HRP Investigators’ Workshop
February 12-13, 2014

Human Research Program
Space Human Factors Habitability
Space Human Factors Engineering

HUMAN-ROBOT INTERACTION
DIRECTED RESEARCH PROJECT

Aniko Sándor, Ph.D.¹
Ernest V. Cross II, Ph.D.¹
Mai Lee Chang²

¹Lockheed Martin, aniko.sandor-1@nasa.gov
¹Lockheed Martin, ernest.v.cross@nasa.gov
²NASA Johnson Space Center, mai.l.chang@nasa.gov
Relevance to the HRP Risks and Gaps

- The goal of this research project is to contribute to the closure of Human Research Program (HRP) gaps relevant to the “Risk of Inadequate Design of Human and Automation/Robotic Integration (HARI)”, by providing information on how display and control characteristics affect operator performance:
  - Gap SHFE-HARI-01: What guidelines and tools can we develop to enable system designers and mission planners to conduct systematic task/needs analyses at the appropriate level of detail to allocate work among appropriate agents (human and automation)?
  - Gap SHFE-HARI-02: How can performance, efficiency, and safety guidelines be developed for effective information sharing between humans and automation, such that appropriate trust and situation awareness is maintained?
Human-Robot Interaction

• Multi-year research project investigating three areas applicable to NASA robot systems:
  1) The effects of video overlays on teleoperation of a robot arm and a mobile robot
  2) The effect of camera locations on a mobile vehicle for teleoperation
  3) The types of gestures and verbal commands applicable to human-robot interaction
I would not necessarily call these three areas. Areas would be broader such as co-located and remote operation in which these three fit under.
Video overlays

- Experimental and field research have revealed numerous issues related to the use of video as the primary means of controlling a robot.
  - Operator may need to perform mental translations and rotations to infer the control movements needed to teleoperate a robotic arm to a desired position (Smith & Stuart, 1989).
  - The use of video is constrained by environmental conditions (e.g., dust, darkness, and severe lighting conditions) and communication limitations, such as time delays, low bandwidth, and jitter.
  - Video may lack the perceptual cues that are used by humans when performing tasks such as driving or controlling a collocated robot (Tittle, et al., 2002; Woods, et al., 2004).

- Overlays can compensate for these issues
Study 1
Situation and command guidance overlays for teleoperation using a hand controller

• The study evaluated the effects of overlays on operator task performance during teleoperation of a robot arm.

• Three overlays were designed to compensate for the lack of perceptual cues by providing guidance:
  – Command guidance (CG) overlay - explicit instructions on what commands to input
  – Situation guidance (SG) overlay - implicit cues so that operators can infer the input commands.
  – The combination of CG and SG (SCG) provides operators with both explicit and implicit cues allowing the operator to choose which symbology to utilize.
Study 1
Method

• Design
  – Within-subjects design with practice and experimental trials
  – Order of overlay conditions counterbalanced

• Participants
  – Eighteen participants with little or no experience with teleoperation

• Task
  – Use the joystick to align the robot arm with the target and then grasp the target using the arm gripper without colliding with the target or the stand.

• Measures
  – Objective:
    • Task success rate
    • Overshoots
    • Task completion time
  – Subjective ratings after each condition:
    • Adequacy of information
    • Ease of accomplishing the task
    • Workload
  – At the end of the study, participants ranked the conditions.
Study 1
Overlay types/Conditions

No guidance

Situation guidance

Command guidance

Combined guidance
Study 1
Robot and joystick

CoroWare CoroBot

Saitek Cyborg joystick
Study 1
Results

• Task success rate
  – No guidance and command guidance led to significantly better performance than the combined guidance overlay
    • Based on subject comments the combined condition had too much information and was confusing

• The overlays had no significant effect on overshoots and task completion time.
Results

Subjective ratings

Adequacy of information (5-point scale, 1 being not at all adequate)

- All overlay conditions were rated as more adequate than the no overlay condition
  - The combined overlay was rated significantly higher than the situation guidance overlay but not significantly higher than the command guidance overlay.
Results

Subjective ratings

Preference ranking: 5-point scale, 1 being most preferred, 4 being least preferred.

- Command guidance was the most preferred, no overlay was the least preferred.

- The overlays had no significant effect on ratings of ease of accomplishing the task and workload.
Situation and command guidance overlays – uplinked commands

• Limitations of Study 1
  – The task was too easy – participants performed well without any overlays
  – The situation guidance overlay did not serve as real situation guidance in the context of the task
  – Frequent malfunctioning of the robot resulted in data loss

• A follow-up study will improve the task and the overlays
  – New robot arm purchased
  – The study will use a hand controller and uplinked command as a within-subjects design
This does not
Study 2
Superimposed and integrated overlays

• When an overlay is superimposed on the external world, it appears to be fixed onto the display and internal to the operators’ workstation.

• Integrated overlays often appear as three-dimensional objects and move as if part of the external world.
  – Studies conducted in the aviation domain show that integrated overlays can improve performance compared to superimposed by reducing the amount of deviation from the optimal path
  – However, integrated overlays can cause “tunnel vision”, a decrease in situation awareness

• The purpose of the study was to investigate whether these results apply to HRI tasks, such as navigation with a mobile robot.
Study 2
Examples

Superimposed overlays

Integrated overlays
Study 2
Method

• **Design**
  – Within-subjects design with practice and experimental trials
  – Order of overlay conditions counterbalanced

• **Participants**
  – Five participants with little or no experience with teleoperation

• **Task**
  – Navigate the robot through the obstacle course as quickly and as accurately as possible without colliding with the obstacles
Study 2
Measures

- **Objective**
  - Number of collisions
  - Average speed
  - Task completion time
  - Deviations from optimal path
  - Situation awareness measure:
    - Participant had to call out “Alien” when they saw a picture of it (among other pictures as distractors)

- **Subjective**
  - After each condition, participants rated:
    - Amount of information provided
    - Ease of accomplishing the task
    - Workload
  - At the end of the study, participants ranked the conditions.
Study 2
Driving course
Study 2
Robot and joystick

TurtleBot

Saitek Cyborg joystick

Drive robot forward and backward

Turn robot left and right by twisting
Study 2
Overlay conditions

Superimposed overlay

Integrated overlay

Head-down overlay
Study 2
Preliminary results

• The integrated overlay was ranked as the most preferred by most participants.

• Limitations of Study 2
  – The task was too predictable
  – Situation awareness measure not sensitive enough
  – Participants could use the fiducial markers for judging distance

• Follow-on study
  – Revise the overlays to make them more similar to the “tunnel-in-the-sky” integrated overlays
  – Make the driving course more challenging
  – Use a better situation awareness measure