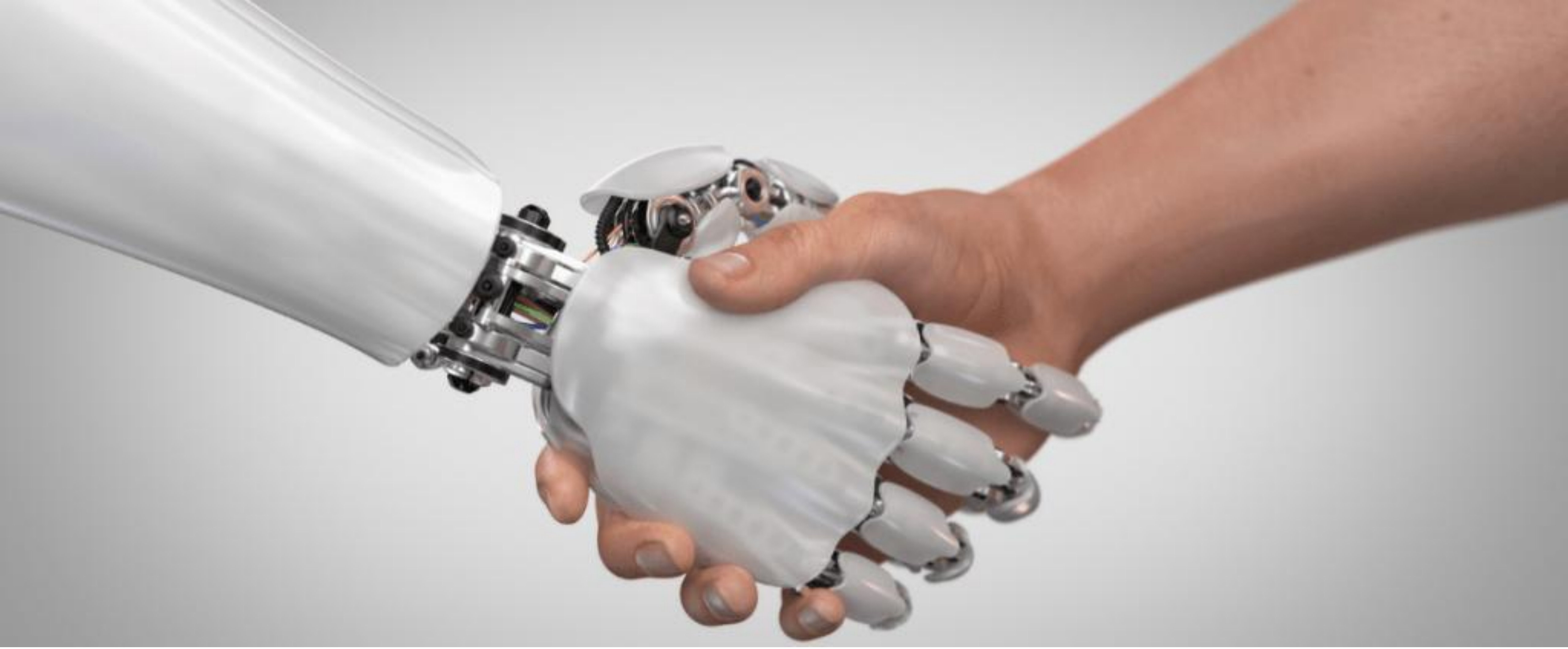


Improving Human-Robot Interaction in Shared Workplaces

Alap Kshirsagar

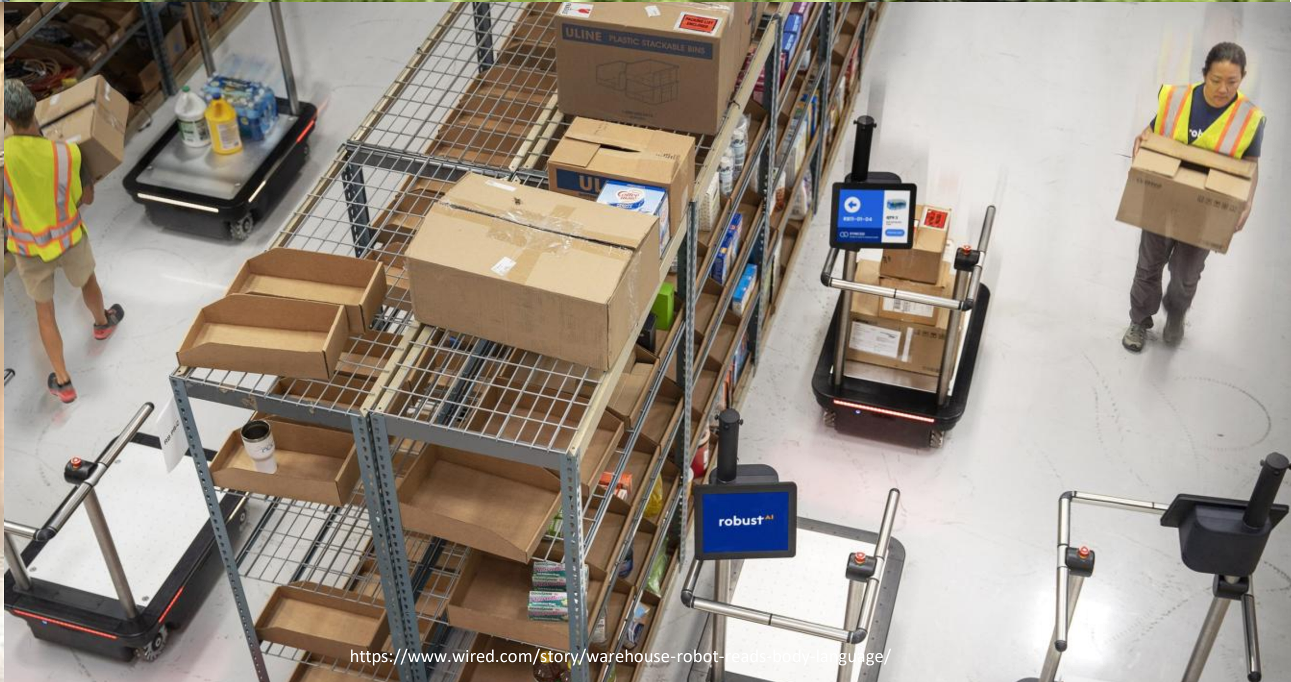
Postdoctoral Researcher, Intelligent Autonomous Systems Group, TU Darmstadt

Increasing shift toward a human-robot joint workforce

https://www.kuka.com/en-de/future-production/human-robot-collaboration

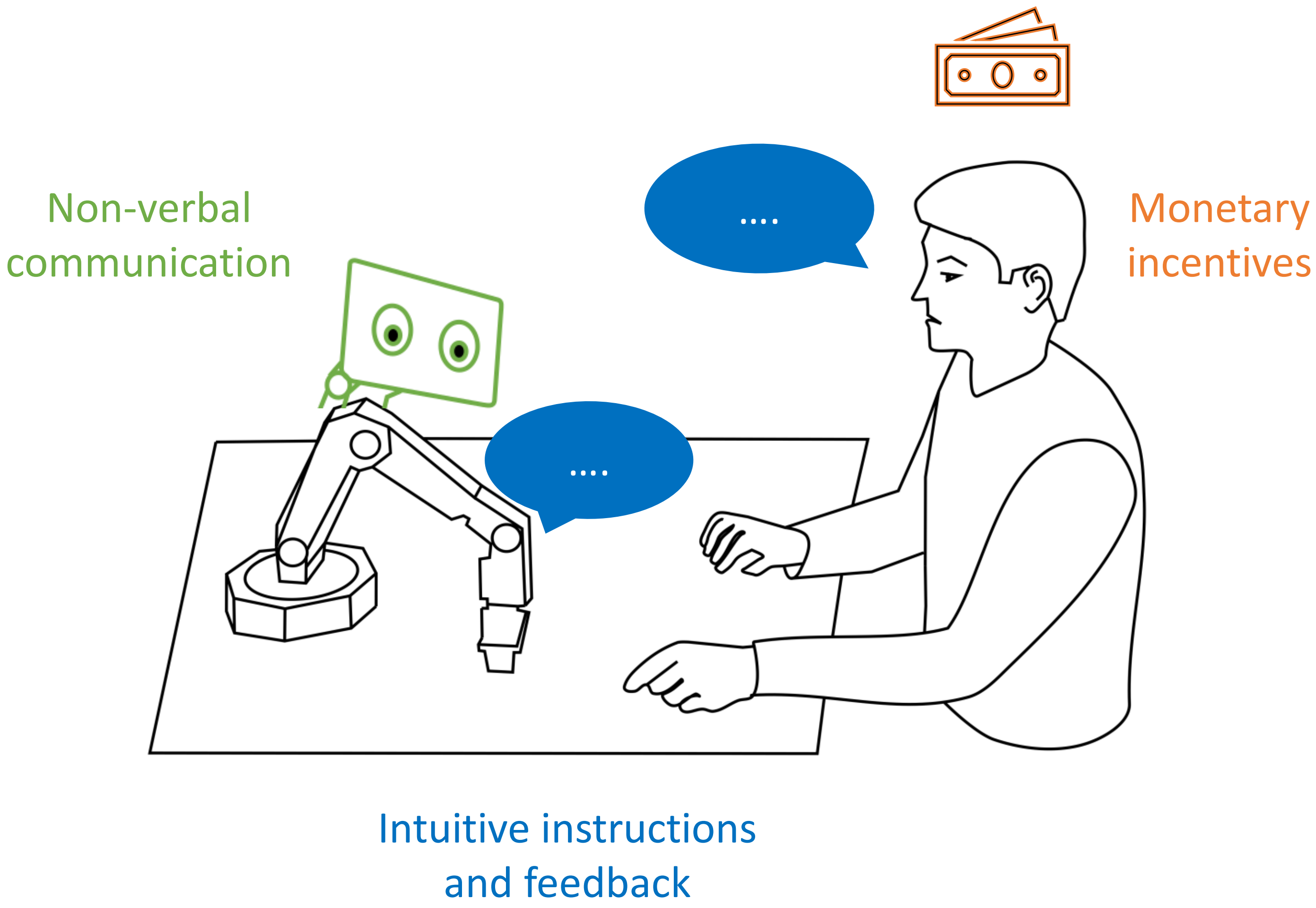
http://www.eng.cam.ac.uk/news/world-s-first-centre-doctoral-training-agri-food-robotics


https://www.txinnovators.com/post/diligent-robotics-moxi-robot



https://www.wired.com/story/warehouse-robot-reads-body-language/

How to improve human-robot interaction in shared workplaces?



Collaborators

Cornell University, USA
Dr. Guy Hoffman, Dr. Hadas Kress-Gazit, Rahul Kumar Ravi, Shemar Christian, Song Ye, Julie Katz

Ben-Gurion University of the Negev, Israel
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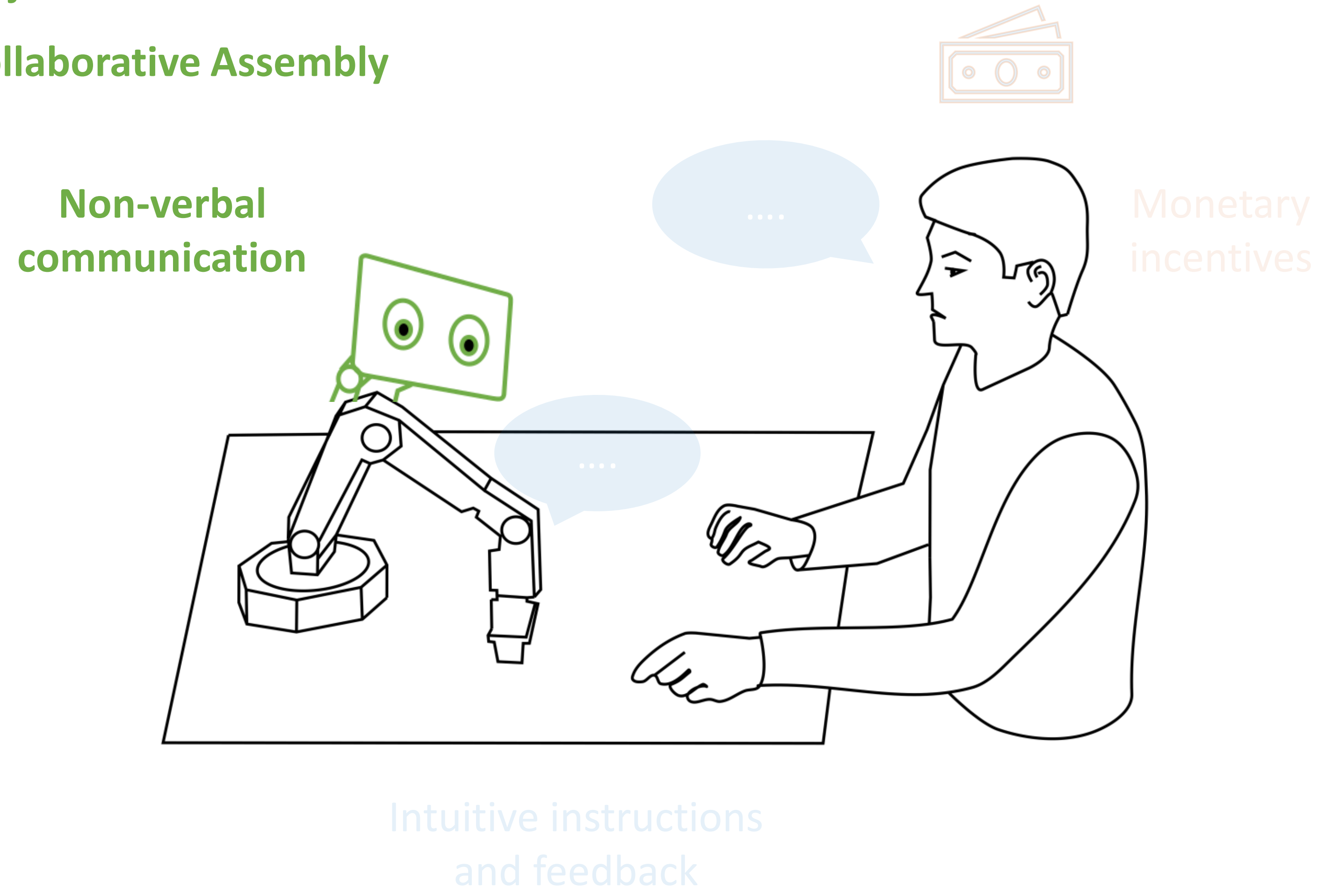
How to improve human-robot interaction in shared workplaces?

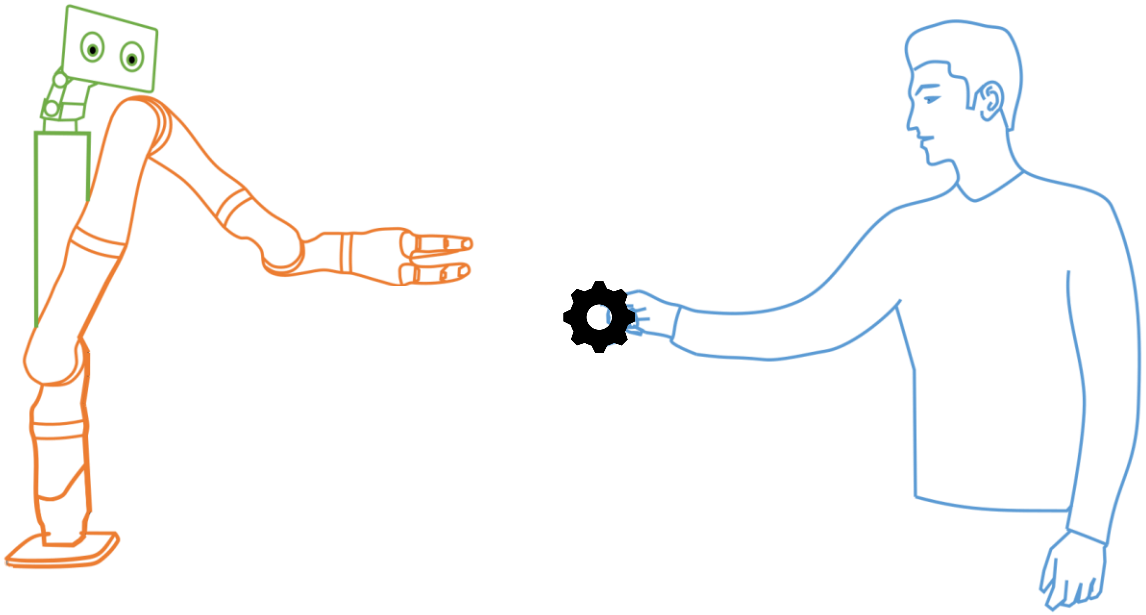
Task 1: Human-Robot Object Handovers

Task 2: Human-Robot Collaborative Assembly



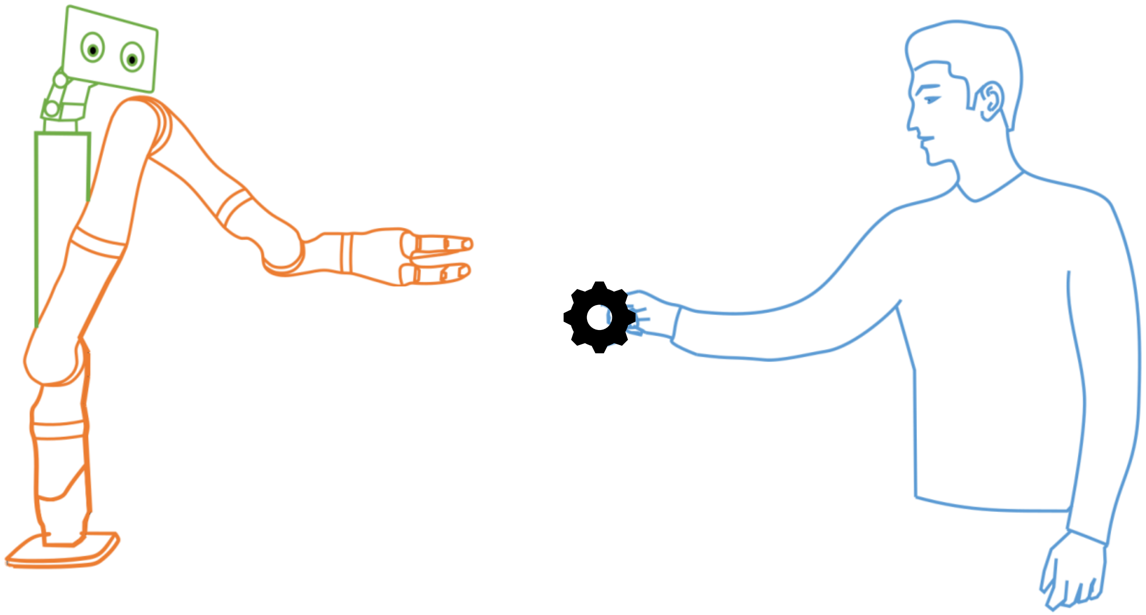
Task 1 : Human-Robot Object Handovers

Which gaze behavior should the robot use when it receives an object from a human?



Gaze Behaviors in Human-to-Human Handovers

Which gaze behavior should the robot use when it receives an object from a human?



Which gaze behaviors do humans use in human-human handovers?

Gaze Behaviors in Human-to-Human Handovers

Dataset: Carfì, Alessandro, et al. "A multi-sensor dataset of human-human handover." Data in brief 22 (2019): 109-117

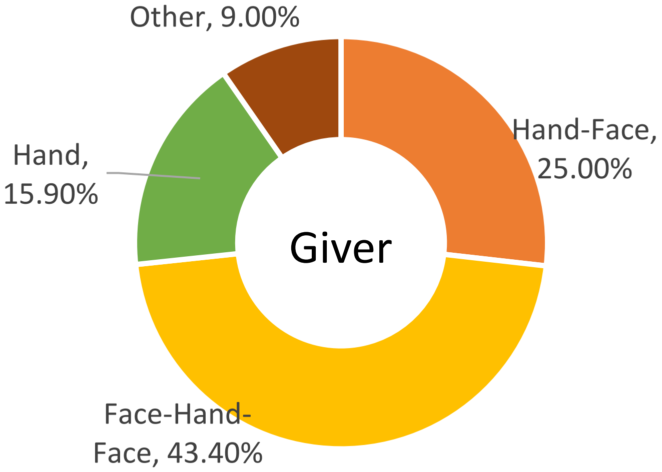
288 handovers, 14214 frames
Annotations: Gaze Location, Handover Phase

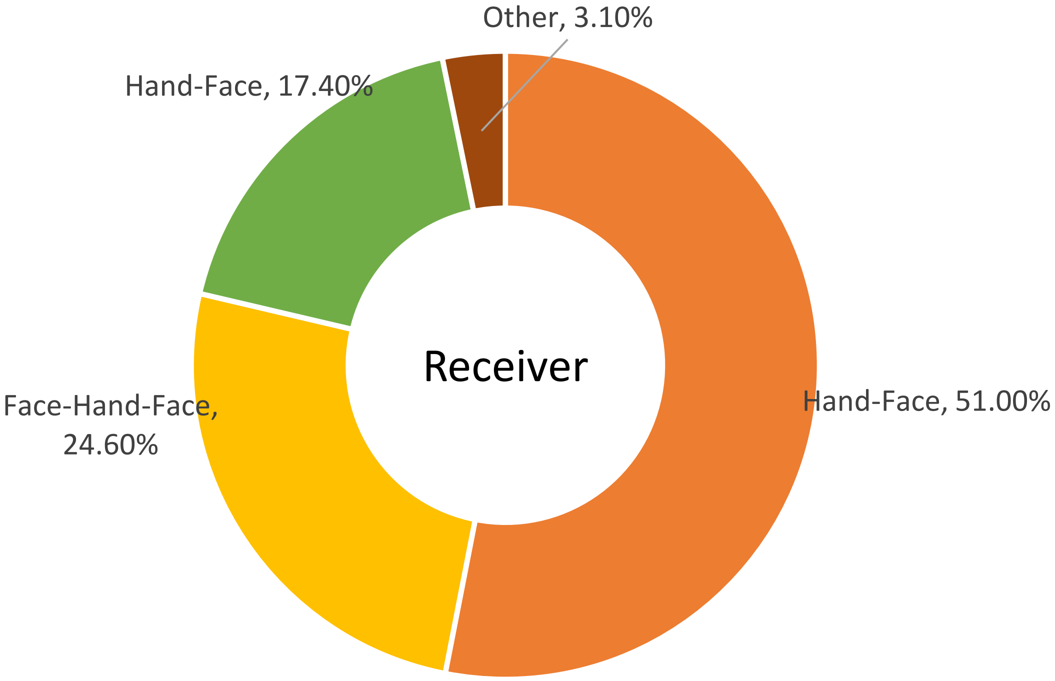
T Sela*, A Kshirsagar*, Y Edan and G Hoffman, "Human Preferences for Robot Eye Gaze in Human-to-Robot Handovers", International Journal of Social Robotics, 2022

Gaze Behaviors in Human-to-Human Handovers

Gaze Behaviors

Hand-Face | Face-Hand-Face | Hand

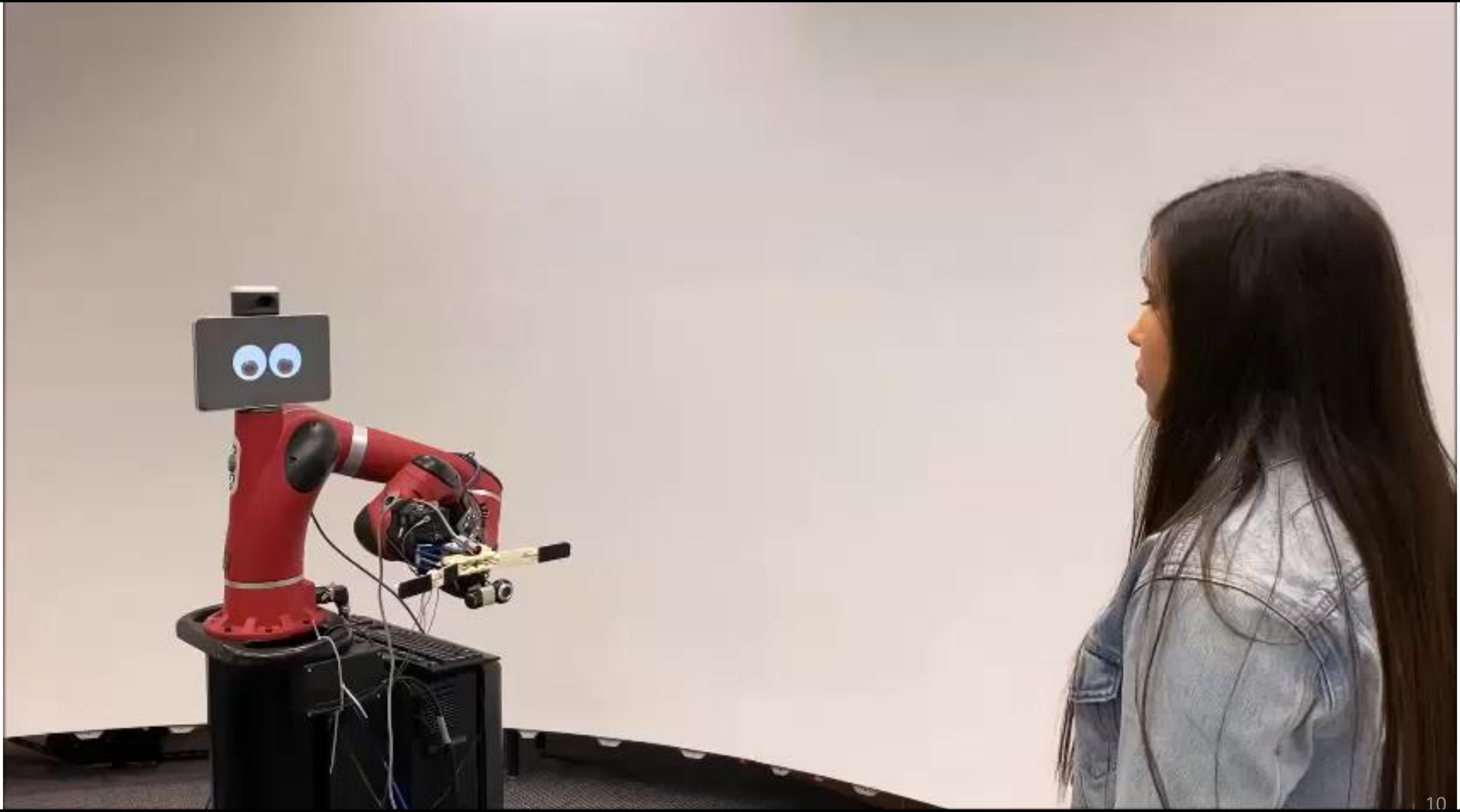




Inter-coder Agreement: 80.9% on 22.2% of the data

T Sela*, A Kshirsagar*, Y Edan and G Hoffman, “Human Preferences for Robot Eye Gaze in Human-to-Robot Handovers“, International Journal of Social Robotics, 2022

Robot Gaze Behaviors in Human-to-Robot Handovers



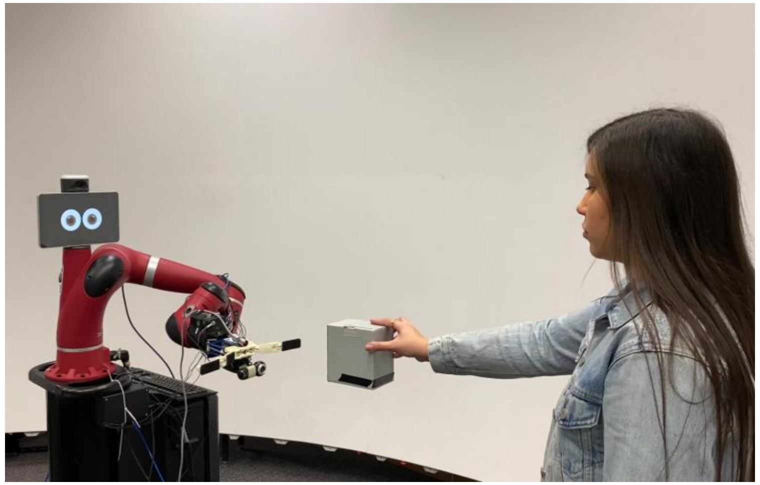
T Sela*, A Kshirsagar*, Y Edan and G Hoffman, “Human Preferences for Robot Eye Gaze in Human-to-Robot Handovers“, International Journal of Social Robotics, 2022

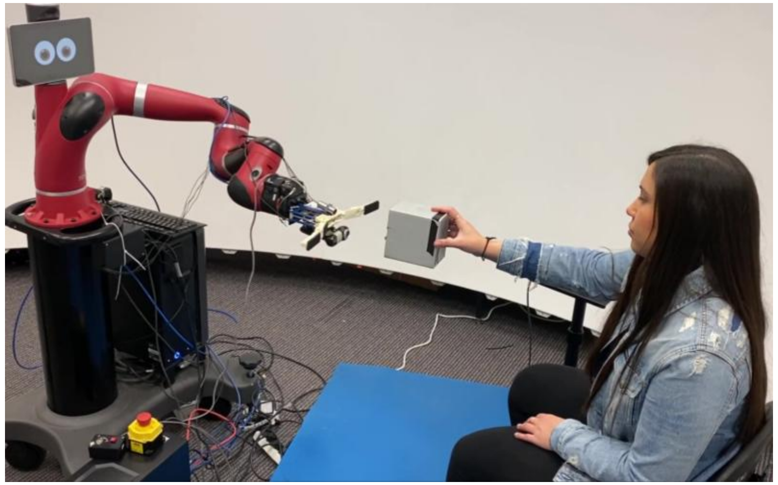
Which Robot Gaze Behavior is preferred in Human-to-Robot Handovers?

Study 1: Participants watched video recordings (Video Study), 72 participants

Study 2: Participants performed handovers (In-person Study), 72 participants

4 Objects, 2 Giver Postures





T Sela*, A Kshirsagar*, Y Edan and G Hoffman, "Human Preferences for Robot Eye Gaze in Human-to-Robot Handovers", International Journal of Social Robotics, 2022

Results: Human Preferences for Robot Receiver's Gaze Behavior

Human-Robot Video Study (likability) ($p < 0.001$) Face-Hand-Face > Hand-Face > Hand

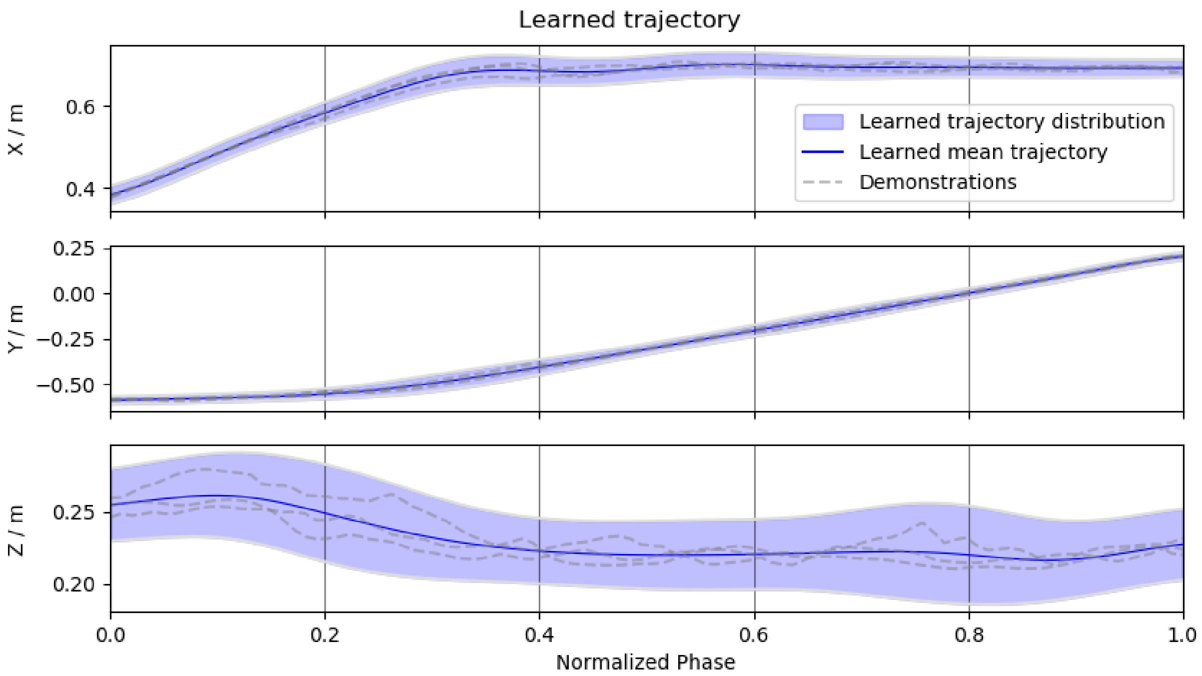
Human-Robot In-person Study (likability) ($p < 0.001$) Face-Hand-Face > Hand-Face > Hand

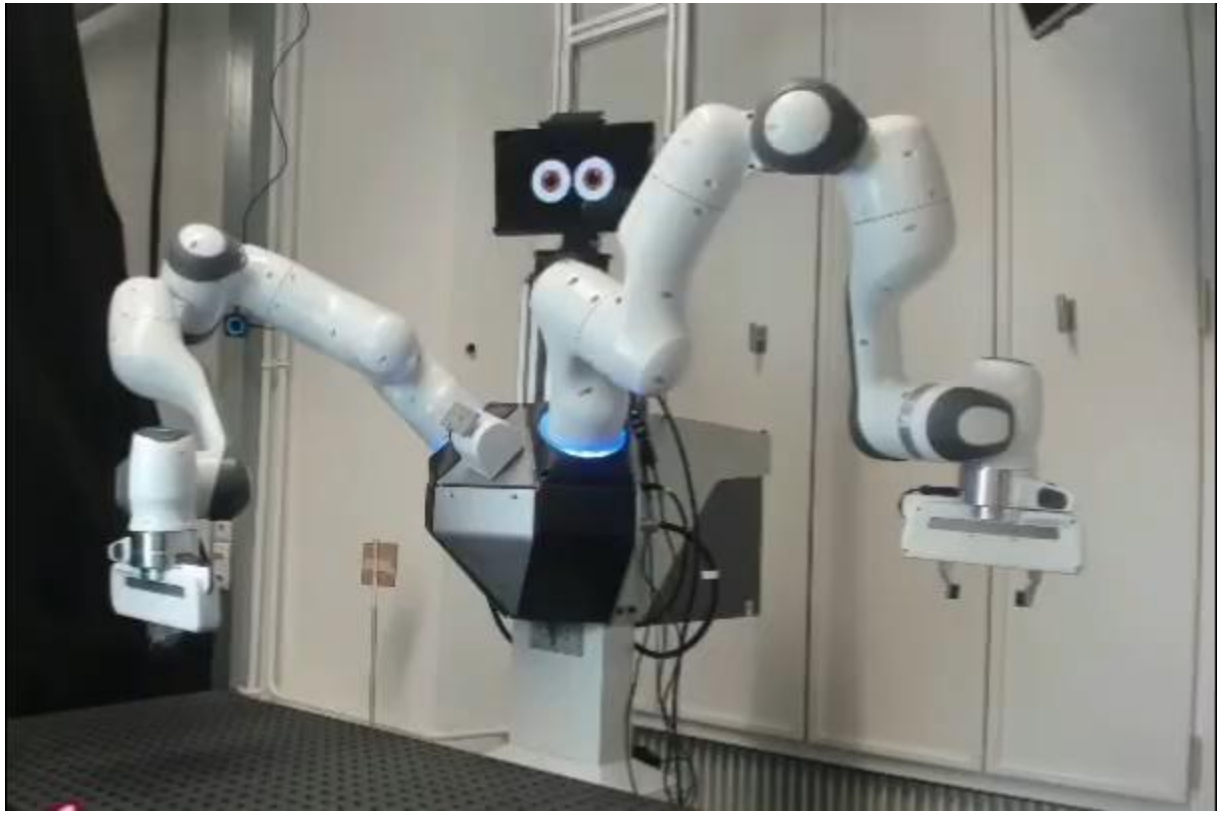
Same preference for 4 object types and 2 postures

T Sela*, A Kshirsagar*, Y Edan and G Hoffman, "Human Preferences for Robot Eye Gaze in Human-to-Robot Handovers", International Journal of Social Robotics, 2022

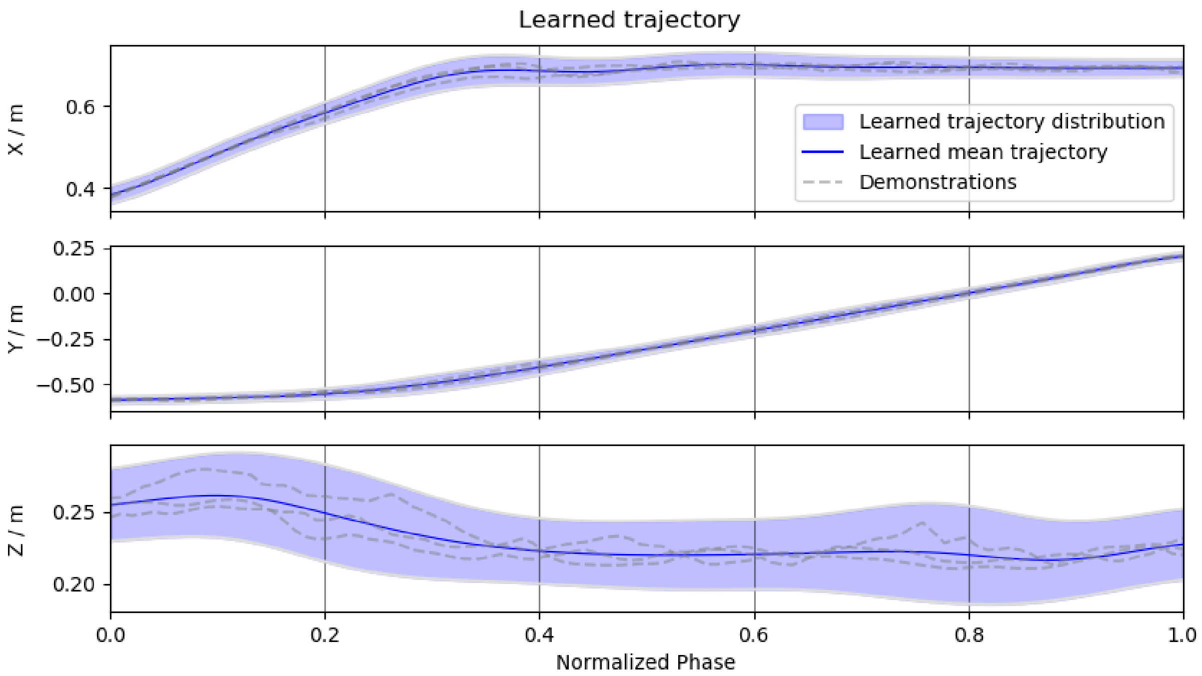
Task 2: Human-Robot Collaborative Assembly

Learning-from-Demonstrations

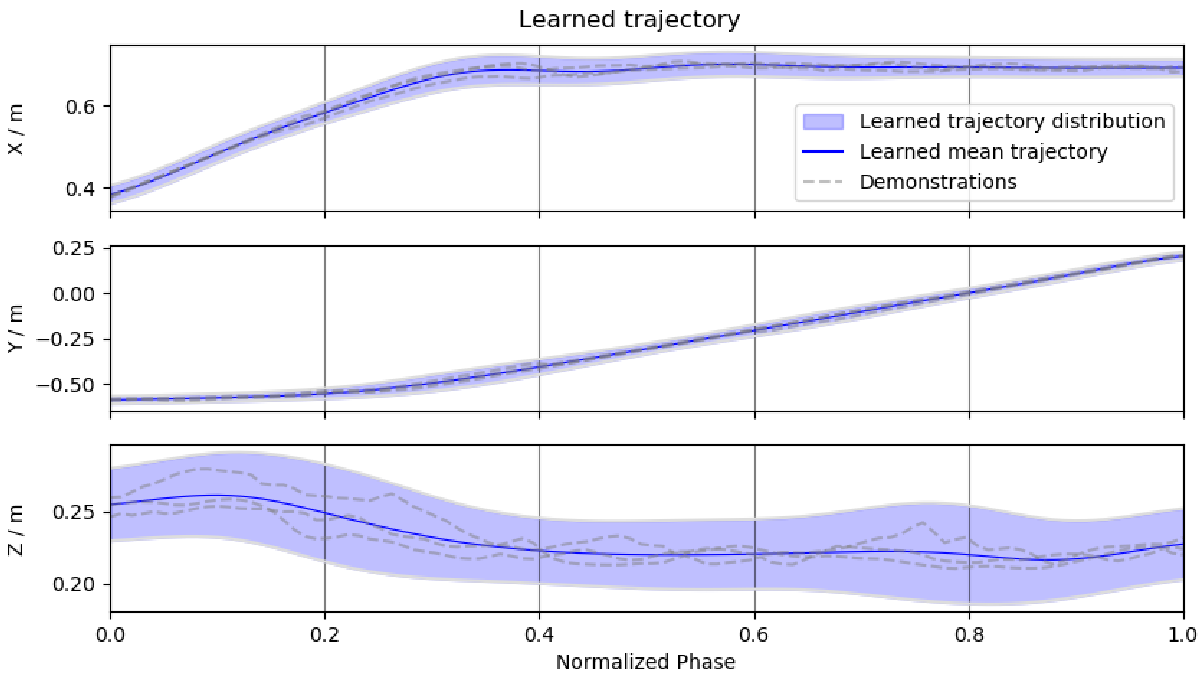




Collision Avoidance

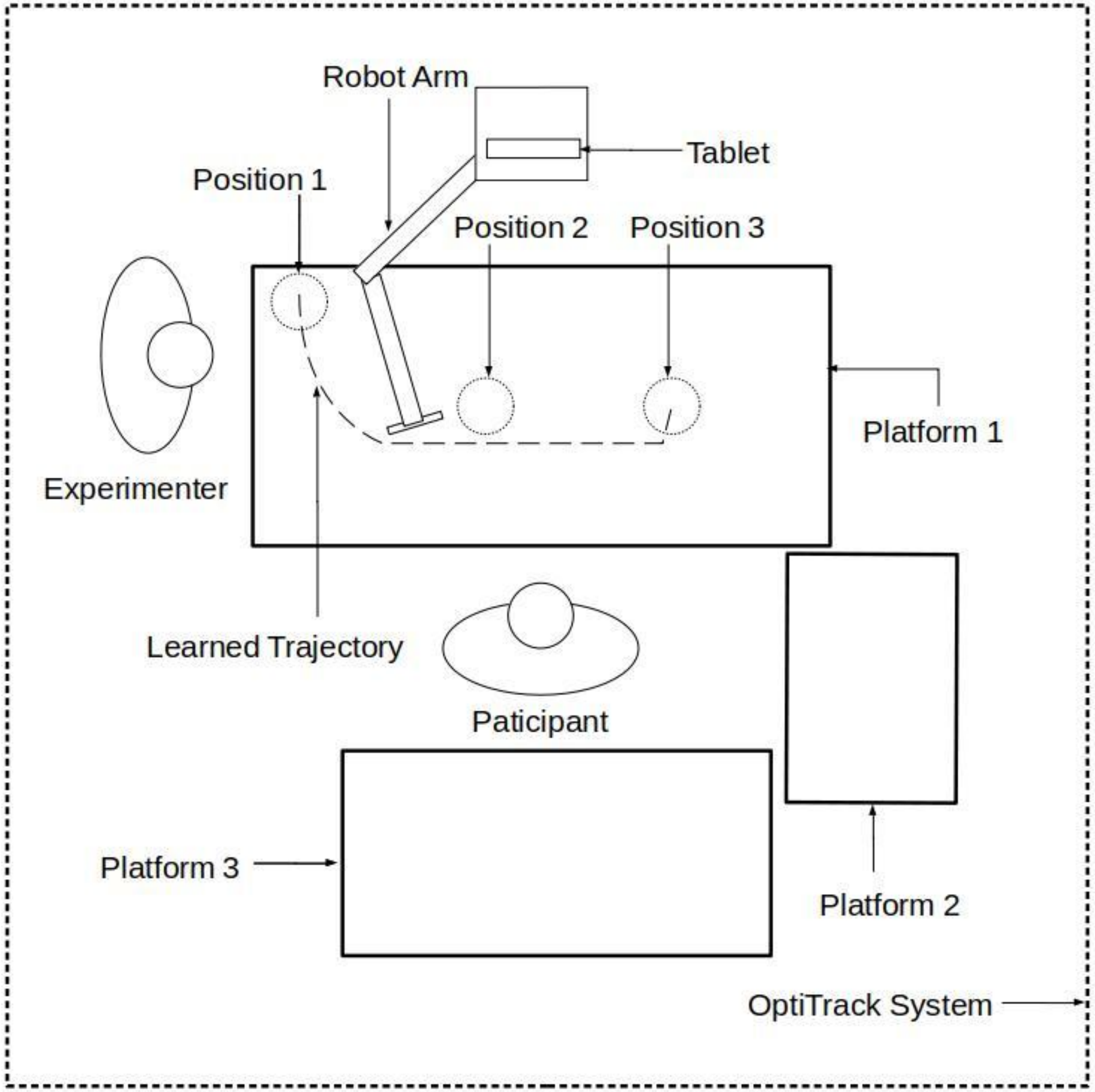


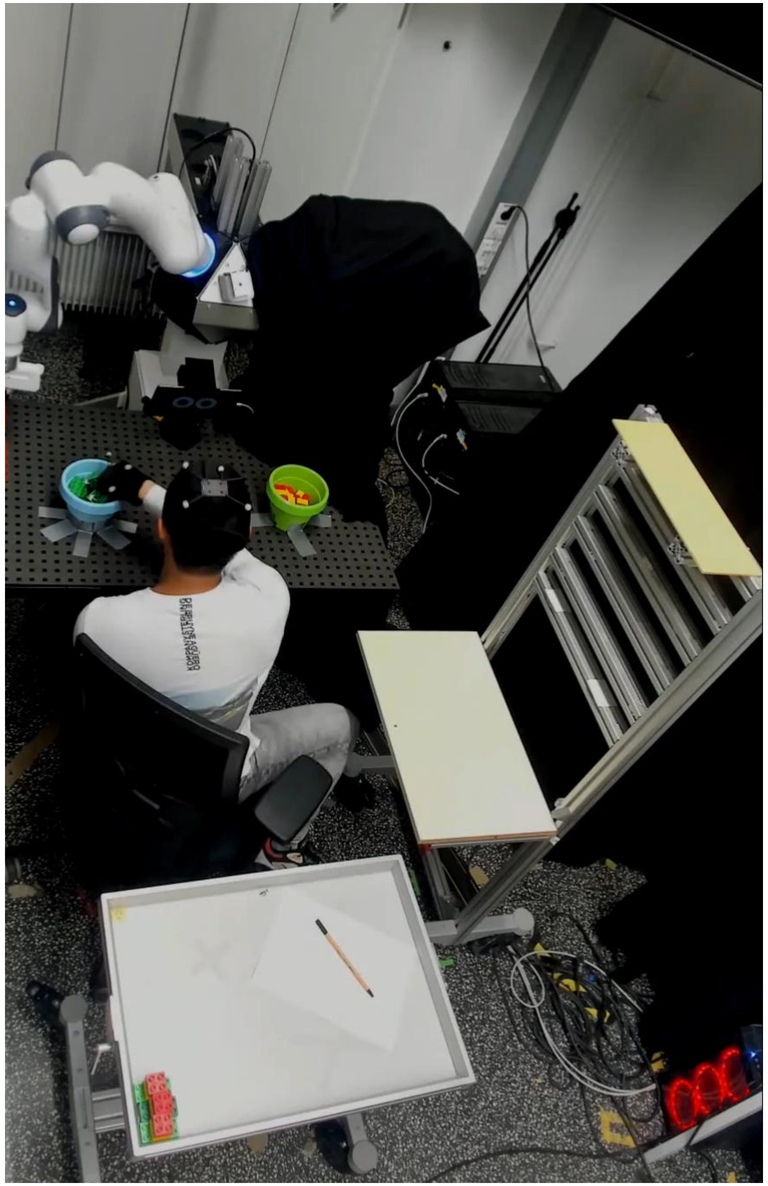
Collision Avoidance



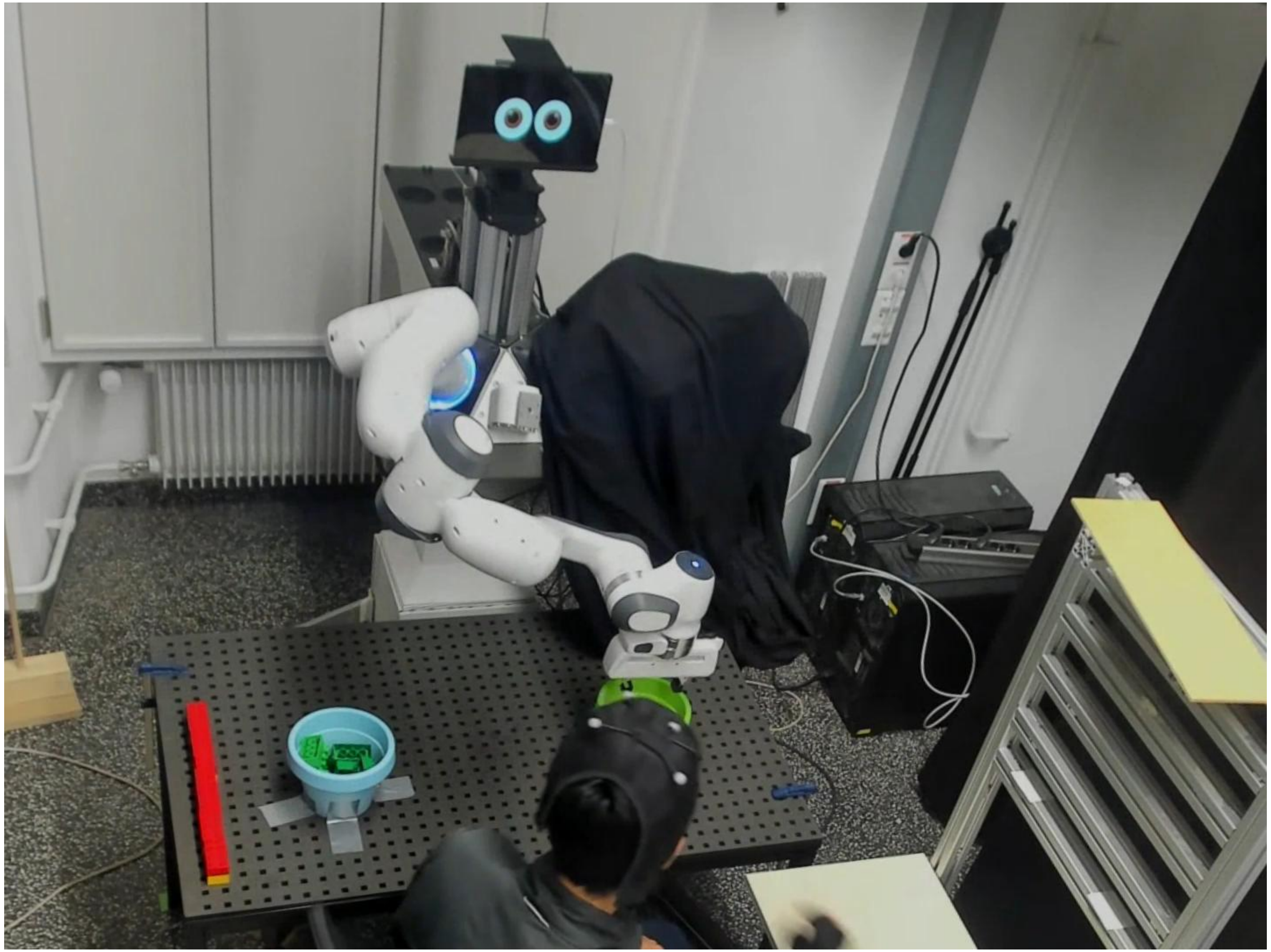
Which gaze behaviour should the robot use to communicate collision avoidance intent?

Experiment Setup



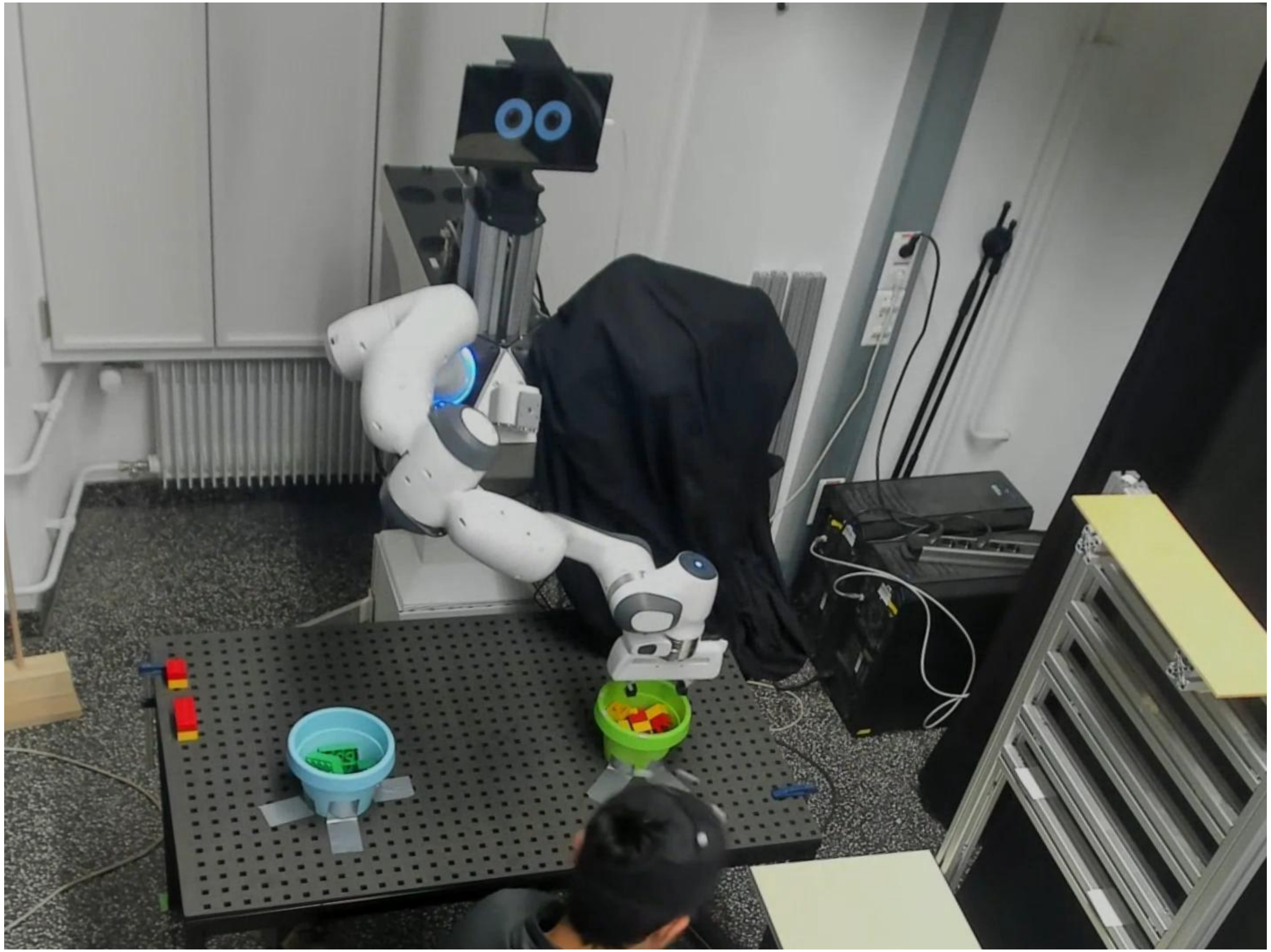


Condition A: The robot always looks forward

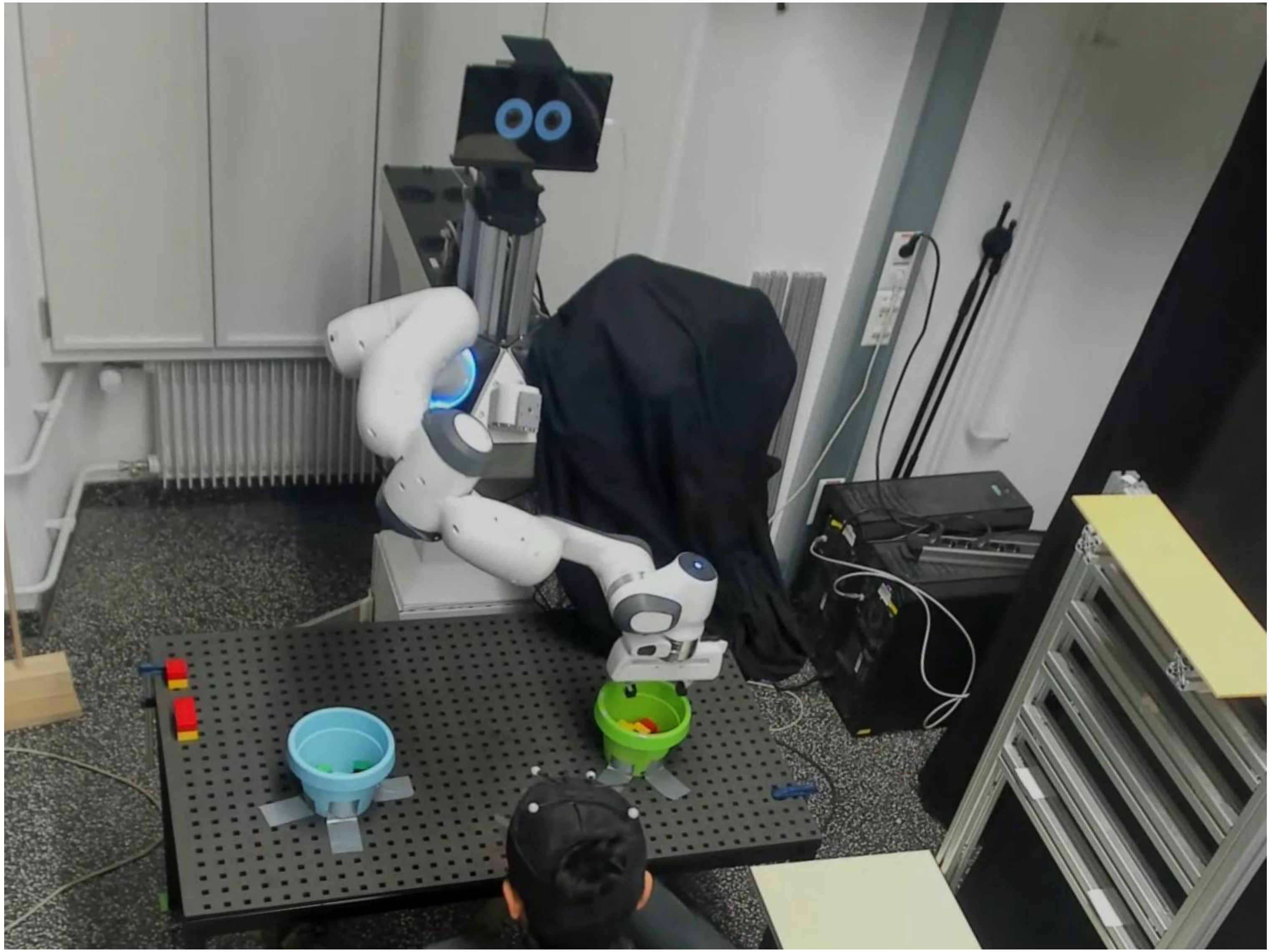


Robot Gaze Behaviors for Communicating Collision Avoidance Intent

Condition B: The robot looks at the human during collision risk

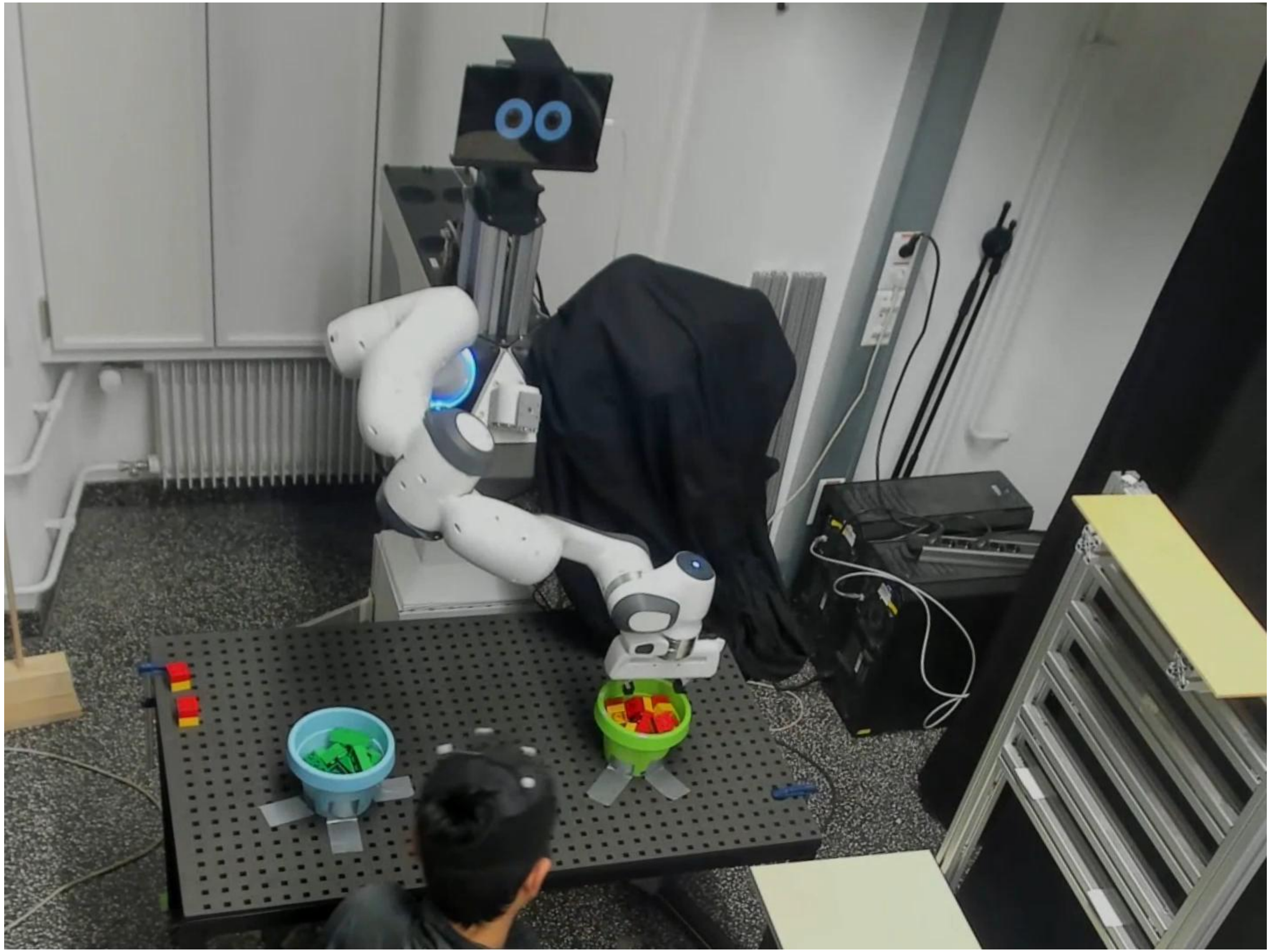


Condition C: The robot looks at the human and shakes its head during collision risk

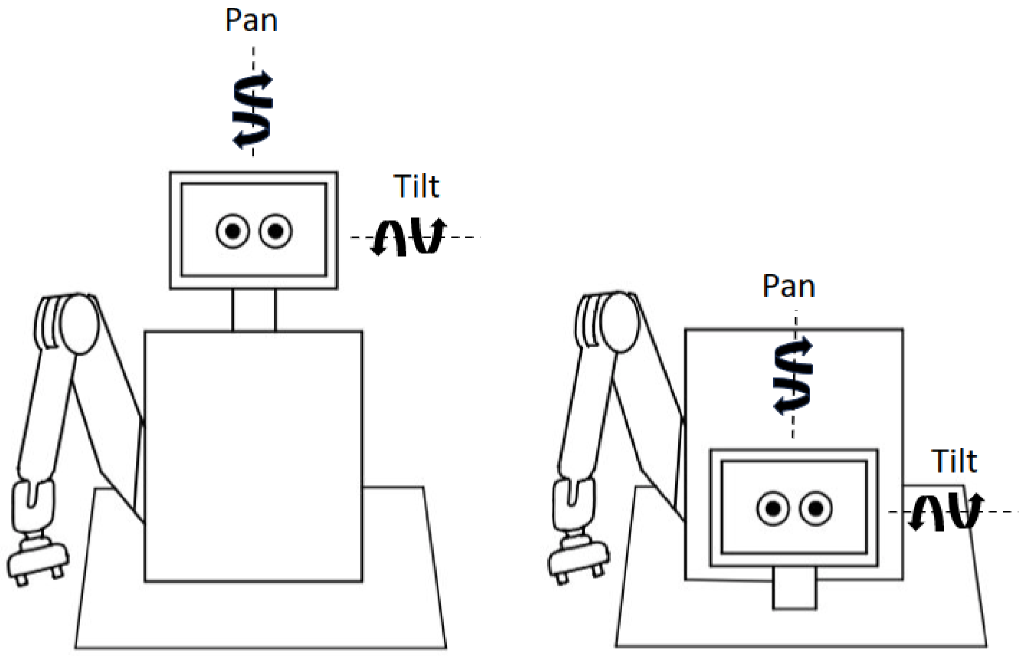


Robot Gaze Behaviors for Communicating Collision Avoidance Intent

Condition D: The robot nods or shakes its head depending on collision risk severity



Robot Gaze Behaviors for Communicating Collision Avoidance Intent



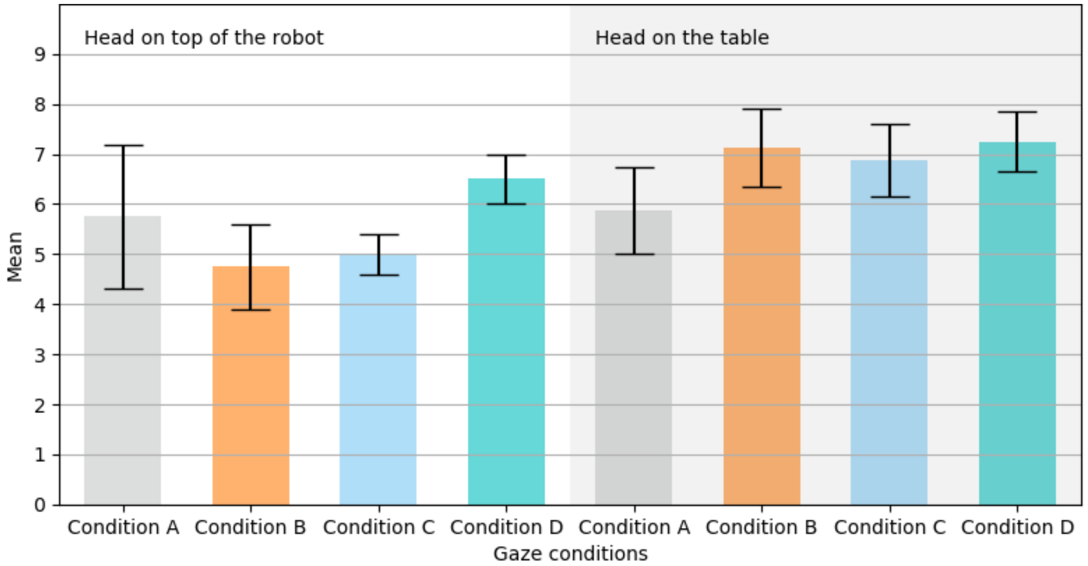
Head position 1

Head position 2

Robot Gaze Behaviors for Communicating Collision Avoidance Intent

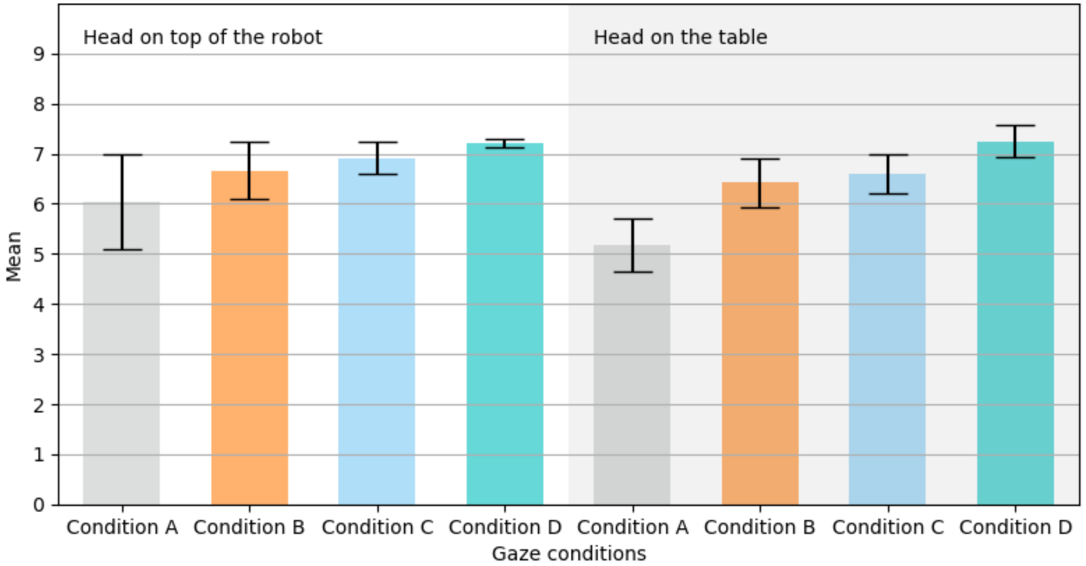
Pilot Study Results (10 Participants)

Intent Communication of the Robot



Head locations: p = .158
Gaze behaviors: p = .434

Perceived Competence of the Robot



Head locations: p = .472
Gaze behaviors: p = .004

Future Work

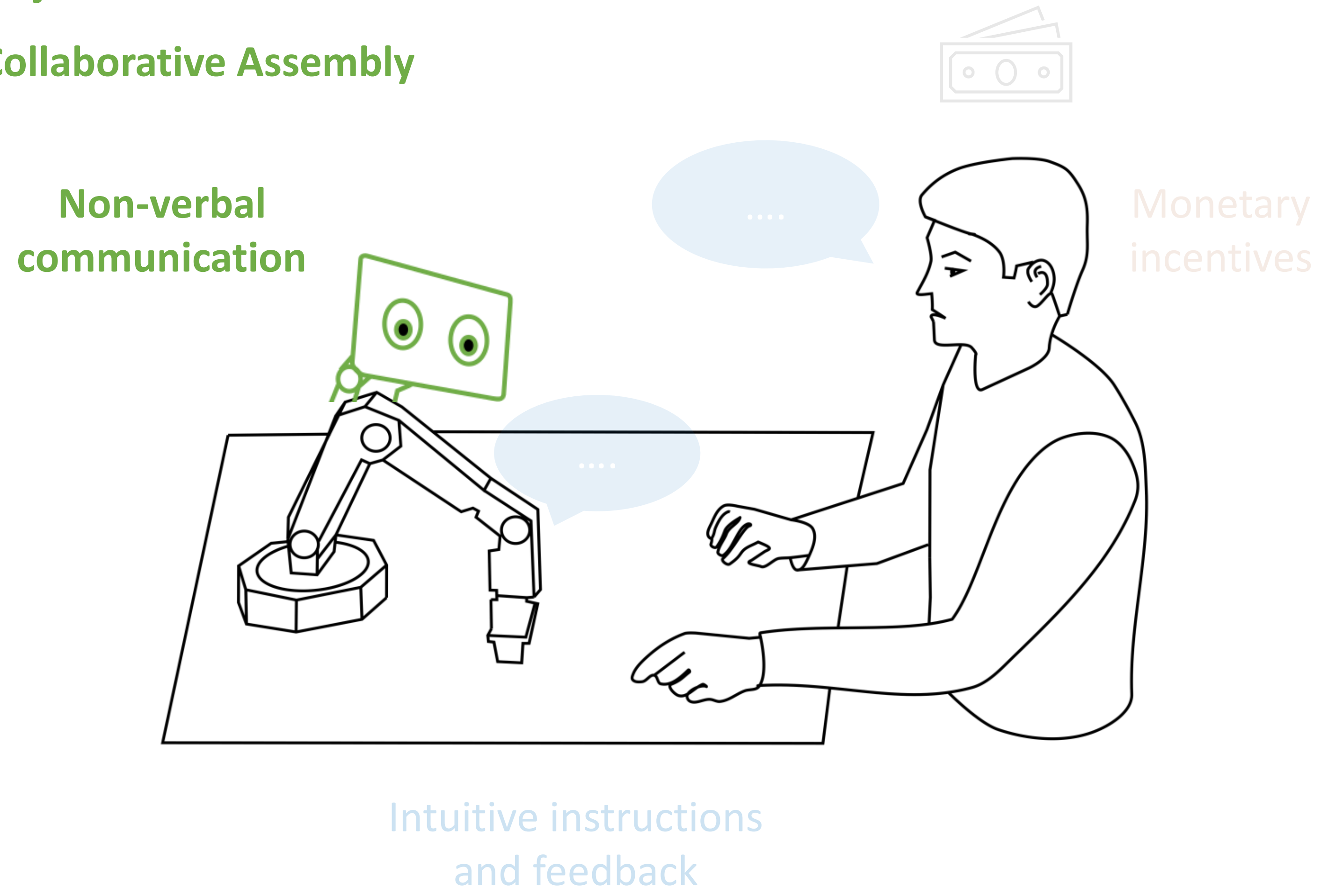
Other communication modalities: eye gazes, facial expressions, light-based signals

Human motion prediction

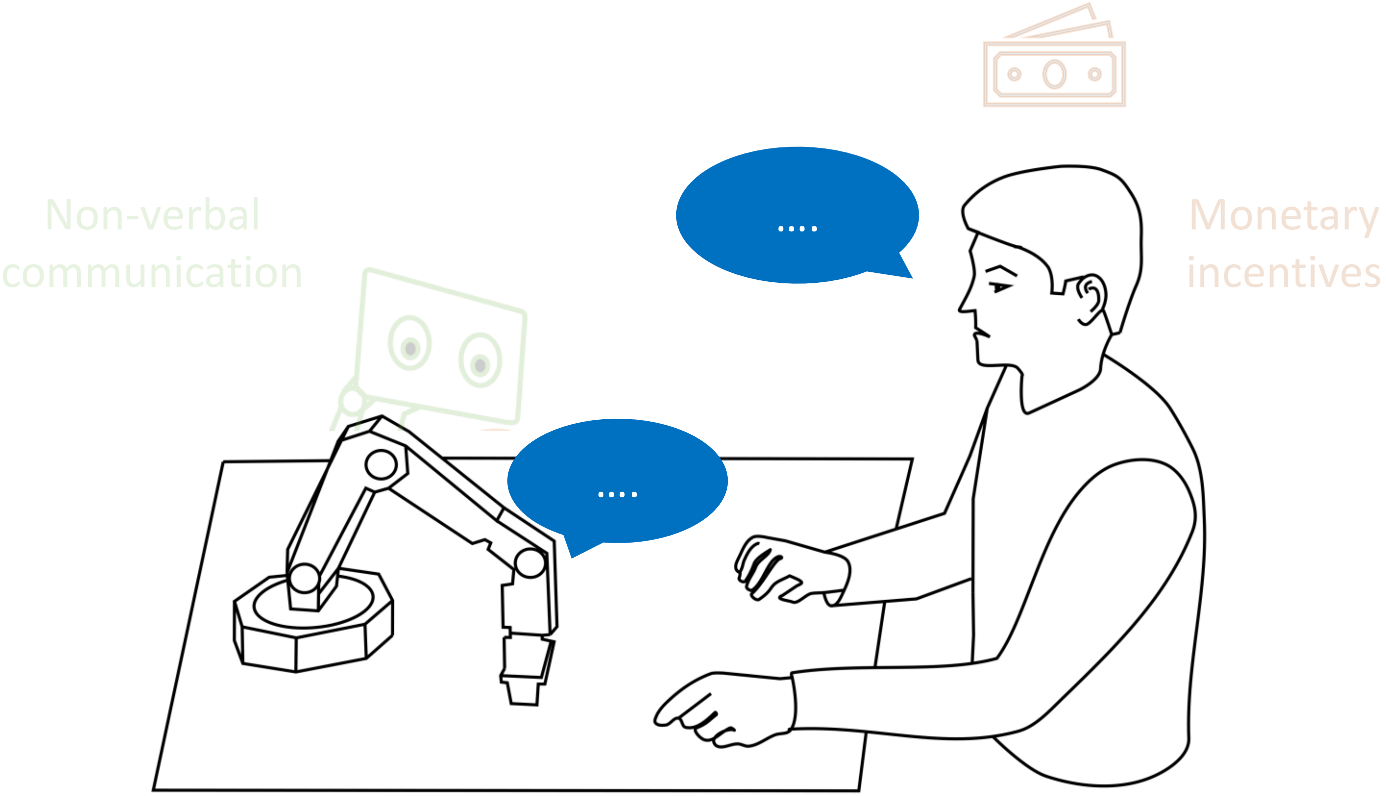
How to improve human-robot interaction in shared workplaces?

Study 1: Human-Robot Object Handovers

Study 2: Human-Robot Collaborative Assembly



How to improve human-robot interaction in shared workplaces?



Intuitive instructions and feedback

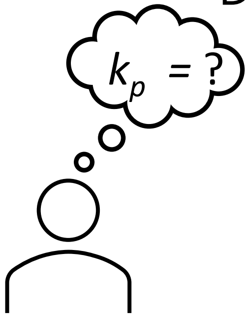
Drawback of Existing Robot Controllers : Non-intuitive Parameters

Proportional Velocity Controller

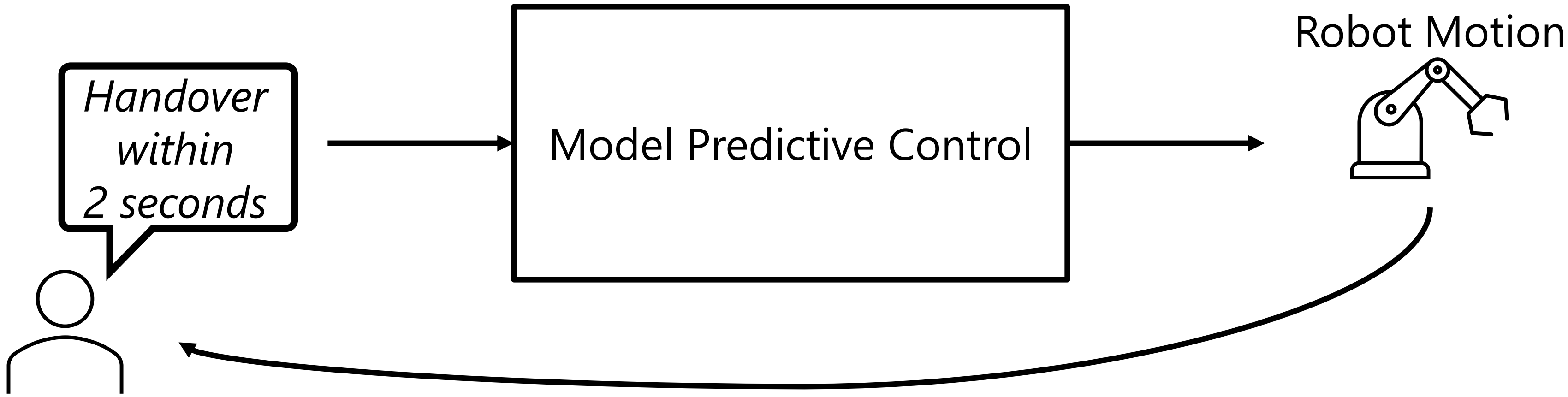
$$\boldsymbol{u}_t = k_p ||\boldsymbol{x}_t - \boldsymbol{h}_t||$$

Robot’s Velocity

Distance Between Robot and Target



“Timing” as a controller parameter? Feedback?



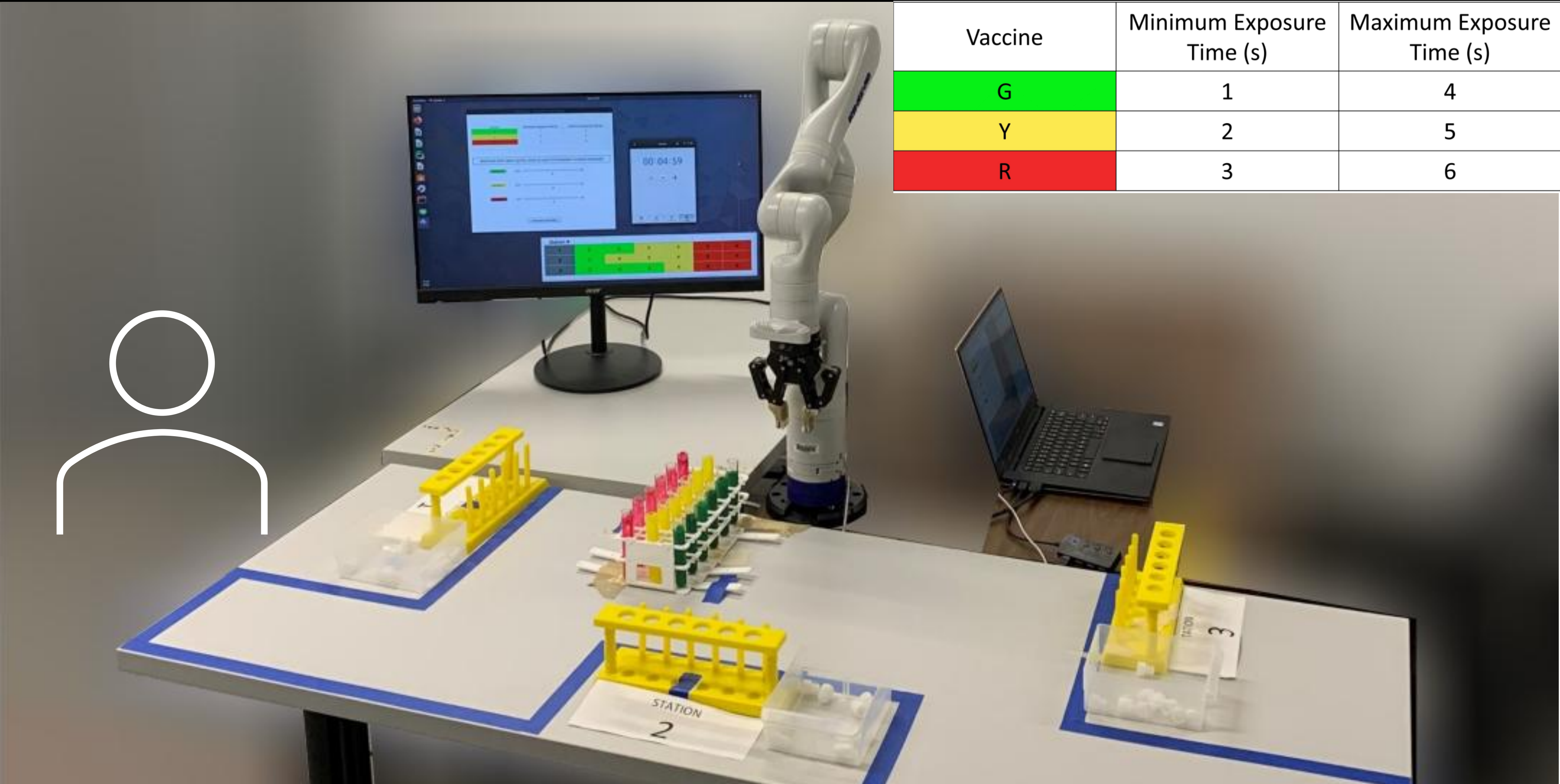
Failure Feedback : *“I can’t reach your hand within 2 seconds”*

Research Question: Does this controller improve user experience and task performance?

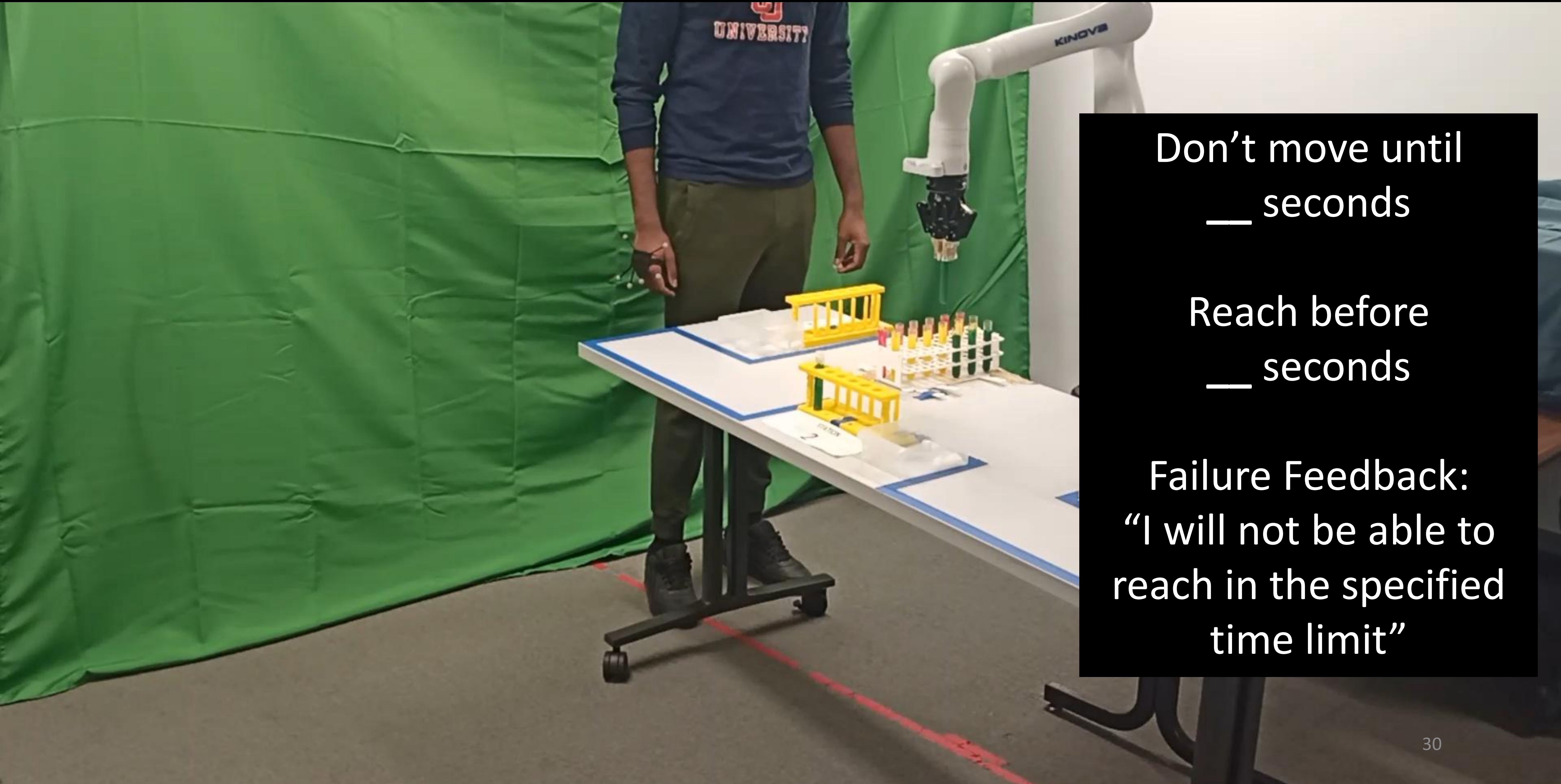
A. Kshirsagar*, R. Ravi*, H. Kress-Gazit and G. Hoffman, “Timing-specified Controllers with Feedback for Human-Robot Handovers”, ROMAN, 2022

User Study

Vaccine	Minimum Exposure Time (s)	Maximum Exposure Time (s)
G	1	4
Y	2	5
R	3	6



Timing Controller

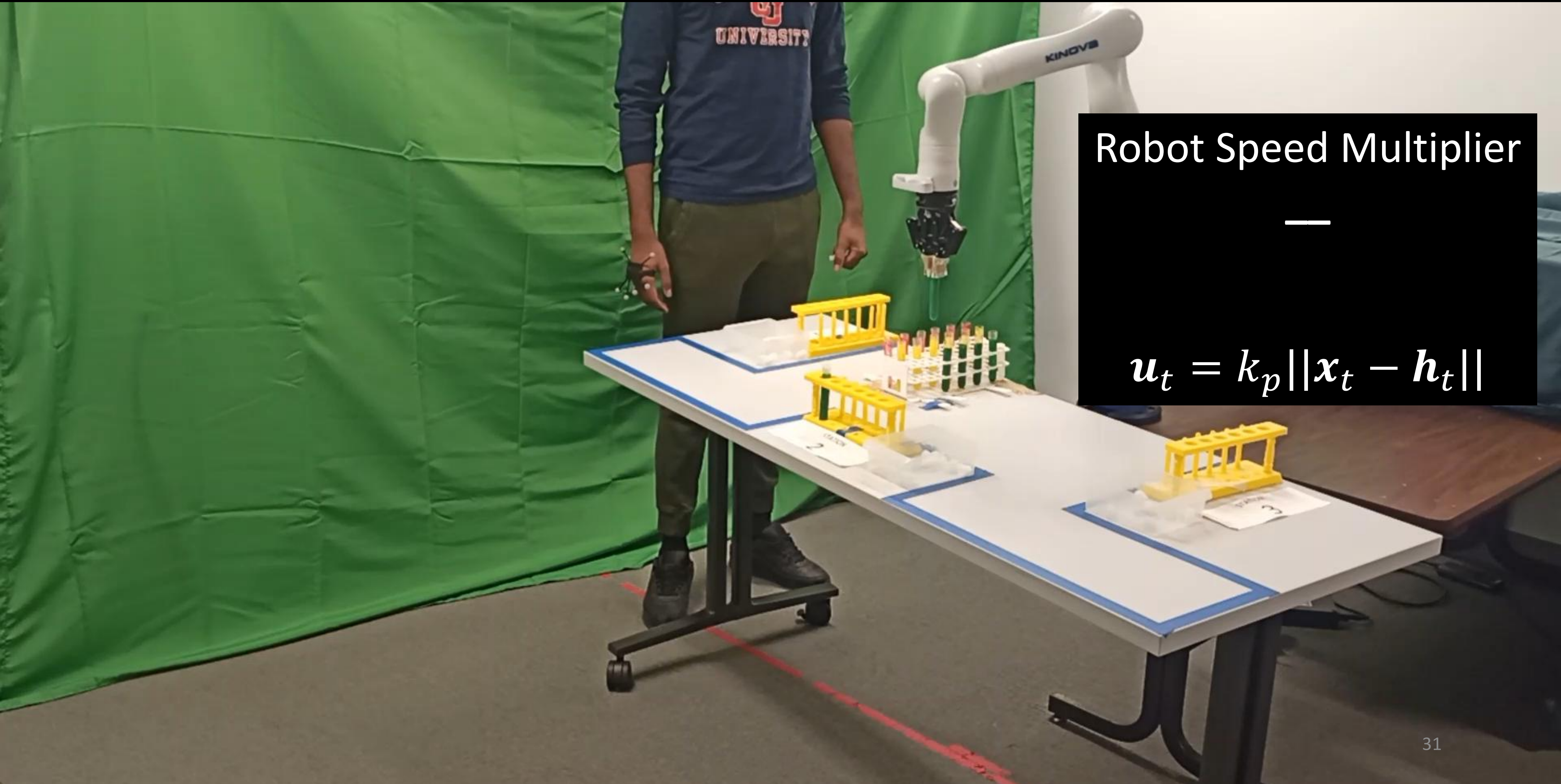


Don’t move until
__ seconds

Reach before
__ seconds

Failure Feedback:
“I will not be able to reach in the specified time limit”

Proportional Velocity Controller

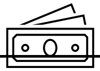


Robot Speed Multiplier

—

$$\boldsymbol{u}_t = k_p||\boldsymbol{x}_t - \boldsymbol{h}_t||$$

User Study: Results

Round	User Experience	Failures	Task Duration
Find Feasible Parameters 	TC > PV*	TC < PV*	TC > PV**
Optimize Parameters	TC > PV	TC < PV*	TC > PV**

TC: Timing Controller

PV: Proportional Velocity Controller (Baseline)

** p-Value < 0.05, ** p-Value < 0.005*

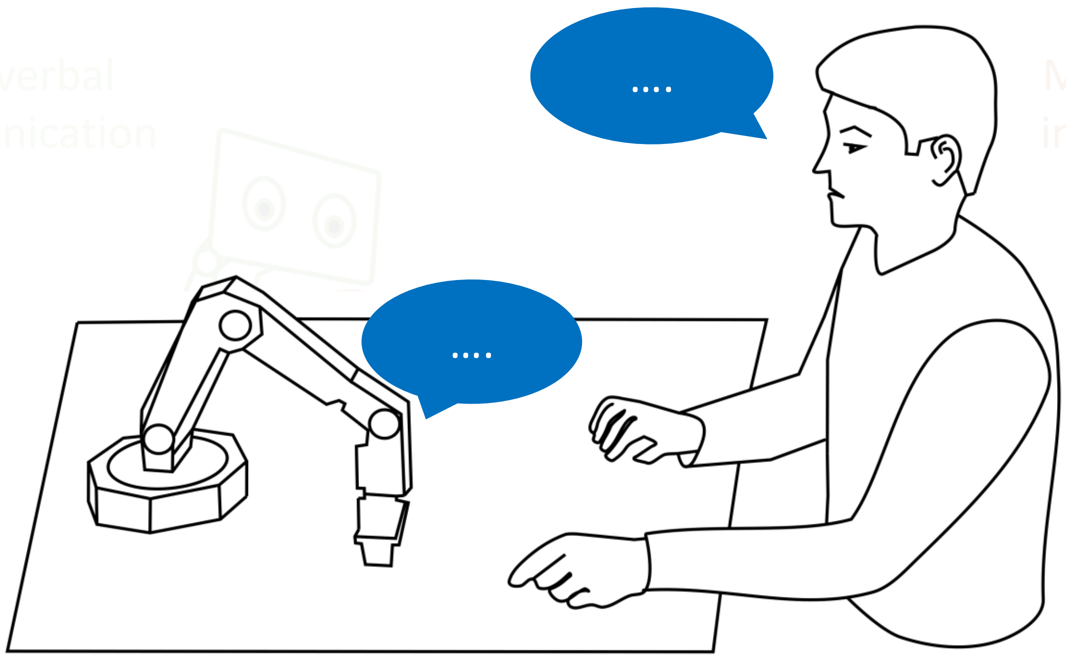
A. Kshirsagar*, R. Ravi*, H. Kress-Gazit and G. Hoffman, “Timing-specified Controllers with Feedback for Human-Robot Handovers”, ROMAN, 2022

How to improve human-robot interaction in shared workplaces?

Timing-specified controllers with feedback can improve user experience, reduce failures, but may reduce productivity*

*Limitations: Study scenario, population sample

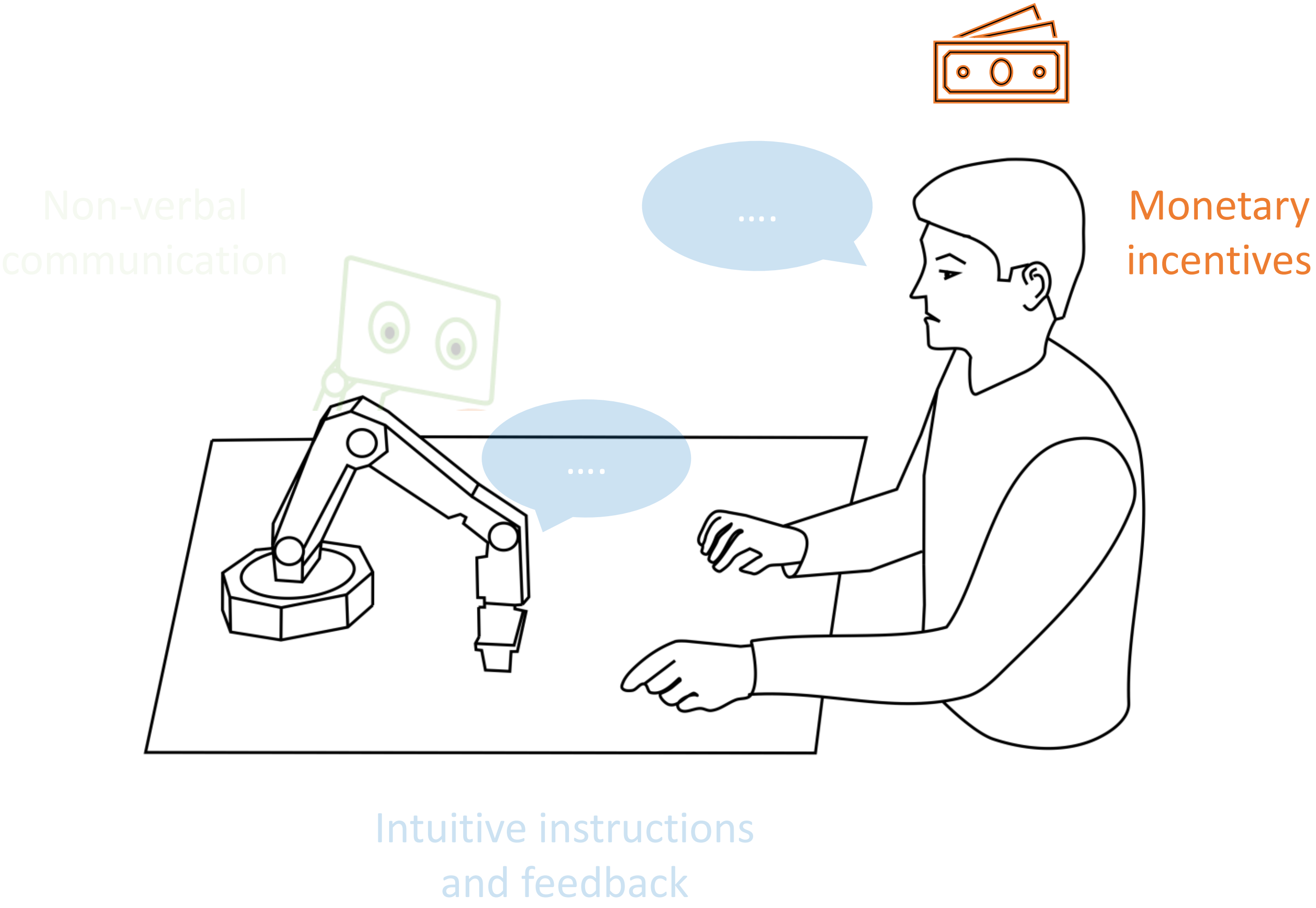
Future Work: Other instruction modalities, Corrective feedback



Intuitive instructions
and feedback

A. Kshirsagar*, R. Ravi*, H. Kress-Gazit and G. Hoffman, “Timing-specified Controllers with Feedback for Human-Robot Handovers”, ROMAN, 2022

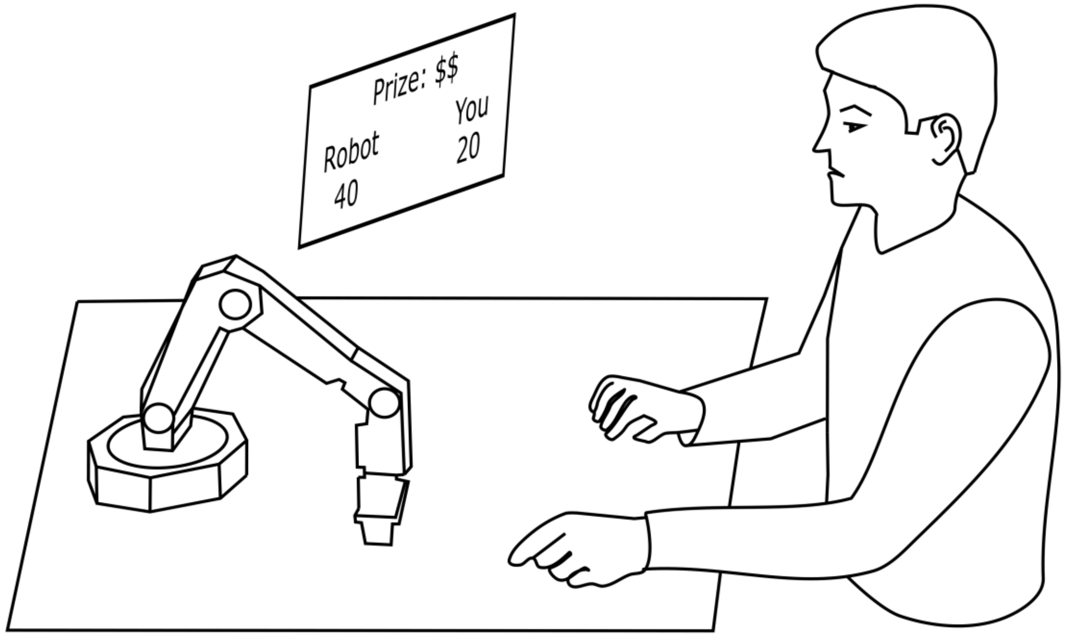
How to improve human-robot interaction in shared workplaces?



How do earning structures and robot performance affect human performance and attitudes?

Competitive Earning Scheme

Collaborative Earning Scheme



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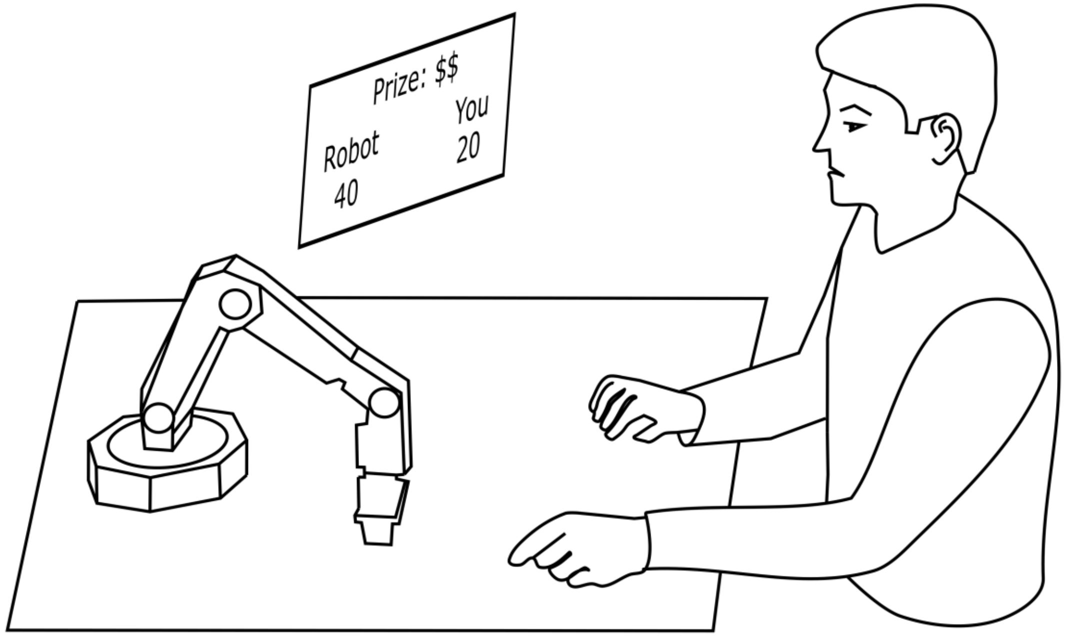
B. Dreyfuss, O. Heffetz, G. Hoffman, G. Ishai, A. Kshirsagar, "Additive vs Subtractive Earning in Shared Human-Robot Work Environments", J. of Econ. Behavior and Organization (Under Review)

Competitive vs Collaborative earning schemes in shared human-robot work environments

Competitive Earning Scheme	Collaborative Earning Scheme
❑ No Effect of Competitor's Effort on Own Effort	❑ No Effect of Collaborator's Effort on Own Effort

Predictions based on traditional economic models "Rational Agents"



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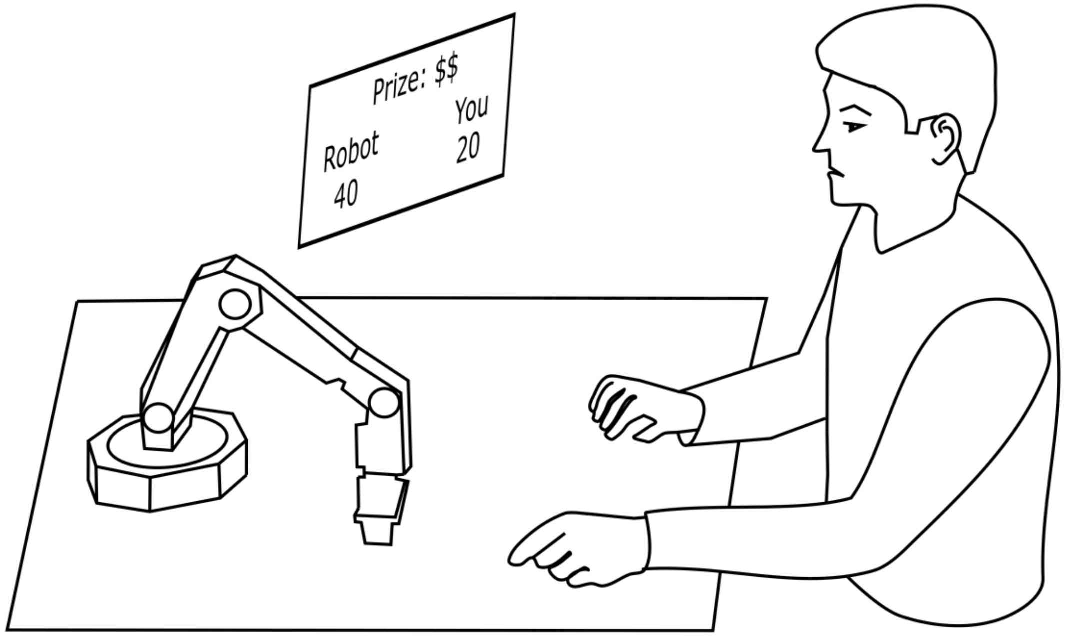
Competitive vs Collaborative earning schemes in shared human-robot work environments

Competitive Earning Scheme	Collaborative Earning Scheme
❑ Negative Effect of Competitor’s Effort (Discouragement Effect)	❑ Positive Effect of Collaborator’s Effort (Encouragement Effect)

Predictions based on:

B. Kőszegi and M. Rabin, “A model of reference-dependent preferences”, Quarterly J. of Eonomics, 2006

D. Gill and V. Prowse, “A structural analysis of disappointment aversion in a real effort competition,” American Economic Review, 2012



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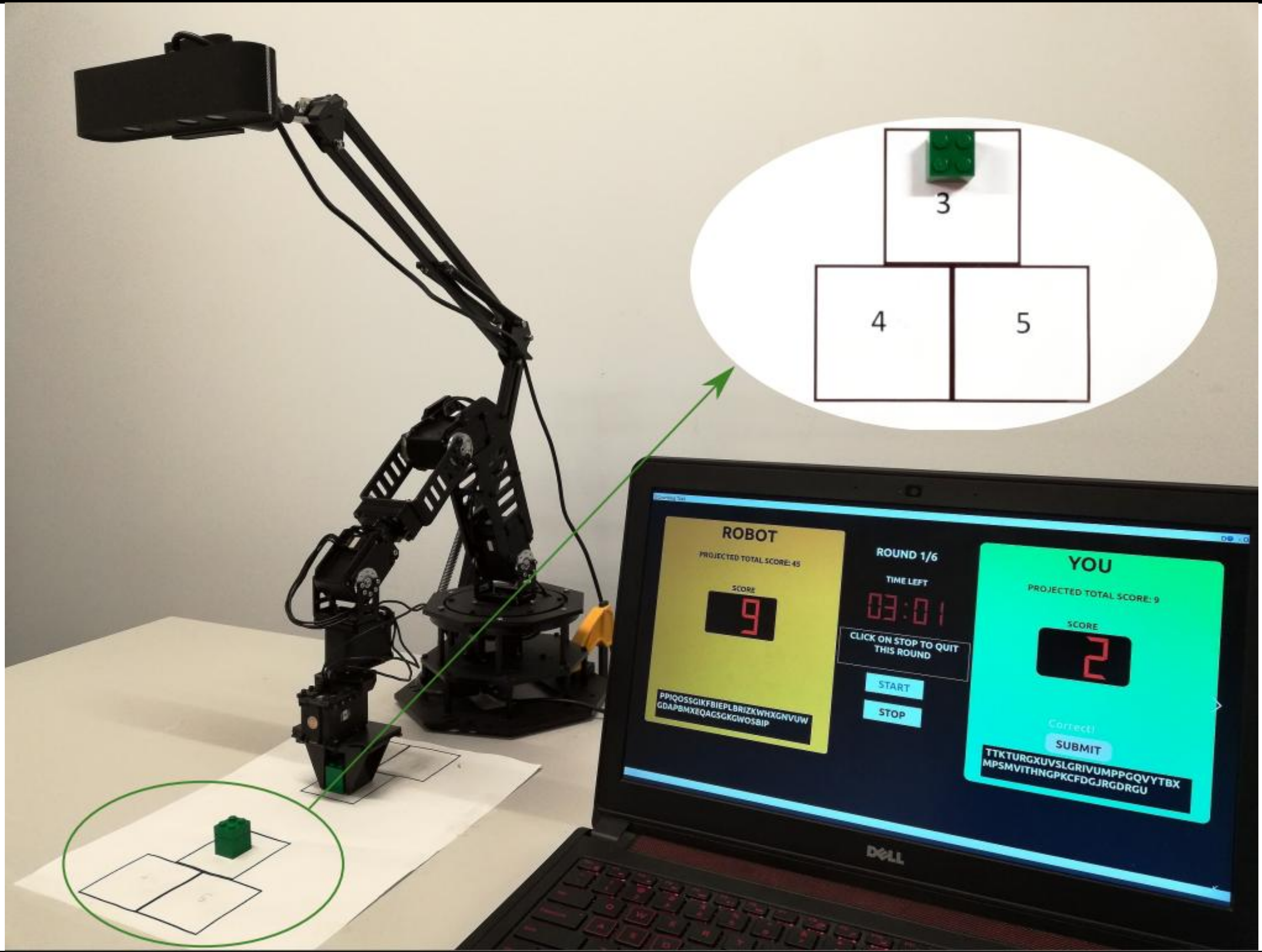
Experiment Setup



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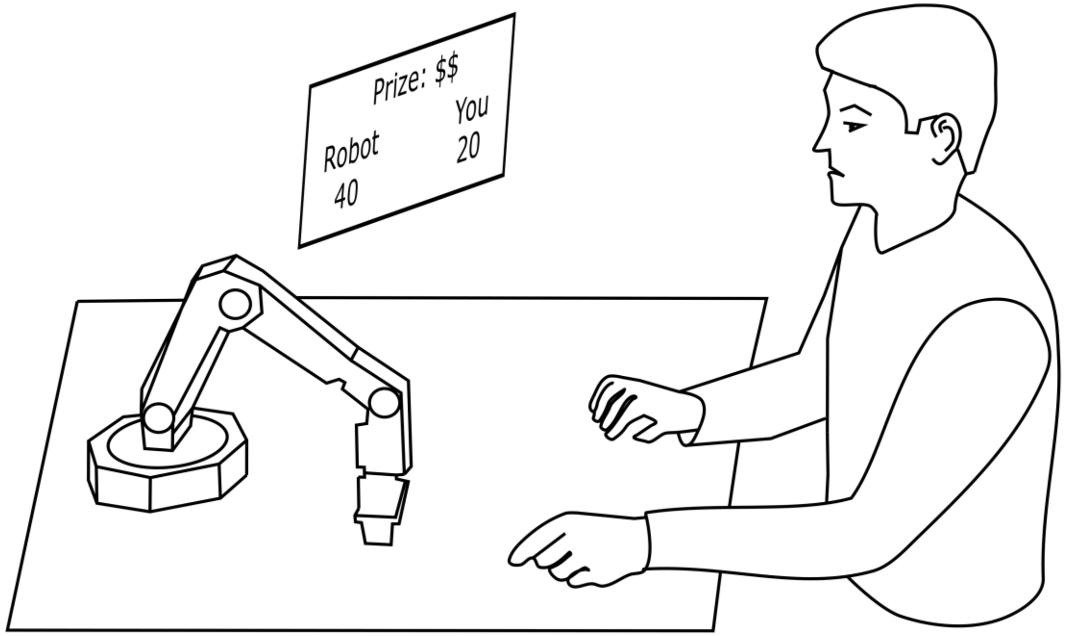
Results

Competitive Earning Scheme	Collaborative Earning Scheme
✅ Negative Effect of Competitor's Effort (Discouragement Effect)	🟡 Positive Effect of Collaborator's Effort (Encouragement Effect)



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Results

Competitive Earning Scheme

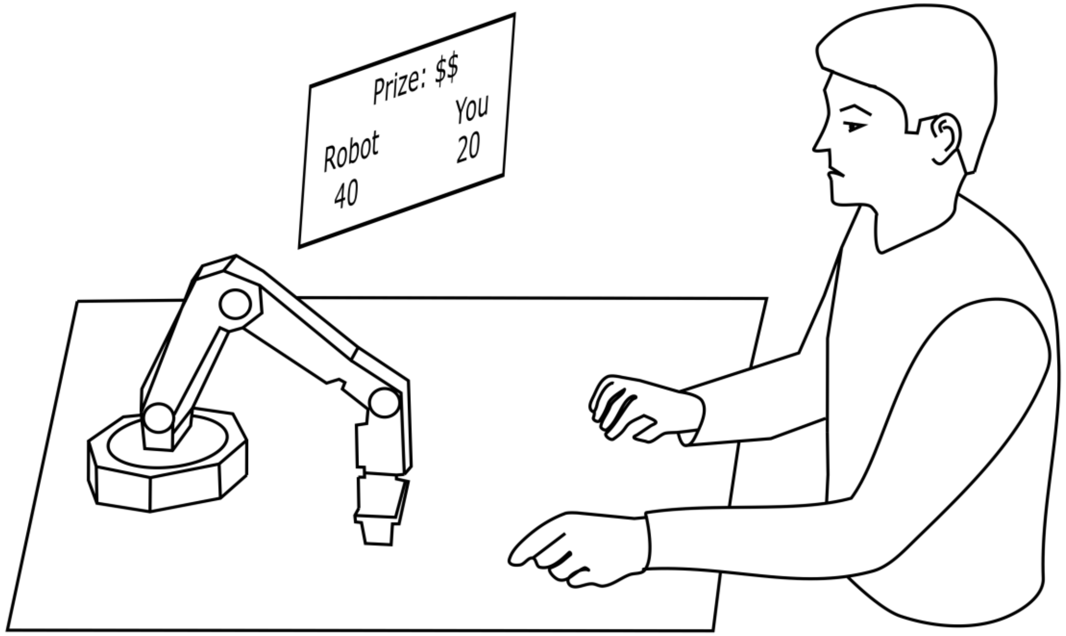
✅ Negative Effect of Competitor's Effort (Discouragement Effect)

Robot Performance **Negatively** Affects Robot Likability
Robot Performance **Negatively** Affects Human's Self-Competence

Collaborative Earning Scheme

🟡 Positive Effect of Collaborator's Effort (Encouragement Effect)

Robot Performance **Positively** Affects Robot Likability
Robot Performance **Negatively** Affects Human's Self-Competence



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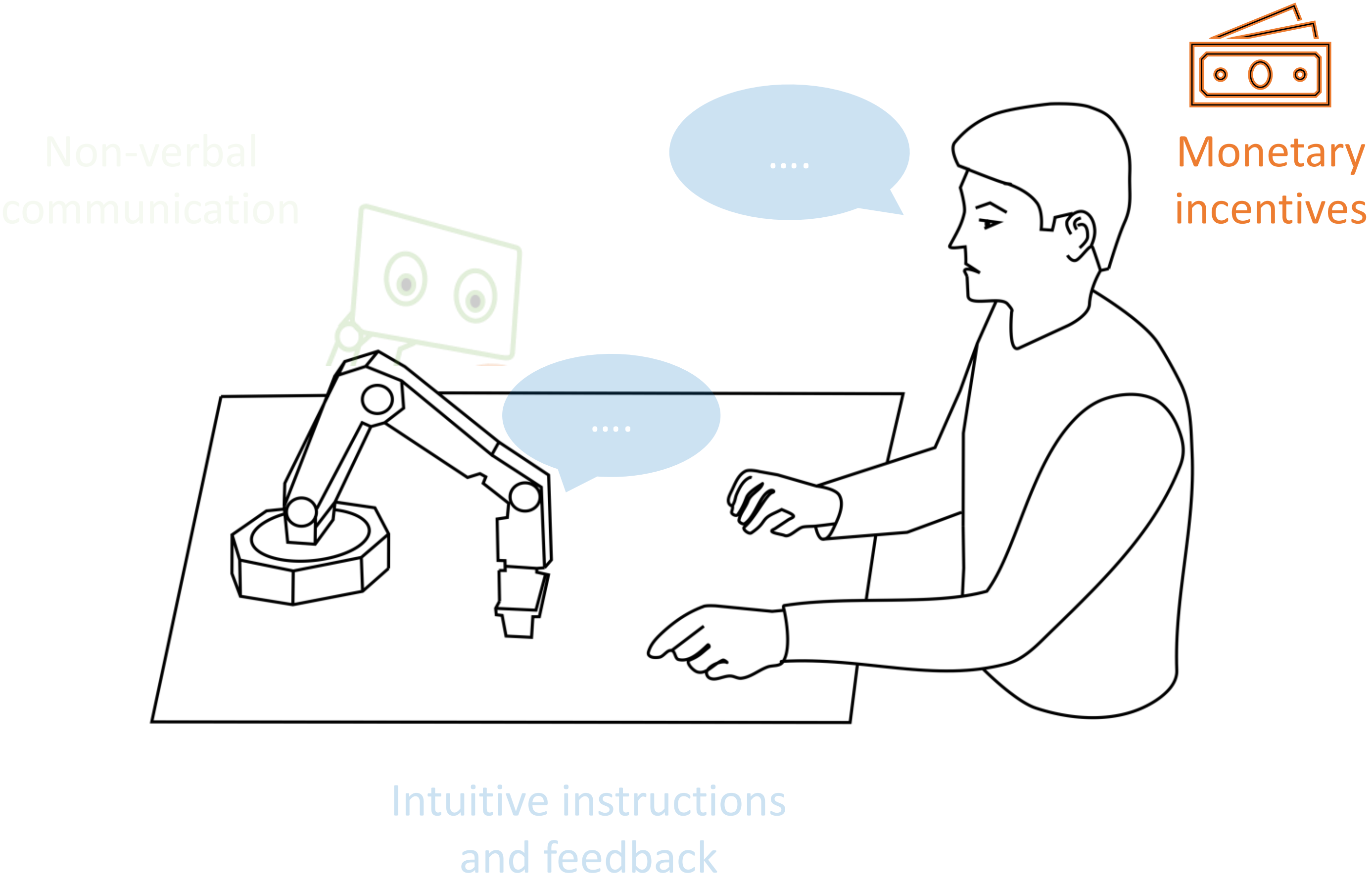
How to improve human-robot interaction in shared workplaces?

Robot performance and earning structures affect worker performance and attitudes

Collaborative earning scheme may improve worker performance and attitudes towards robots*

*Limitations: Study scenario, population sample

Future Work: Other earning structures, Robot behaviors, Real industrial settings



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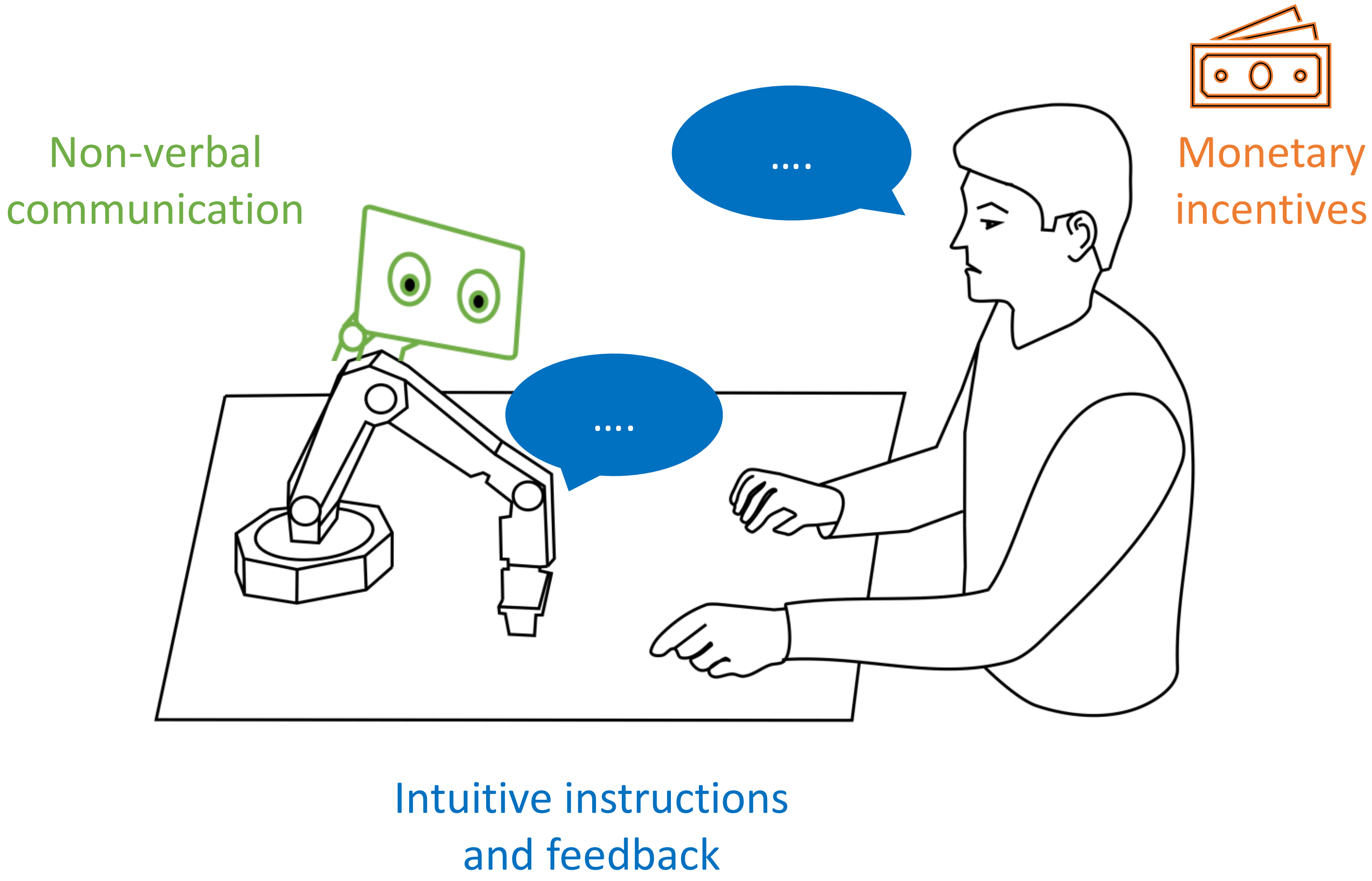
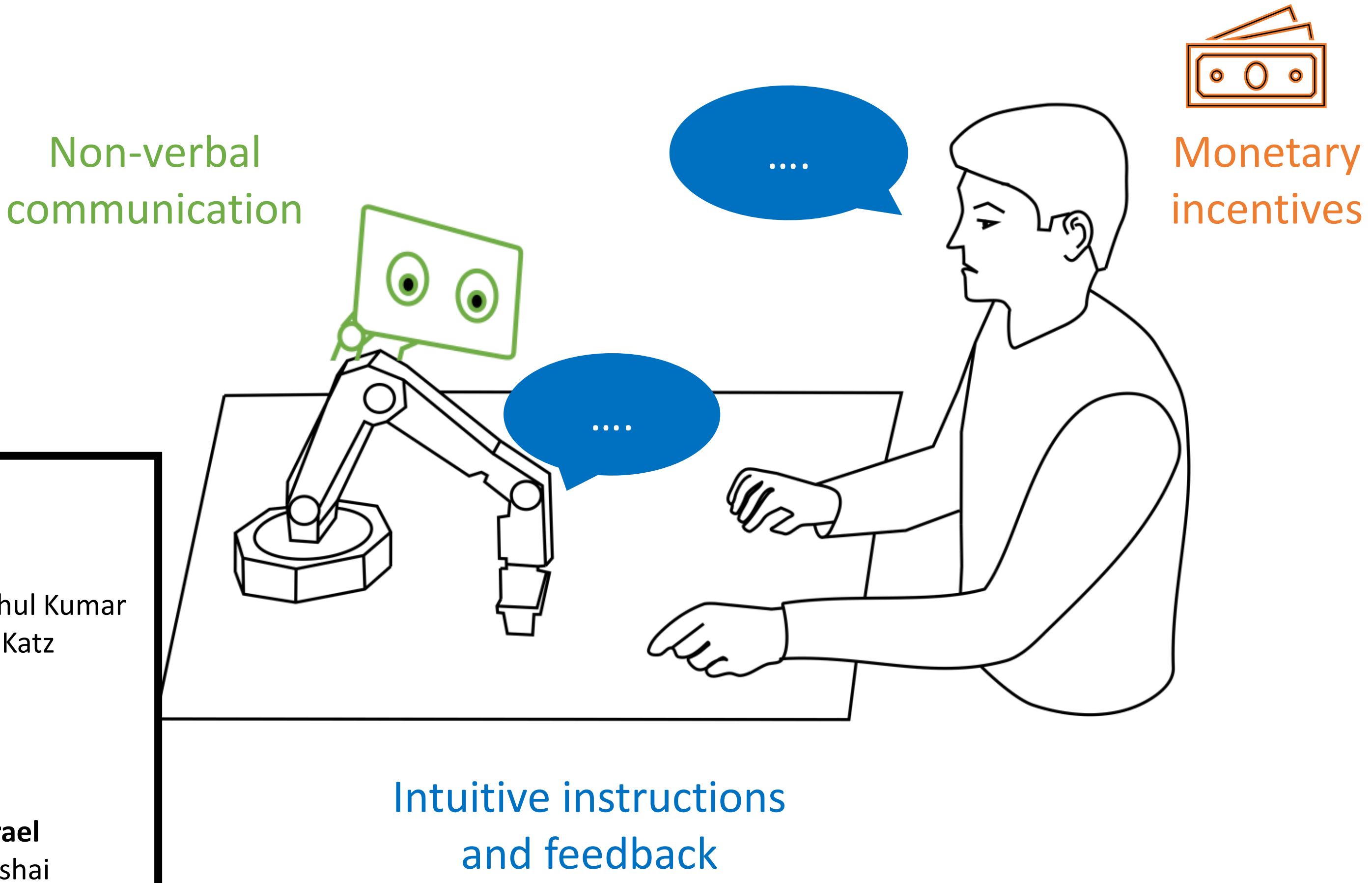
Summary


Non-verbal communication
Monetary incentives
Intuitive instructions and feedback

Thank you



Collaborators

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Dr. Guy Hoffman, Dr. Hadas Kress-Gazit, Rahul Kumar Ravi, Shemar Christian, Song Ye, Julie Katz

Ben-Gurion University, Israel
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