Developing and Evaluating Ecologically Valid Study Tasks to Investigate Human-Robot Teaming

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Background & Motivation

Gap 1: Characterizing Psychological Safety

Psychological Safety: "the shared belief held by members of a team that the team is safe for interpersonal risk taking" [3]

→ Studied extensively in large human-human teams and associated with higher personal engagement and performance

→ **Gap in studying psychological safety in operational environments and human-robot interaction (HRI)**

Gap 2: Current Methods in Study Tasks

Researchers often employ computer-based tasks, simplified physical tasks, or completely in-the-wild tasks [2,4,5]

Ecological validity: the degree to which proximal cues in the laboratory are correlated to the environment [1]

→ Study setup elicits responses directly relevant to intended environments

→ **Gap in development of ecologically valid study tasks that are both controlled and relevant to operational environments**

Objective

Develop and evaluate **ecologically valid tasks** that:
1) mimic spaceflight surface **operations** and
2) can be implemented in an experiment investigating team dynamics constructs that contribute to **psychological safety** in **human-robot collaboration**

Task Development & Study Methods

Task Development Process

Study Task Criteria	
Ecological Validity	Psychological Safety
Derived from real human spaceflight surface operation tasks	Induces interpersonal risk-taking
Mimics parameters of spaceflight surface operations	Induces some form of creativity
Feasible to execute in the laboratory	Has quantifiable performance metrics
Mimics human-robot team dynamics during operations	Can be accomplished in collaboration with a robotic agent

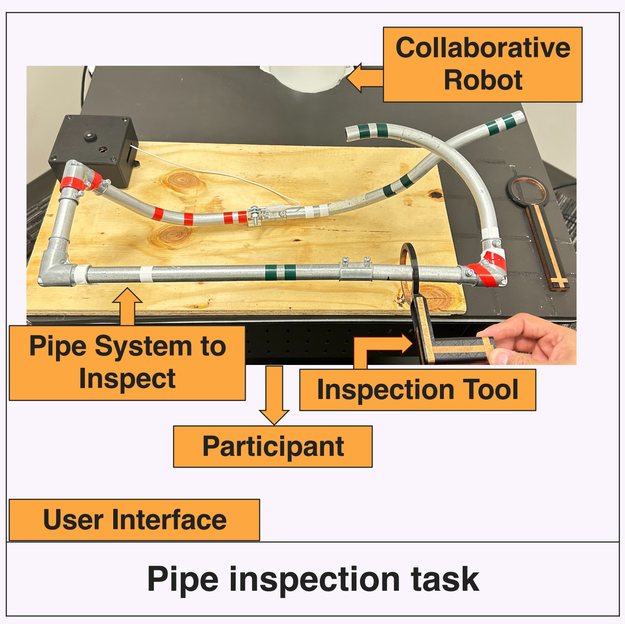
Experimental Design

Within-participants (n = 33)	**Gender** = 15 female, 16 male, 2 transgender **Sex assigned at birth** = 16 female, 17 male **Mean age** = 29.7±10.9 years

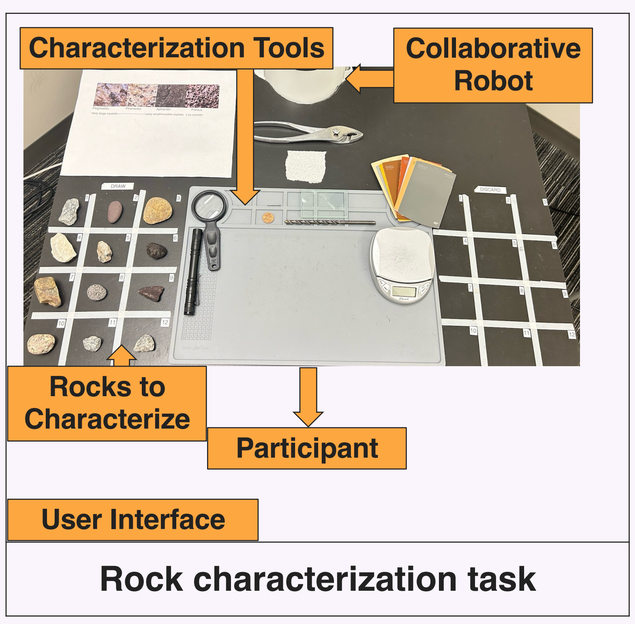
12 trials (3 minutes each)

6 pipe inspection trials (randomized)		6 rock characterization trials (randomized)	
3 trials w/ human	3 trials w/ robot	3 trials w/ human	3 trials w/ robot

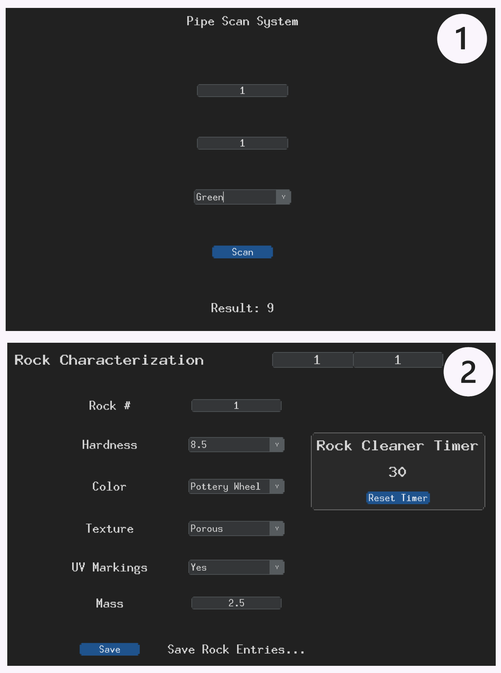
Task Setup



Pipe inspection task



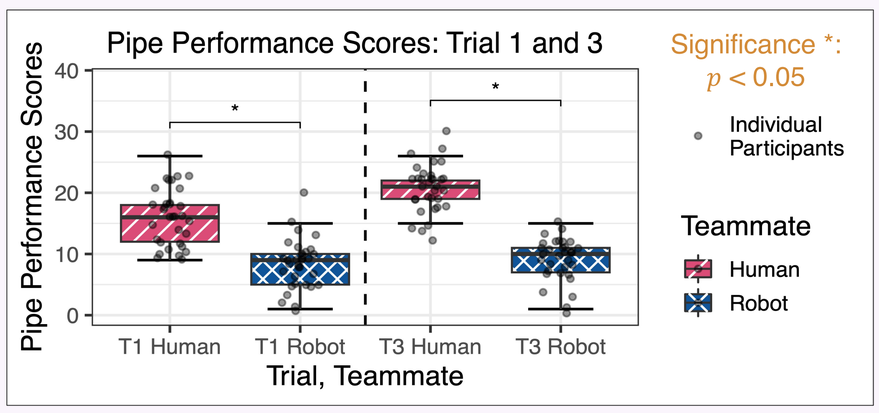
Rock characterization task



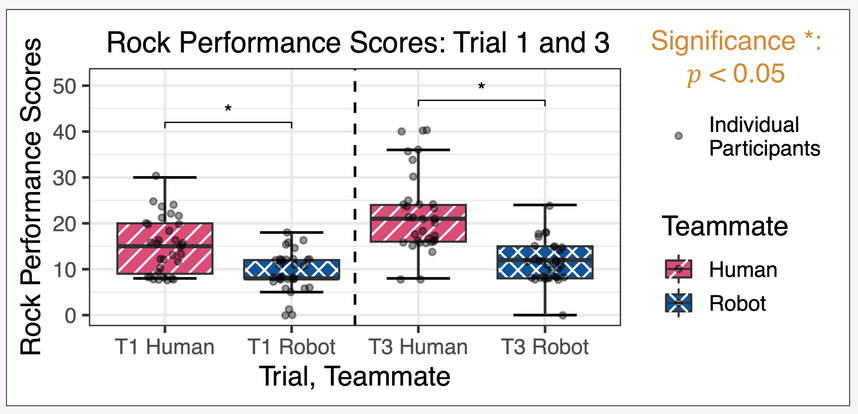
User interface for
1) pipe task and 2) rock task

Robot teammate: Franka Research 3
7 degrees of freedom robotic arm

Task Evaluation: Results



Task performance scores from Trial 1 and Trial 3 for pipe tasks.



Task performance scores from Trial 1 and Trial 3 for rock tasks.

Repeated Measures ANOVA Results: Task performance as it relates to teammate type and trial number		
	Pipe Inspection Task	Rock Characterization Task
Main effect: Teammate	$F_{(1,32)} = 307.16$, $p < 0.05$, $\eta^2_p = 0.88$	$F_{(1,32)} = 86.37$, $p < 0.05$, $\eta^2_p = 0.80$
Main effect: Trial	$F_{(1.69,54.23)} = 11.32$, $p < 0.05$, $\eta^2_p = 0.26$	$F_{(1.66,53.09)} = 28.01$, $p < 0.05$, $\eta^2_p = 0.47$
Interaction effect: Teammate x Trial	$F_{(1.96,62.80)} = 7.63$, $p < 0.05$, $\eta^2_p = 0.19$	$F_{(1.87,59.99)} = 6.87$, $p < 0.05$, $\eta^2_p = 0.18$

Post-hoc results: Significant differences between earlier and later trials for human pipe, human rock, and robot rock combinations
Significant differences between human and robot performance scores across trials 1-3 for pipe and rock tasks

Pipe Performance Scores Over Trials 1-3		
Trial	Human Score (M±SD)	Robot Score (M±SD)
1	16.12 ± 4.68	8.33 ± 3.97
2	19.15 ± 4.89	8.82 ± 3.21
3	20.64 ± 3.88	9.12 ± 3.45

Rock Performance Scores Over Trials 1-3		
Trial	Human Score (M±SD)	Robot Score (M±SD)
1	15.18 ± 6.12	9.45 ± 4.37
2	19.33 ± 7.46	11.39 ± 4.21
3	22.15 ± 8.74	11.61 ± 4.48

Discussion

Participants demonstrated higher performance scores when working with a human vs. robot teammate.

Unequal capabilities of teammates + 82% of participants having less experience with robots may explain lower performance with robot.

Performance scores increased over trials (more for human), indicating possible learning effects.
→ Implications for task ordering

Conclusion & Future Work

These **collaborative**, **ecologically valid** study tasks that are **operationally relevant** to human spaceflight elicit significant performance differences that may be relevant to **human-human and human-robot team dynamics.**

Analyze teaming questionnaires, physiological data, and behavioral data

Equalize capabilities between active teammates

References

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Video

Contact & Connect

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