HRP Investigators' Workshop
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Human Research Program
Space Human Factors Habitability
Space Human Factors Engineering

HUMAN-ROBOT INTERACTION DIRECTED RESEACH 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

CEV(L1

Slide 3

CEV(L1 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

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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

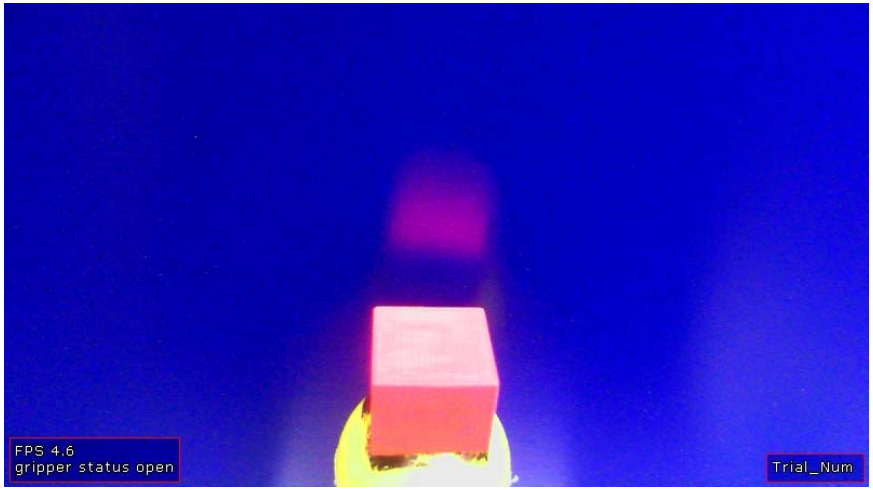
Study 1
Situation and command guidance overlays for teleoperation using a hand controller

- 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.

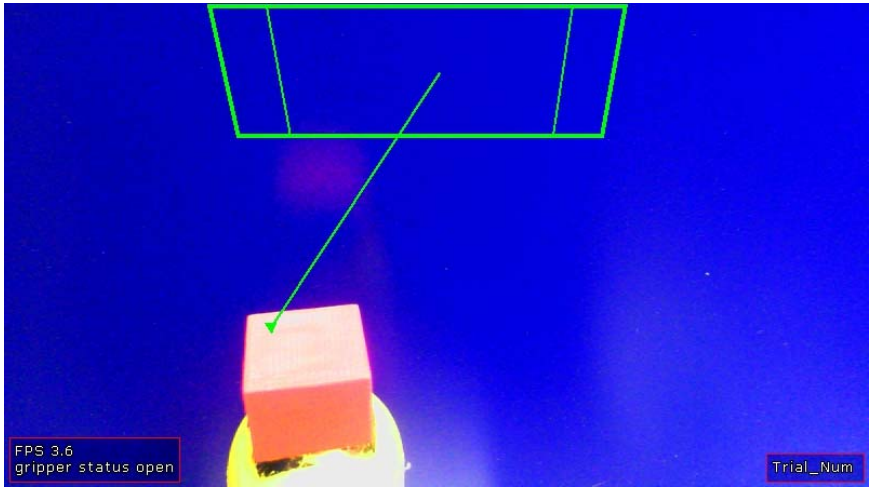
Study 1
Method

- 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.

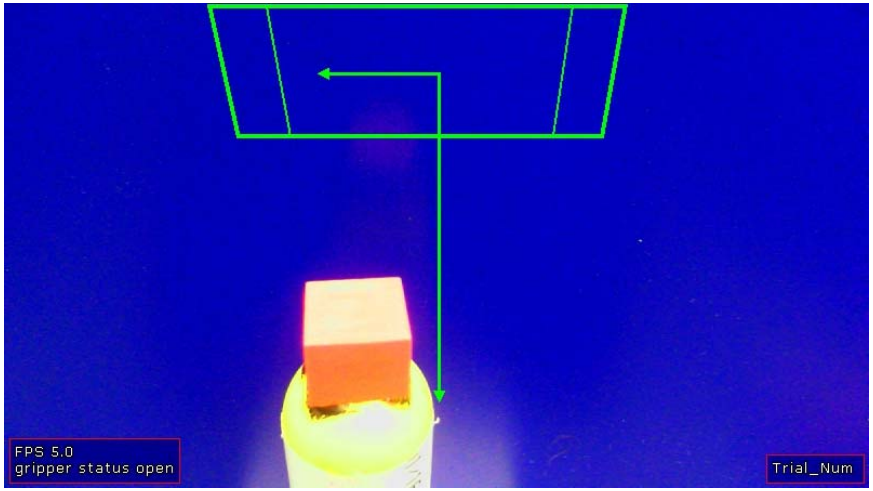
Study 1
Overlay types/Conditions



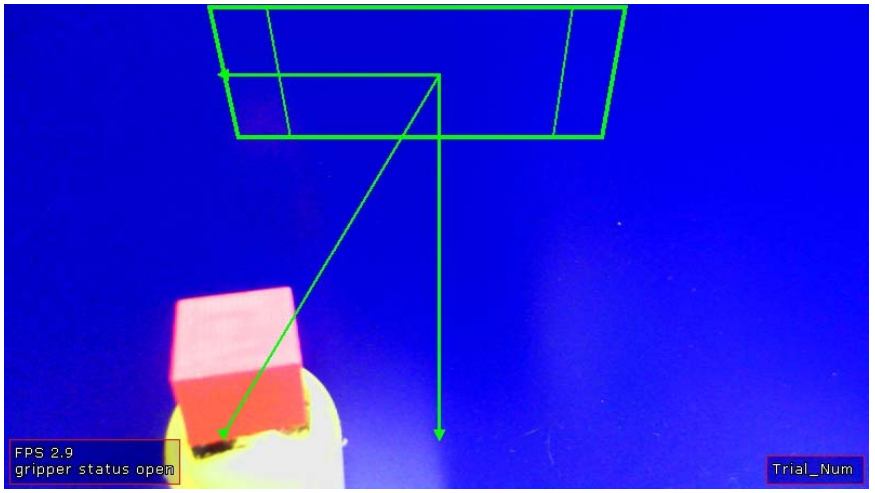
No guidance



Situation guidance

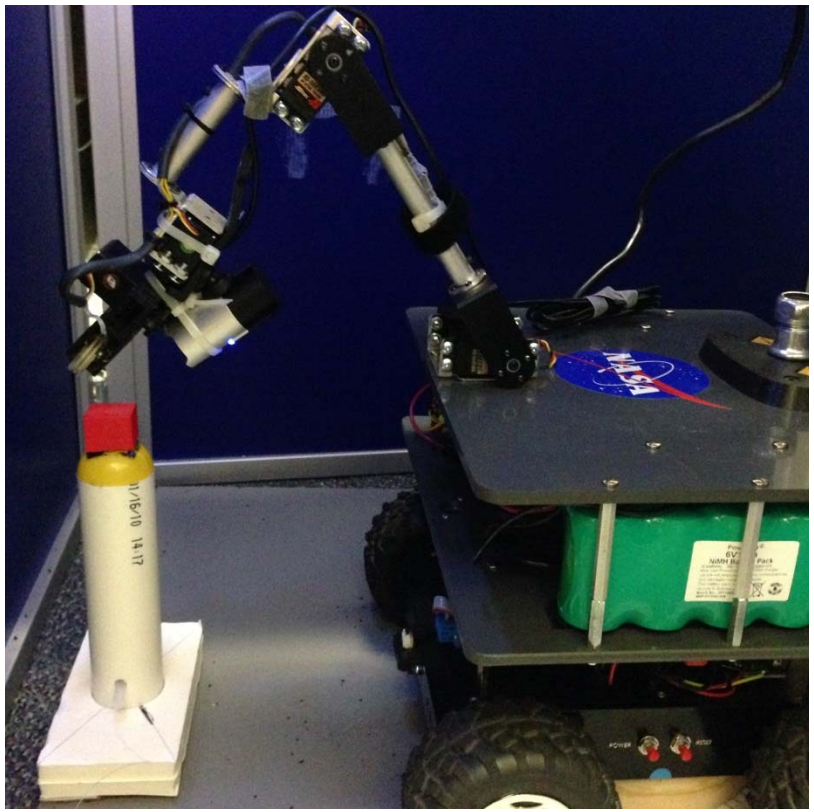


Command guidance

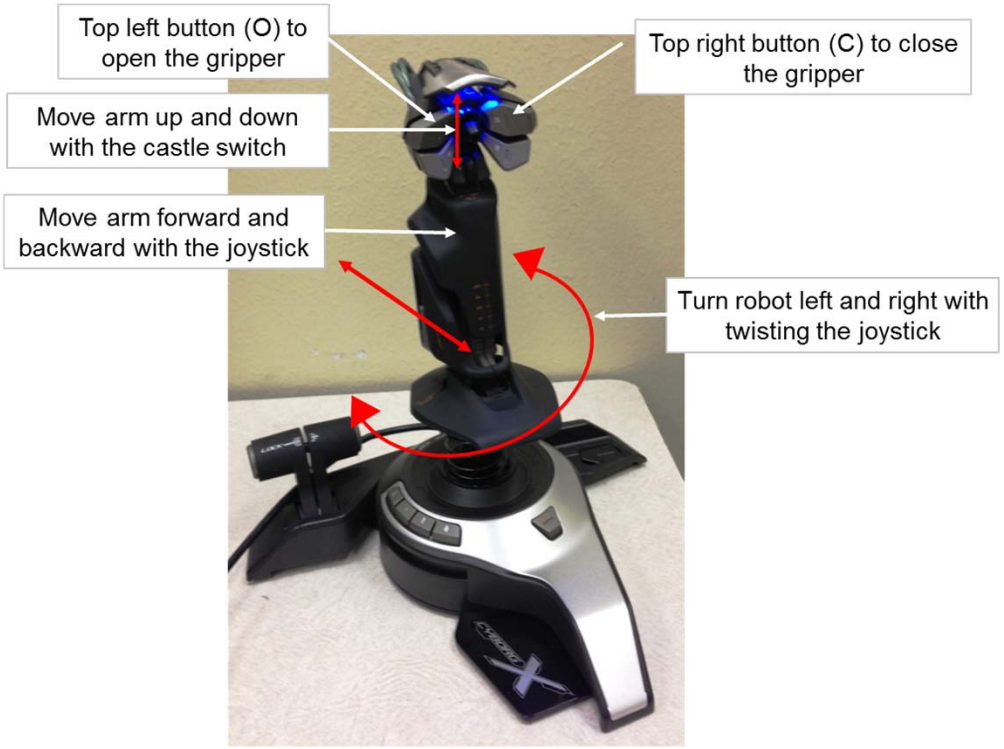


Combined guidance

Study 1
Robot and joystick



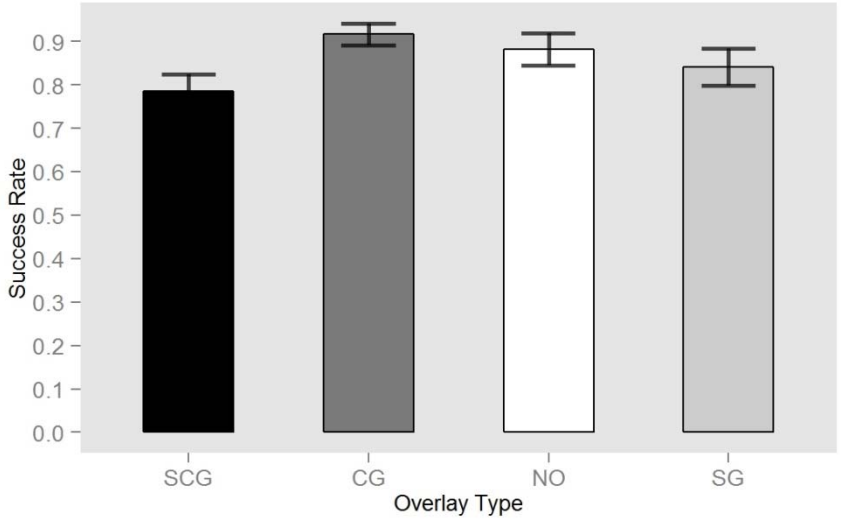
CoroWare CoroBot



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

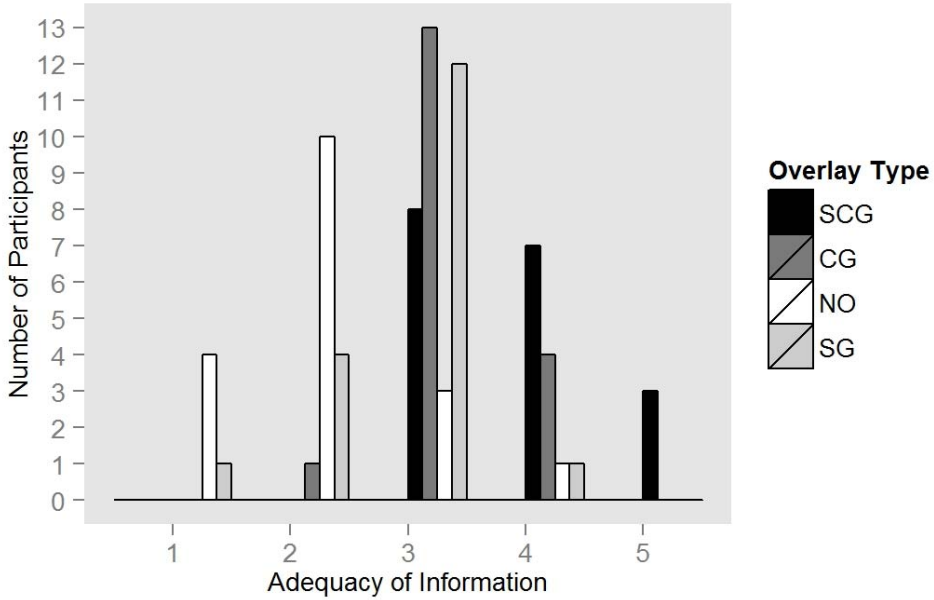


- The overlays had no significant effect on overshoots and task completion time.

Results
Subjective ratings

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

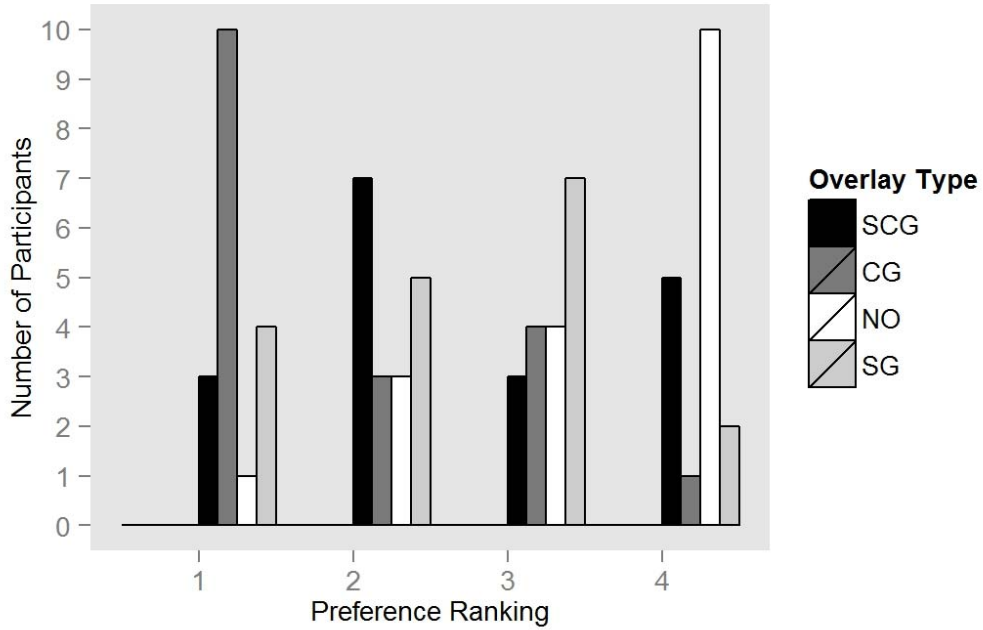
- All overlay conditions were rated as more adequate than the no overlay condition
  - The combined overlay was rated significantly higher than the situation guidance overlay but not significantly higher than the command guidance overlay.



Results
Subjective ratings

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

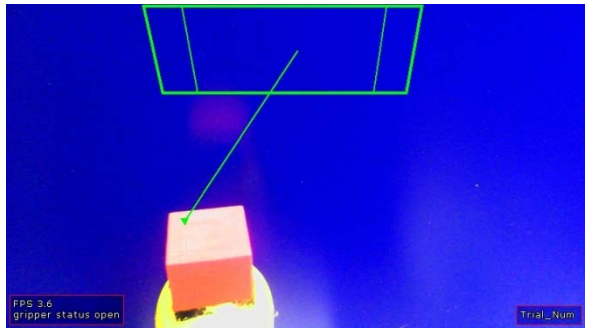
- Command guidance was the most preferred, no overlay was the least preferred.



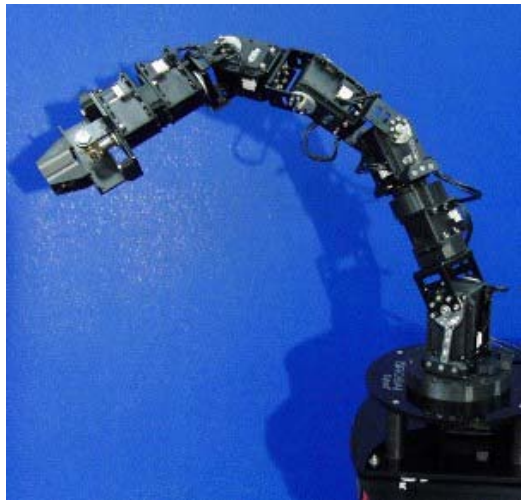
- The overlays had no significant effect on ratings of ease of accomplishing the task and workload.

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



Situation guidance overlay



Cyton Gamma 300 with 7 DOF

Slide 12

CEV(L5 This does not

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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

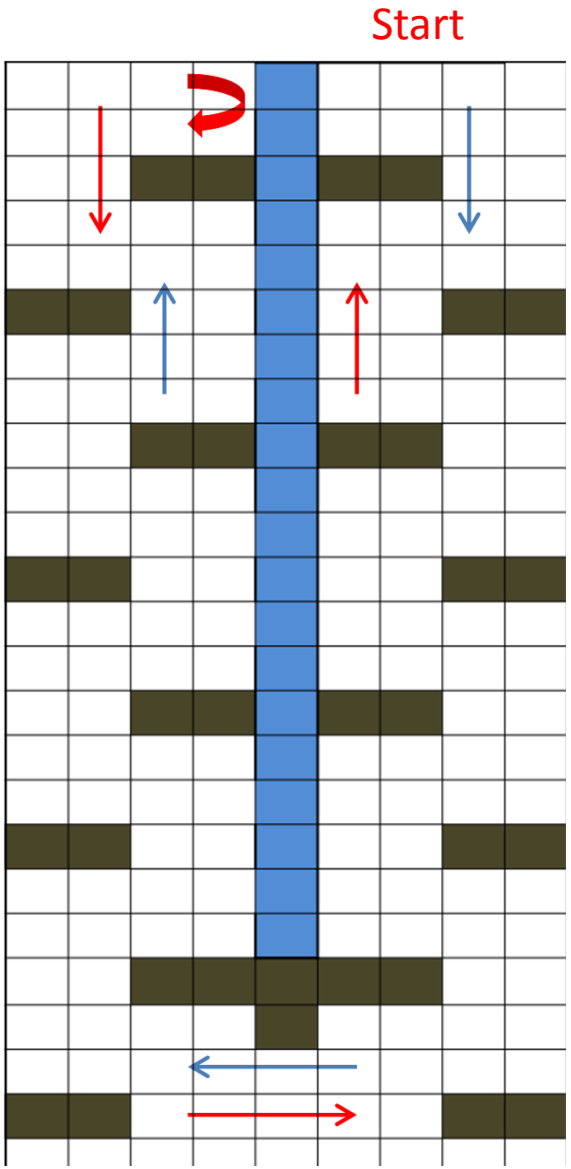
Study 2
Method

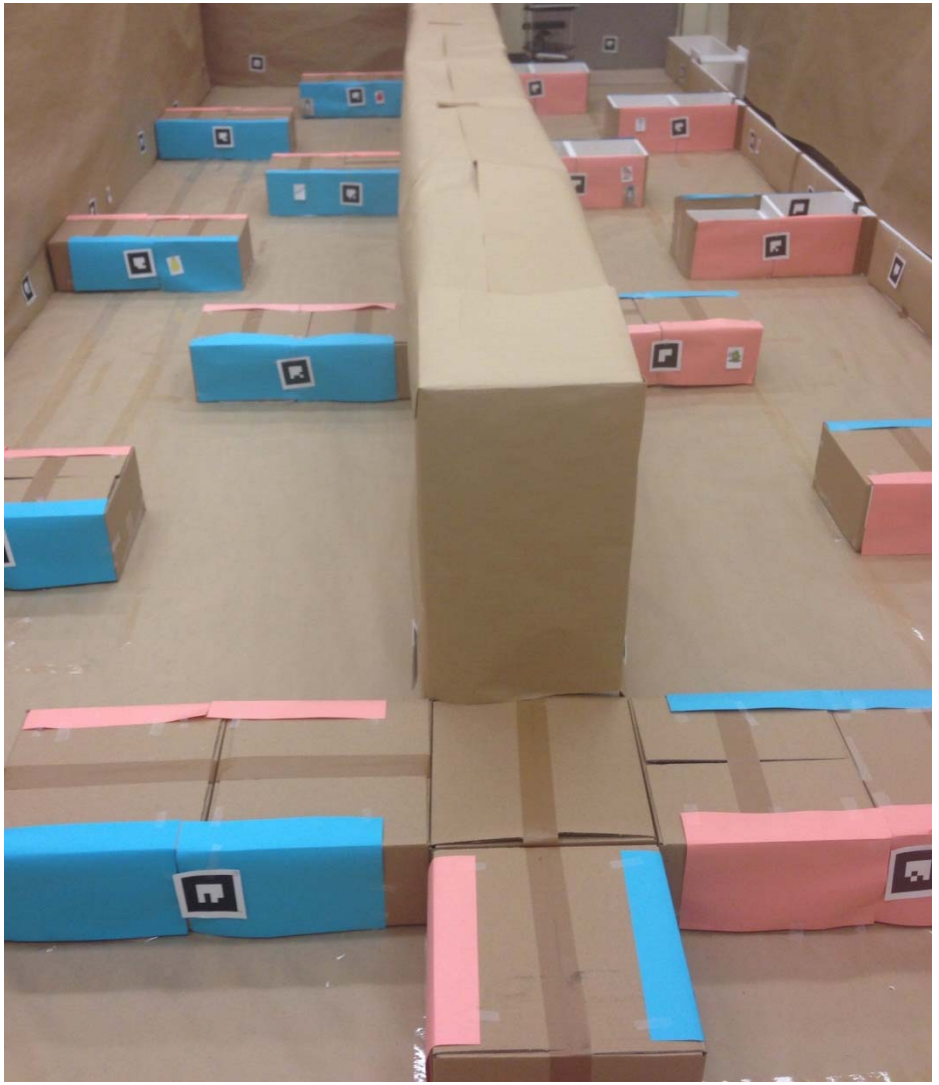
- Design
  - Within-subjects design with practice and experimental trials
  - Order of overlay conditions counterbalanced
- Participants
  - Five participants with little or no experience with teleoperation
- Task
  - Navigate the robot through the obstacle course as quickly and as accurately as possible 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.

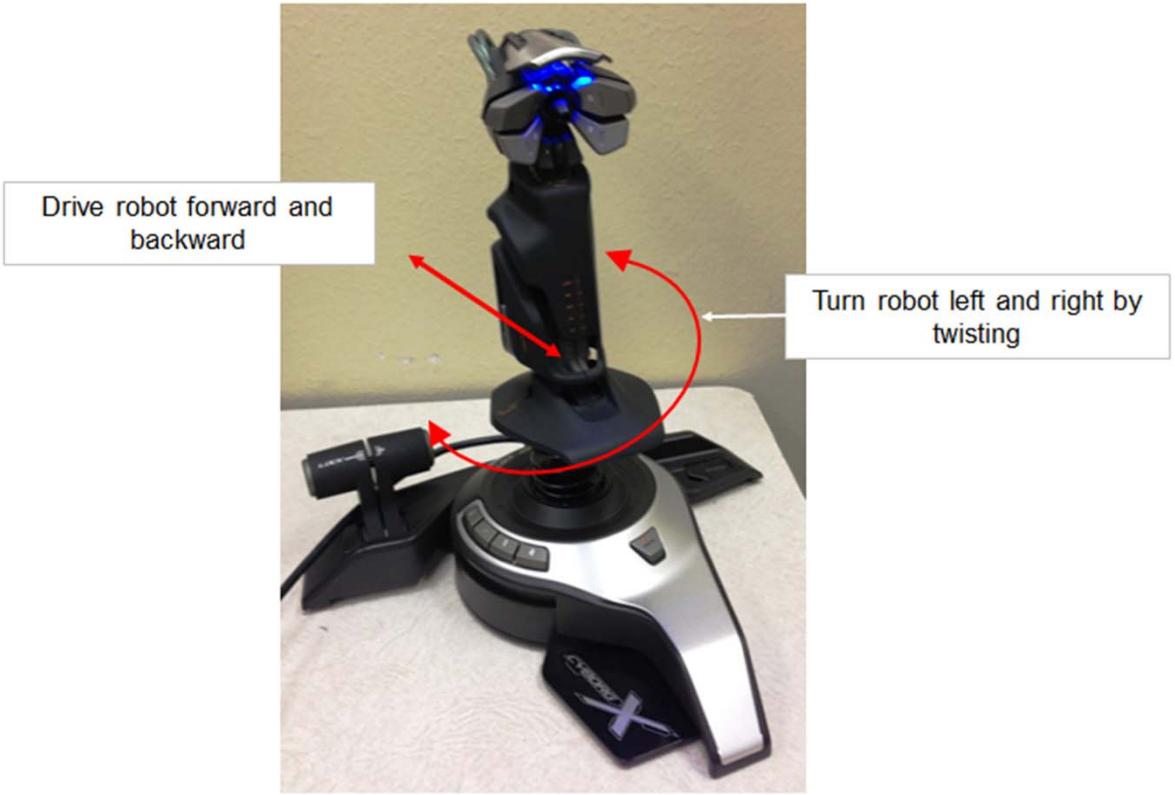
Study 2
Driving course





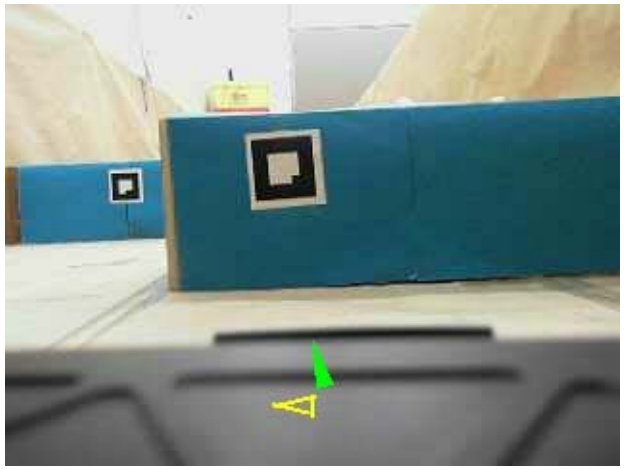
Study 2
Robot and joystick

TurtleBot

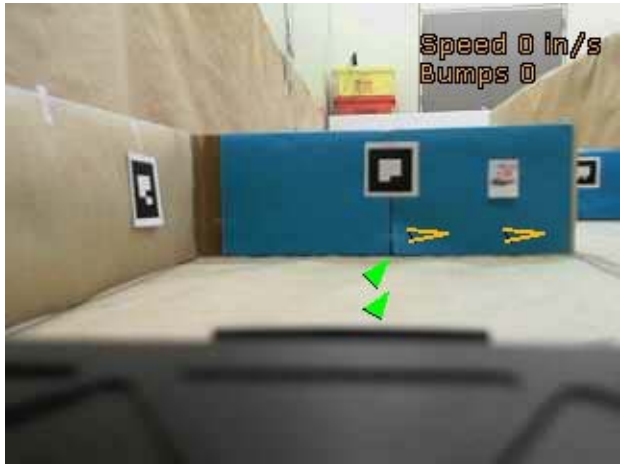


Saitek Cyborg joystick

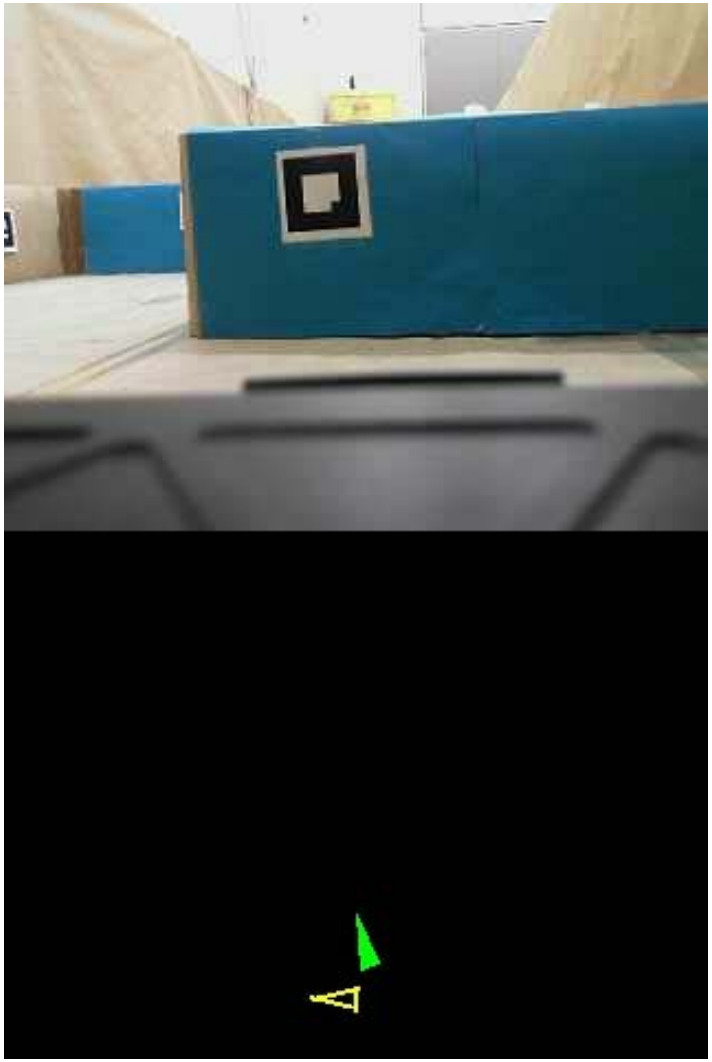
Study 2
Overlay conditions



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 predicable
  - 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