HRP Investigators’ Workshop  
February 12-13, 2014

Human Research Program  
Space Human Factors Habitability  
Space Human Factors Engineering

HUMAN-ROBOT INTERACTION  
DIRECTED RESEARCH PROJECT

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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.
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

Top left button (O) to open the gripper
Move arm up and down with the castle switch
Move arm forward and backward with the joystick
Top right button (C) to close the gripper
Turn robot left and right with twisting the 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.

![Graph showing adequacy of information for different overlay types]
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
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