasks, where the left and right hands work cooperatively but separately on different (usually 2 DOF) tasks. The USAF employs a Two Handed Coordination Test to screen pilot candidates. However in flying the right hand controls attitude (3 DOF), while the left hand controls throttle (1DOF). There are no fully validated tests of bimanual telerobotic skill. We plan to develop such a test this year. So far our project has largely addressed spatial skills, so investigating the motor control aspects will usefully broaden our scope. Assessments of ATV/HTV docking task, bimanual control literature, and bimanual control test methodologies are underway.
Bibliography Type:	Description: (Last Updated: 12/18/2024)
Abstracts for Journals and Proceedings	Collins A, Tomlinson Z, Oman C, Liu A, Natapoff A. "Investigating the effects of frame disparity on the performance of telerobotic tasks." 59th International Astronautical Congress, Glasgow, Scotland, Sept 29 - Oct 3, 2008. 59th International Astronautics Congress, Abstract Book, October 2008. , Oct-2008
Abstracts for Journals and Proceedings	Liu AM, Oman CM, Natapoff A, Coleman C. "Spatial ability as a predictor of space robotics training performance." 79th Annual Scientific Meeting of the Aerospace Medical Association, Boston, MA, May 11-15, 2008. Aviat Space Environ Med. 2008 Mar;79(3):288-9. , Mar-2008
Abstracts for Journals and Proceedings	Oman CM, Liu AM, Tomlinson ZA, Natapoff A, Collins A, Pontillo TM, Silverman JB. "Advanced displays for efficient training and operation of robotic systems." Neurophysiology session poster, 2009 NASA Human Research Program Bioastronautics Investigators' Workshop, League City, TX, February 2- 4, 2009. NASA Human Research Program Bioastronautics Investigators' Workshop, Abstract Book, February 2009. , Feb-2009
Abstracts for Journals and Proceedings	Tomlinson ZA, Oman CM, Liu AM, Natapoff A, Silverman J. "Influence of spatial ability on primary and secondary space telerobotic operator performance." 80th Annual Meeting of the Aerospace Medical Association Los Angeles, CA, May 3-7, 2009. Aviat Space Environ Med. 2009 Mar;80(3):221. , Mar-2009
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. , Jul-2009
Awards	Oman CM. "2009 HRP Bioastronautics Investigators' Workshop L.R. Young Bioastronautics Achievement Award, February 2009." Feb-2009
Dissertations and Theses	Tomlinson ZA. "Influence of spatial abilities on primary and secondary space telerobotics operator performance." Dissertation, Massachusetts Institute of Technology, Cambridge, MA, February 2009. , Feb-2009
Papers from Meeting Proceedings	Collins A, Tomlinson Z, Oman C, Liu A, Natapoff A. "Investigating the effects of frame disparity on the performance of telerobotic tasks." 59th International Astronautical Congress, Edinburgh, Scotland, Sept 29- Oct 3, 2008. International Astronautical Congress, Paper IAC-08-B3.6, September 2008. , Sep-2008