From Distraction to Interaction

Leveraging Robot-Driven Interplay for Effective Technical Education Amid Interruptions

Emmanuel Adéníran

Yale SOCIAL ROBOTICS LAB

The Challenge of Interruptions

Have you struggled with interruption?

Yale
SOCIAL ROBOTICS LAB

Interruptions: The Toll on Productivity and Society

- High monetary costs:
  - For example, in airline transportation and logistics, Gontar et al. (2017).
  - Over $32 billion in losses, Ball et al. (2010).

Cascading Delays/Cancellations

Yale SOCIAL ROBOTICS LAB

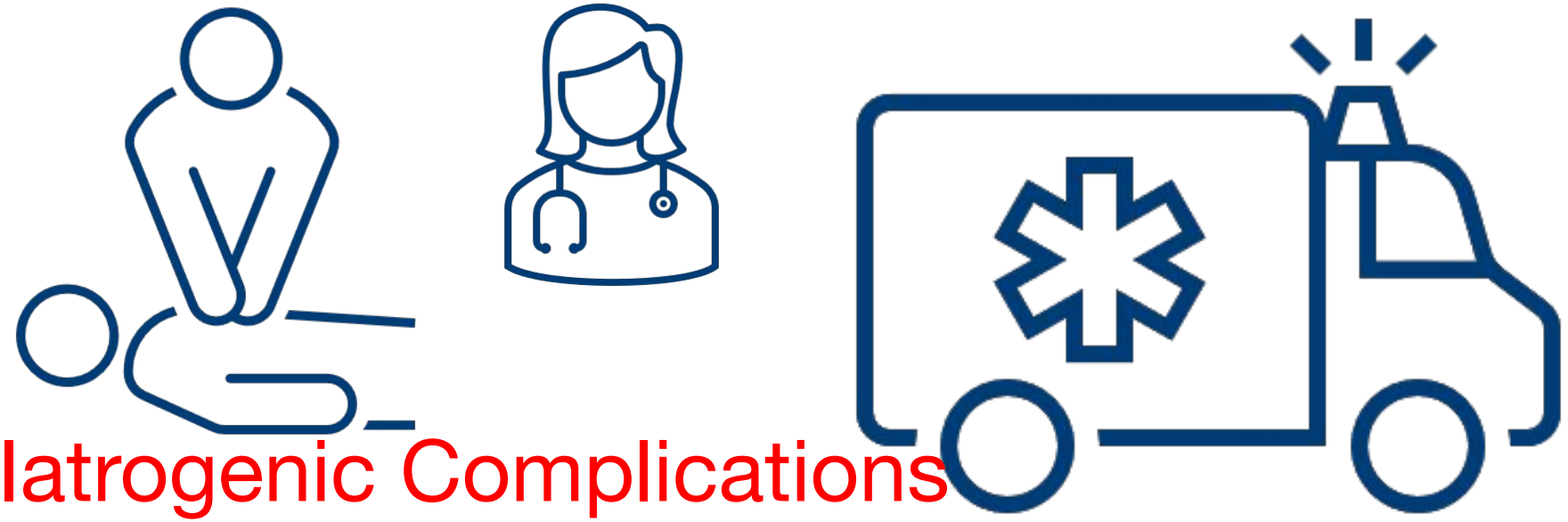
Interruptions: The Toll on Productivity and Society

- Injury:
  - 49% of 38,063 errors in administering medication, Johnson et al. (2017)

Medication Errors

Interruptions: The Toll on Productivity and Society

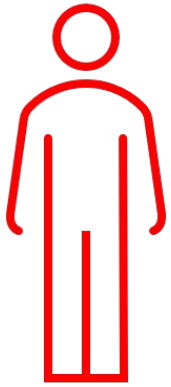
- Death:
  - Errors result in preventable deaths, Pereira-Lima et al. (2019)…



Iatrogenic Complications

Interruptions: The Toll on Productivity and Society

- Wellbeing:
  - Lost work productivity, Dabbish and Kraut (2004).
  - Social alienation or anxiety, Ramnauth et al., (2022)



Thesis Statement

Robots can augment learning environments to support technical education by managing interruptions.

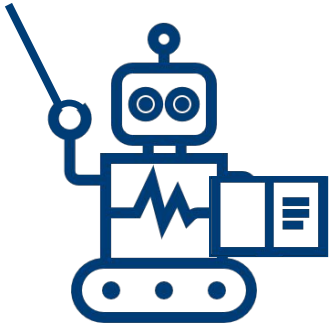
Yale
SOCIAL ROBOTICS LAB

Outline: Robotics and Human Adaptivity

Study 1:

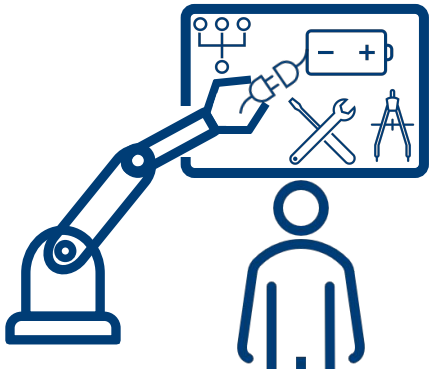
Modeling the Effects of Interruptions

Study 2:



Robot-Assisted Interruption Training for ASD Adults

Study 3:



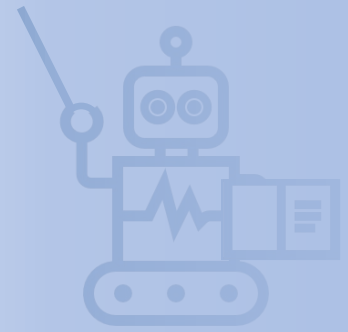
Supporting Recovery from Distractions

Outline: Robotics and Human Adaptivity

Study 1:

Modeling the Effects of Interruptions

Study 2:



Robot-Assisted Interruption Training for ASD Adults

Motivation: Modeling the Effects of Interruptions

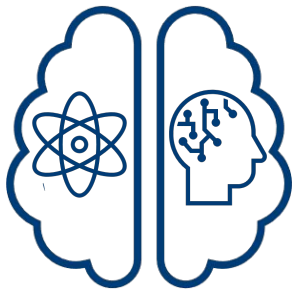
Investigate how interruptions affect learning/performance and the role of teaching strategies in reducing these impacts.

How can we train people to better deal with interruptions?

Yale
SOCIAL ROBOTICS LAB

Hard Problems: Modeling the Effects of Interruptions

- Key Challenges:
  - It is unclear what factors are important
  - It is unclear what training method should be use



Hypotheses: Modeling the Effects of Interruptions

Structured training enhances interruption management, improves learning, and lowers errors*:

H1: Practice is sufficient.

H2. Interruptions skills are generalizable, not specific.

H2-1. Skill transfers to different primary tasks.

H2-2. Skill transfers to different interruptions.

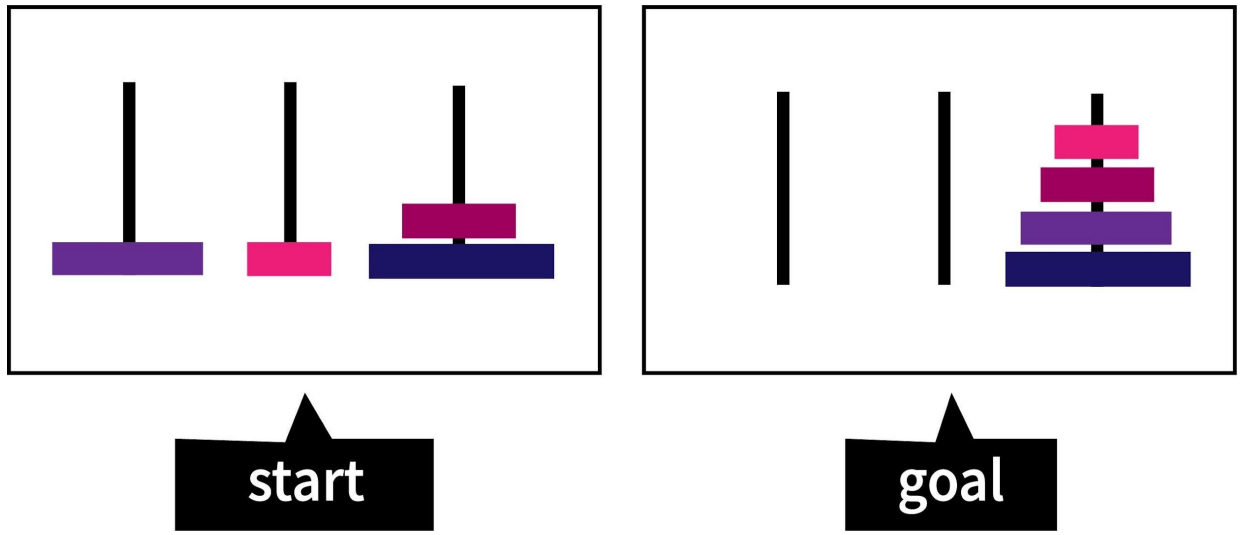
H3: Training outcomes depend on the primary task's memory load.

*Donaldson, M.S., Corrigan, J.M., & Kohn, L.T., eds. (2000). To Err is Human: Building a Safer Health System.

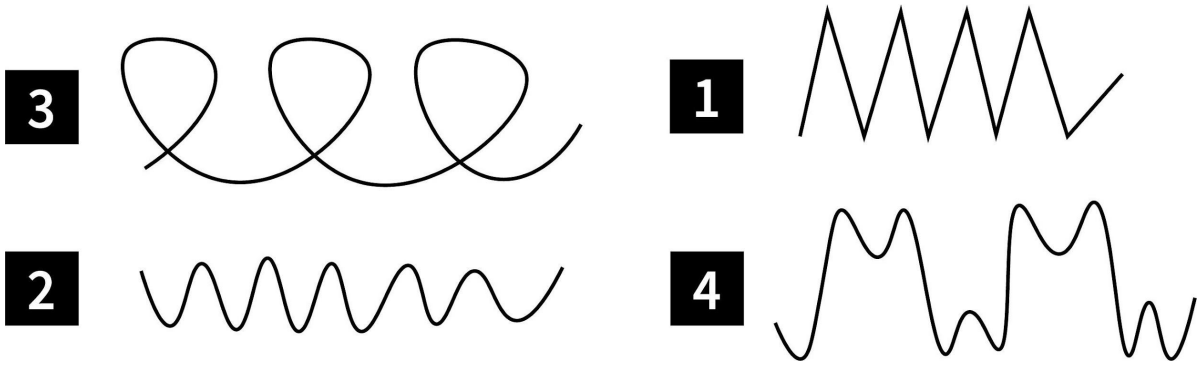
Yale SOCIAL ROBOTICS LAB

Task Analogues for Interruption Management

Tower of Hanoi Task

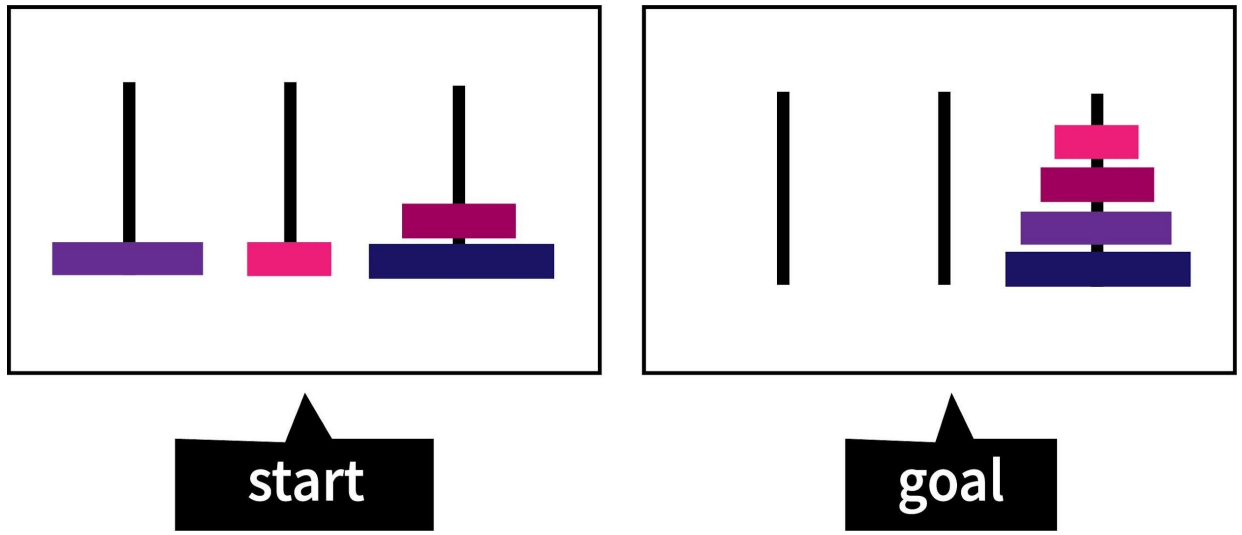


Path Recall Task



Task Analogues for Interruption Management

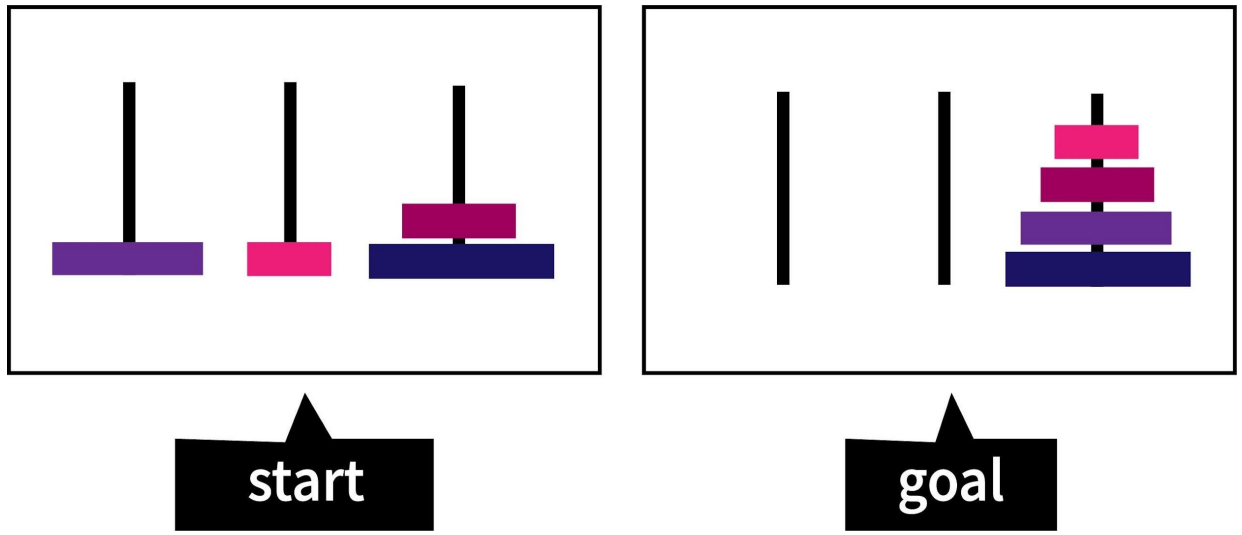
Tower of Hanoi Task



Path Recall Task

Task Analogues for Interruption Management

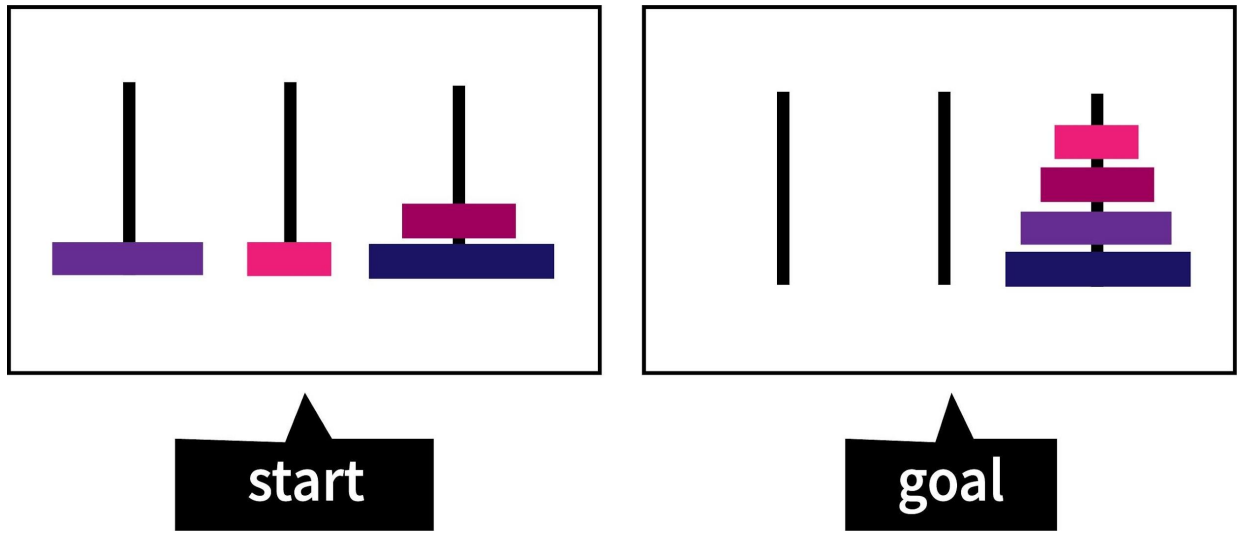
Tower of Hanoi Task



Path Recall Task

Task Analogues for Interruption Management

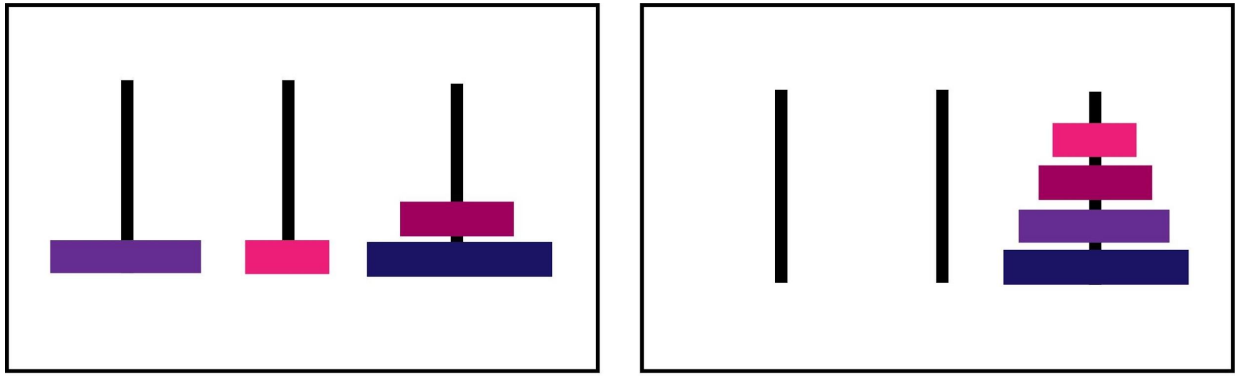
Tower of Hanoi Task



Path Recall Task

Task Analogues for Interruption Management

Tower of Hanoi Task



start

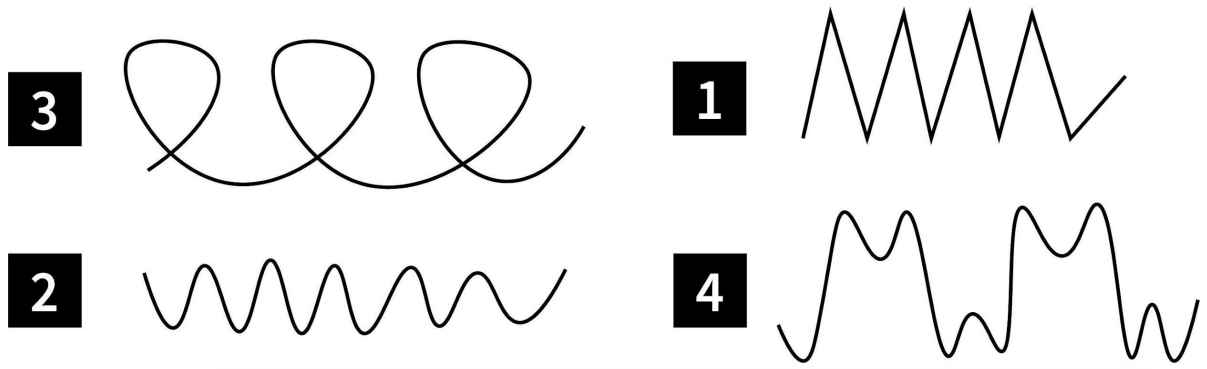
goal

4 x 4

3 x 7

Comparative Math Interruption

Path Recall Task



meaning

text color

red

black

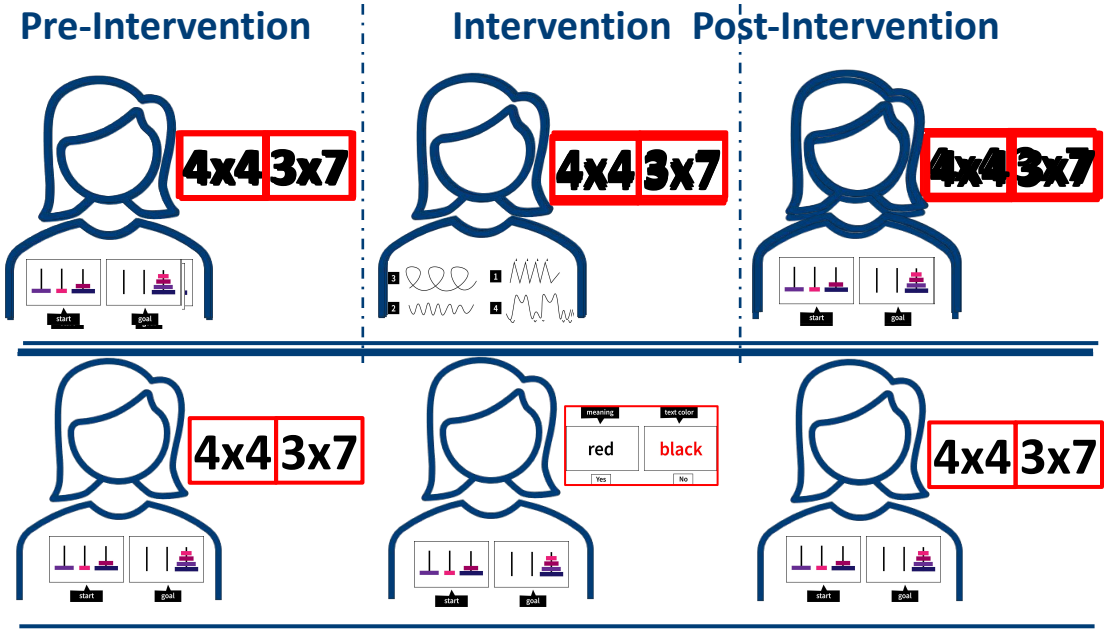
Yes

No

Stroop-like Interruption

Method: Study Design Overview

- **16 Groups across 3 phases**:
  - **Group 1**: Varied Tasks, Same Interruptions:
  - **Group 2**: Same Task, Varied Interruptions:
  - **Group 3**: Sequential Tasks (Like Group 1):
  - **Group 4**: Sequential Tasks (Like Group 2):



Tasks in Blue and interruptions in Red

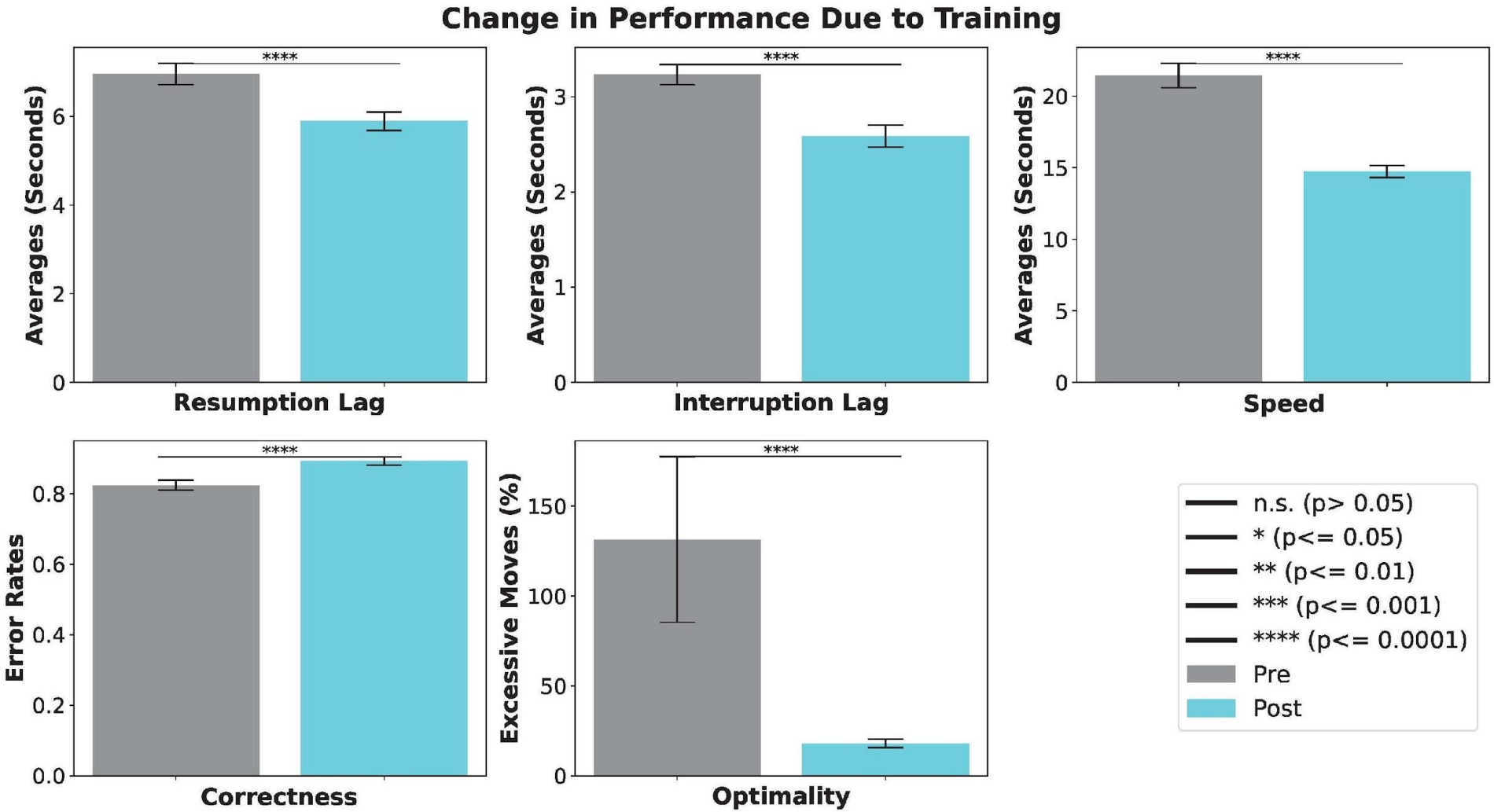
Sample Population and Metrics

- 240 participants
  - 50/50 male/female, English-speaking, no color blindness.
- Resumption Lag
- Interruption Lag
- Accuracy Metrics:
  - Strategic Problem-Solving:
  - Memory* Retention and Recall
- Response Speed

* Trafton, G., & Harrison, A. (2023). A memory for goals model of prospective memory. In Proceedings of the Annual Meeting of the Cognitive Science Society (Vol. 45, No. 45).

Yale SOCIAL ROBOTICS LAB

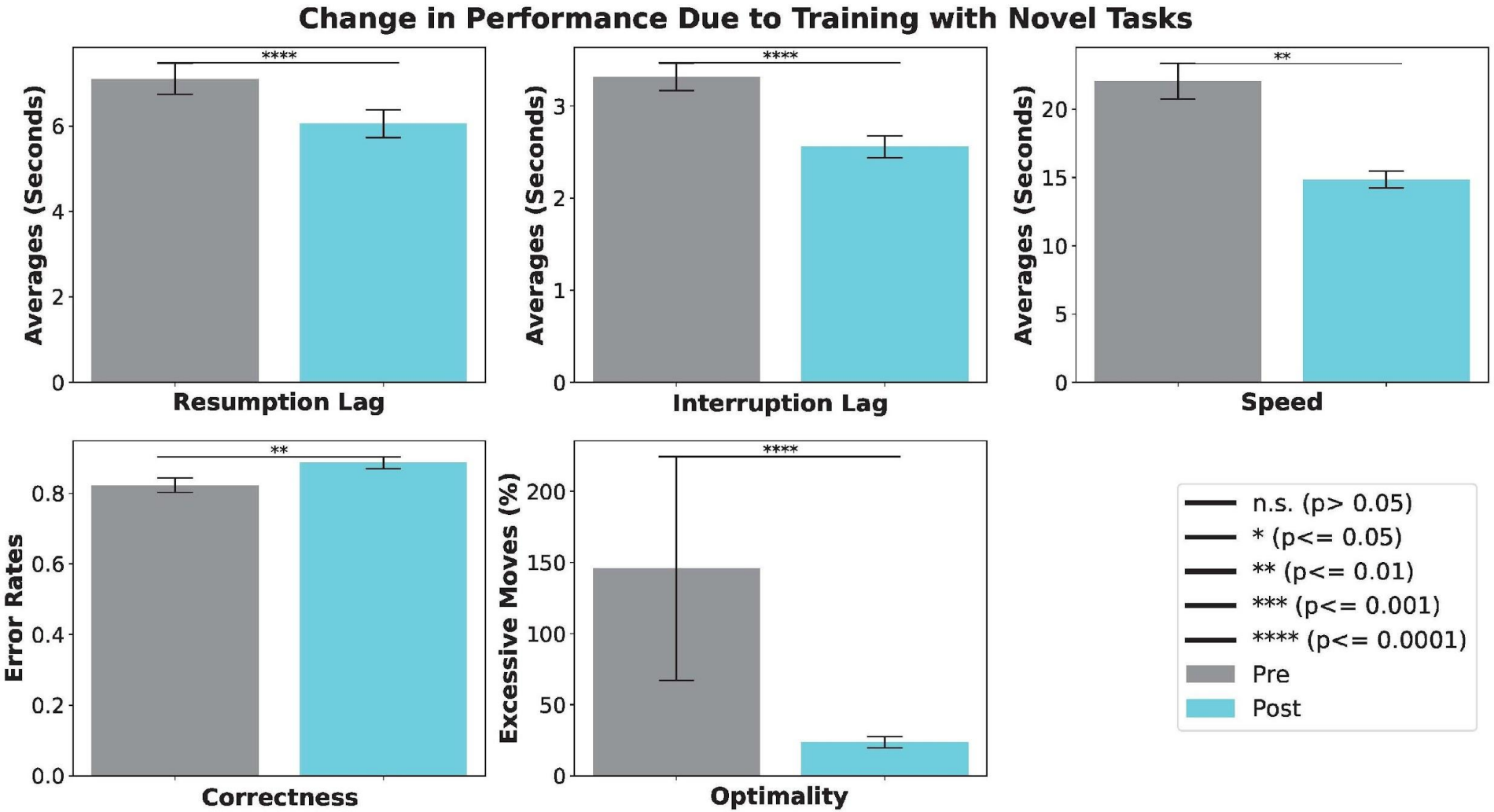
Findings: Practicing Hypothesis



These results support **H1**: Practice is sufficient.

Yale SOCIAL ROBOTICS LAB

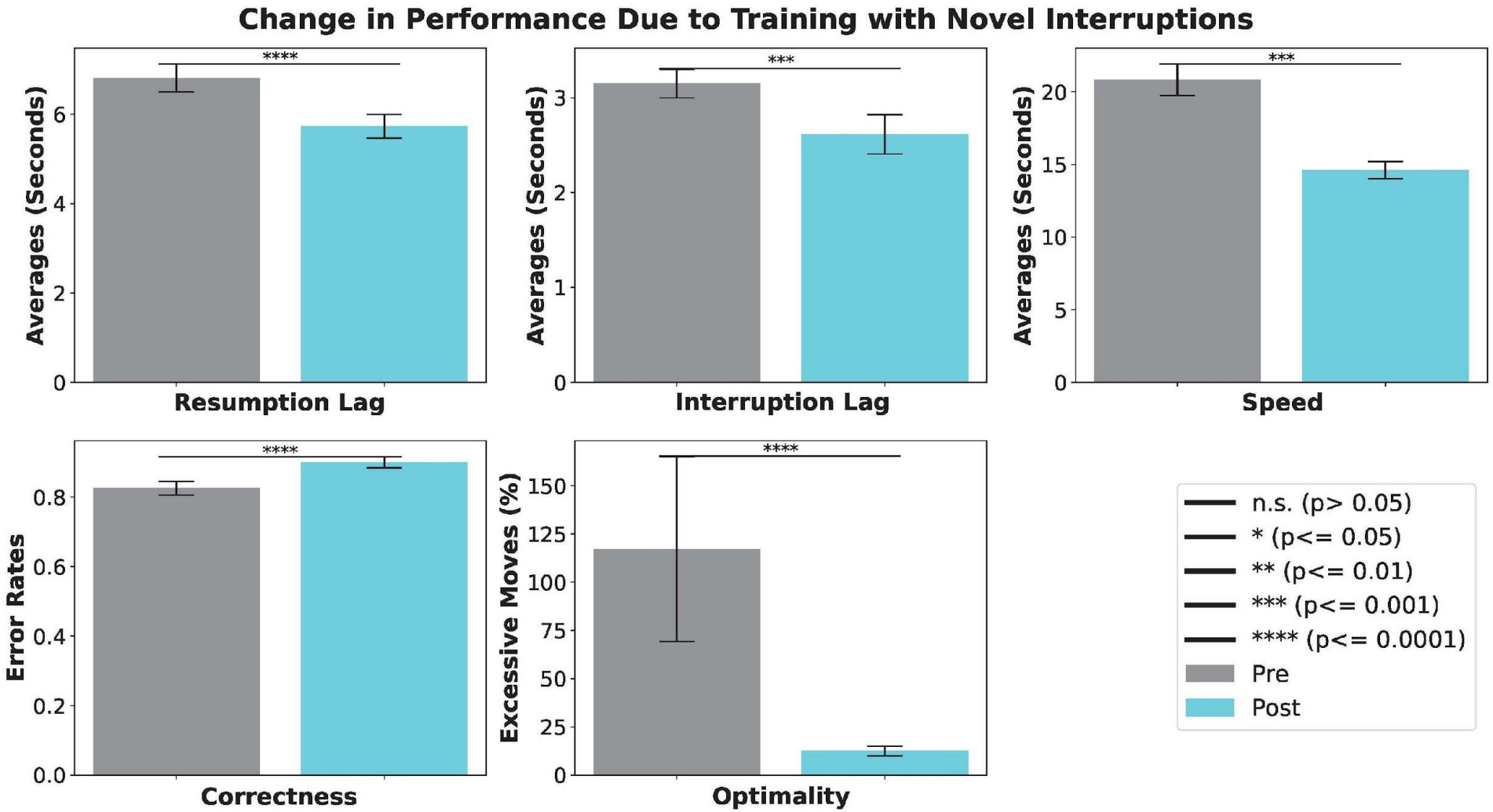
Findings: Transfer Hypothesis (Novel Tasks)



These results support **H2-1**: Skill transfers to different primary tasks.

Yale SOCIAL ROBOTICS LAB

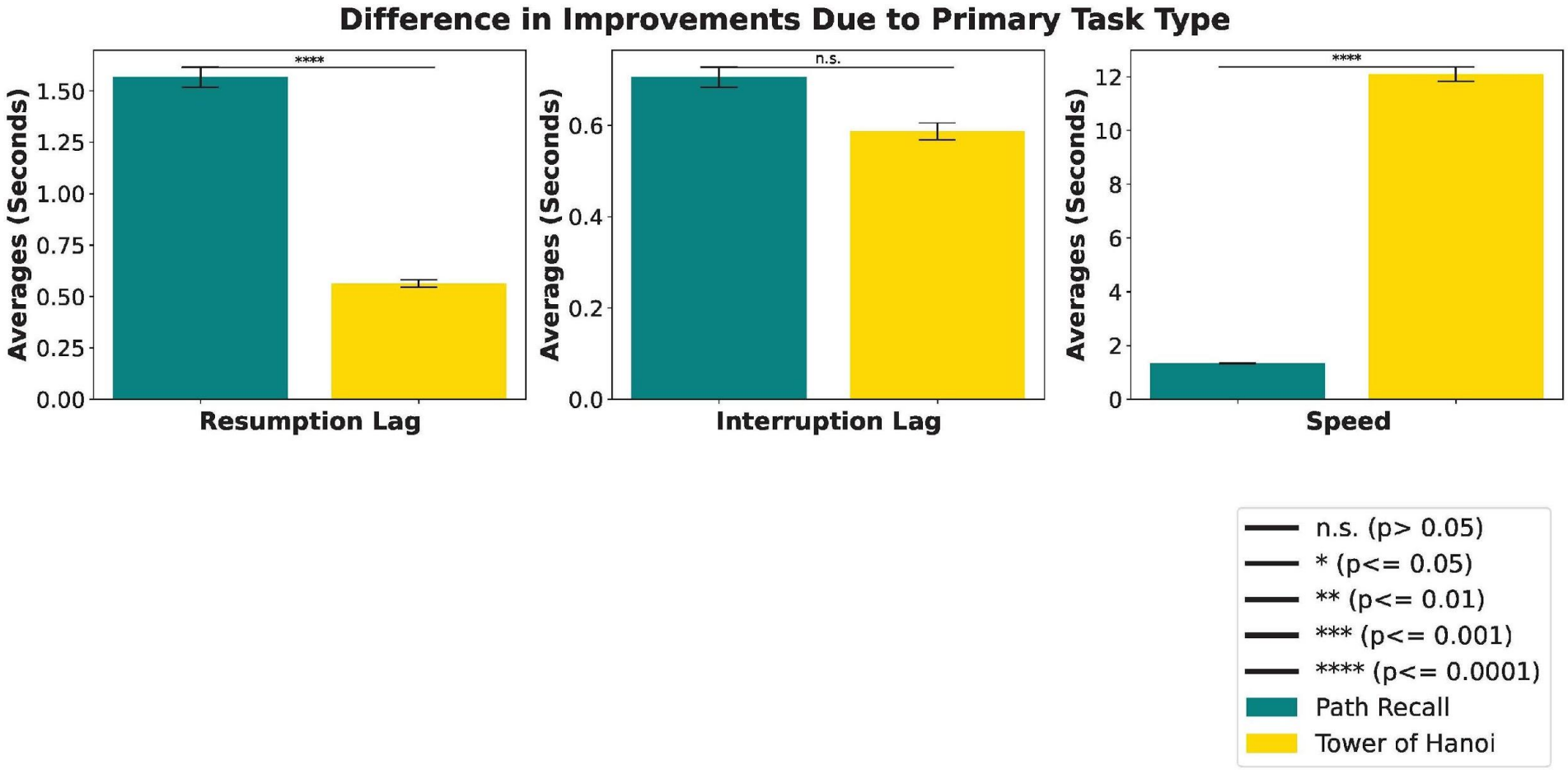
Findings: Transfer Hypothesis (Novel Interruptions)



These results support **H2-2**: Skill transfers to different interruptions.

Yale SOCIAL ROBOTICS LAB

Findings: Task Type Hypothesis



These results support **H3**: Training outcomes depend on the primary task's memory load.

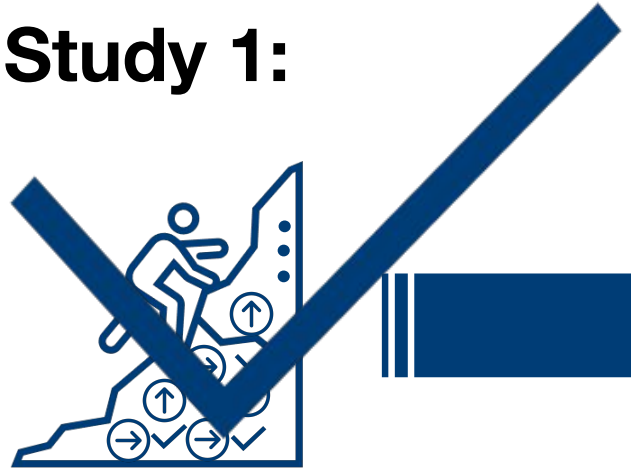
Takeaways

- Practice is effective.
- Transferability to different primary tasks.
- Adaptability to different interruptions.
- Task type consideration in training design.

Yale
SOCIAL ROBOTICS LAB

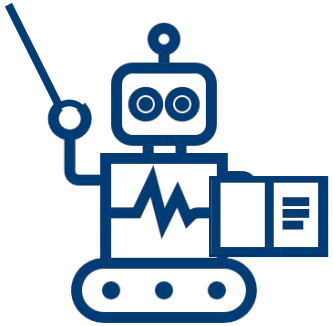
Outline: Robotics and Human Adaptivity

Study 1:



Modeling the Effects of Interruptions

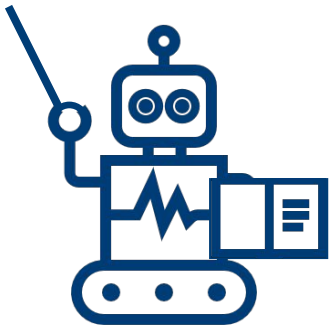
Study 2:



Robot-Assisted Interruption Training for ASD Adults

Robotics for Individuals with ASD

Tailored technology-based interventions boost work skills and job independence in adults with ASD - Johnson et al. 2020.

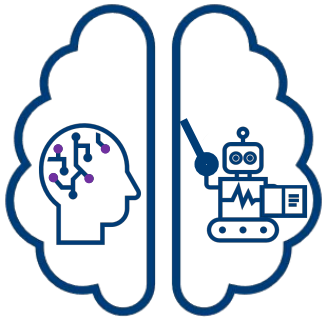


Johnson, K.R., Ennis-Cole, D., & Bonhamgregory, M. (2020). Workplace success strategies for employees with autism spectrum disorder: A new frontier for human resource development. Human Resource Development Review, 19(2), 122-151.

Yale SOCIAL ROBOTICS LAB

Hard Problems

- Key Challenges:
  - Operate in the home.
  - Fully autonomous system.*
  - Operates over weeks.



*Sapounidis, T., & Alimisis, D. (2021). Educational robotics curricula: Current trends and shortcomings. In Educational Robotics International Conference. Cham: Springer International Publishing.

Yale SOCIAL ROBOTICS LAB

Social Robots for Interruption Management

Goal: Explore the impact of social robotic training systems on enhancing interruption management skills in workplace settings.

Key Objectives:

Robotics for Interruption Management.

Response to Different Types of Interruptions.

Yale
SOCIAL ROBOTICS LAB

Method: Study Design Overview

- Iterative Development & Feedback (Eval 1):
  - Surveys with adults with ASD and employers, focusing on:*
    - Interruption frequency and recovery time.
    - Acceptance and usability of robots for training.

- Final Deployment & Training (Eval 2):

*Bruyère, S.M., Chang, H.-Y., & Saleh, M.C. (2020). Preliminary Report Summarizing the Results of Interviews and Focus Groups with Employers, Autistic Individuals, Service Providers, and Higher Education Career Counselors on Perceptions of Barriers and Facilitators for Neurodiverse Individuals in the Job Interview and Customer Interface Processes. K. Lisa Yang and Hock E. Tan Institute on Employment and Disability.

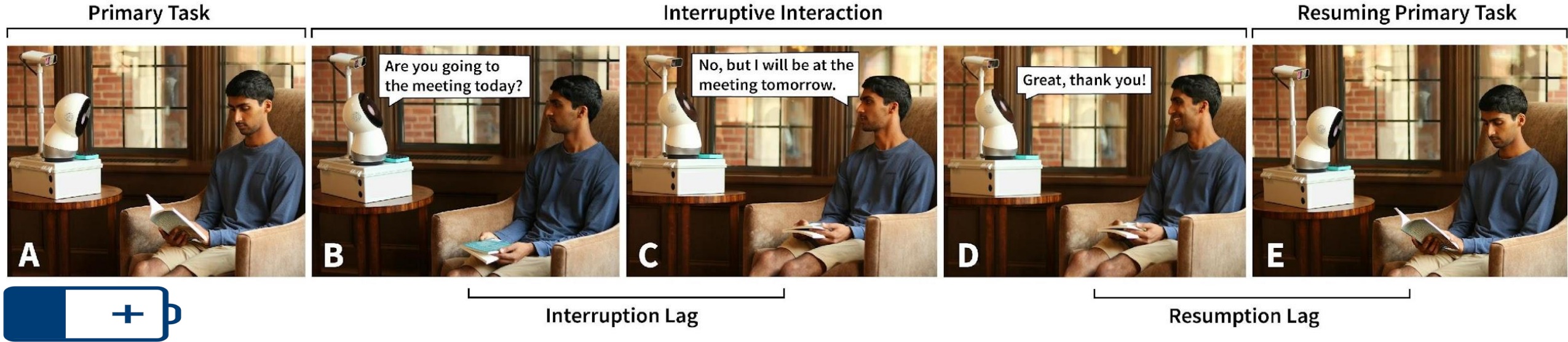
Yale SOCIAL ROBOTICS LAB

Objectives of the Iterative Design Development

- In User's Homes
  - Familiarity and Destigmatizing
- Autonomous
  - Modular
  - Schedule Flexibility
  - Connectivity
  - Self-Charging
- Training Sessions
  - 2 hours of daily interactions
- Robot: The Interruptions Skills Training and Assessment Robot (ISTAR).

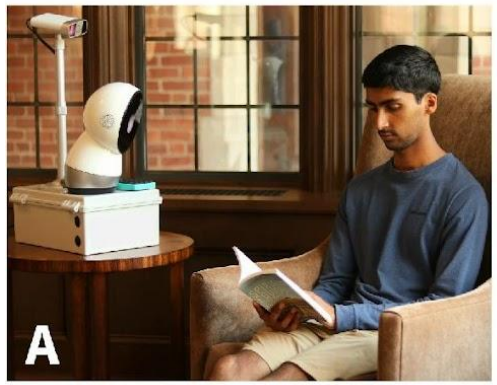
Yale
SOCIAL ROBOTICS LAB

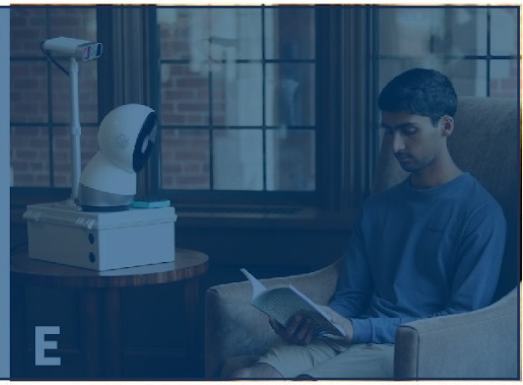
Interruptive Interactions with ISTAR



Interruptive Interactions

Primary Task | Interruptive Interaction | Resuming Primary Task





Interruption Lag

Resumption Lag

Interruptive Interactions

Interruptive Interactions

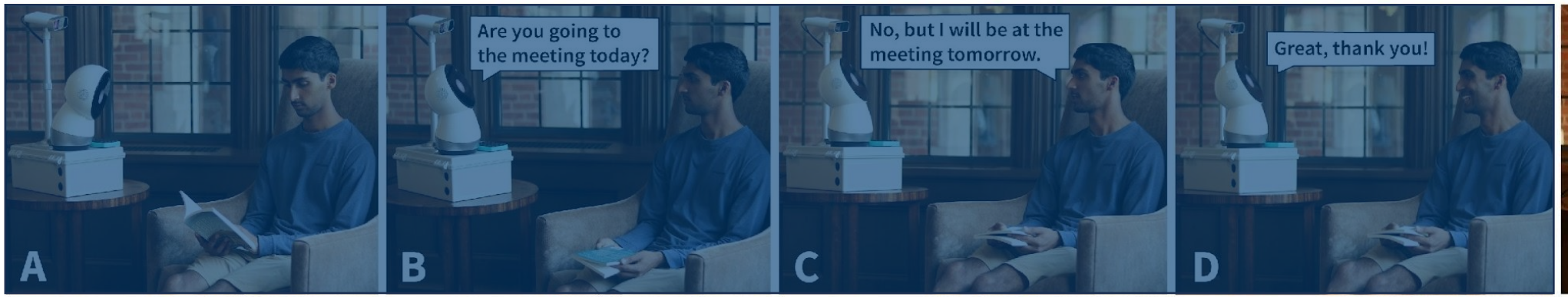
Interruptive Interactions

Interruptive Interactions

Primary Task

Interruptive Interaction

Resuming Primary Task

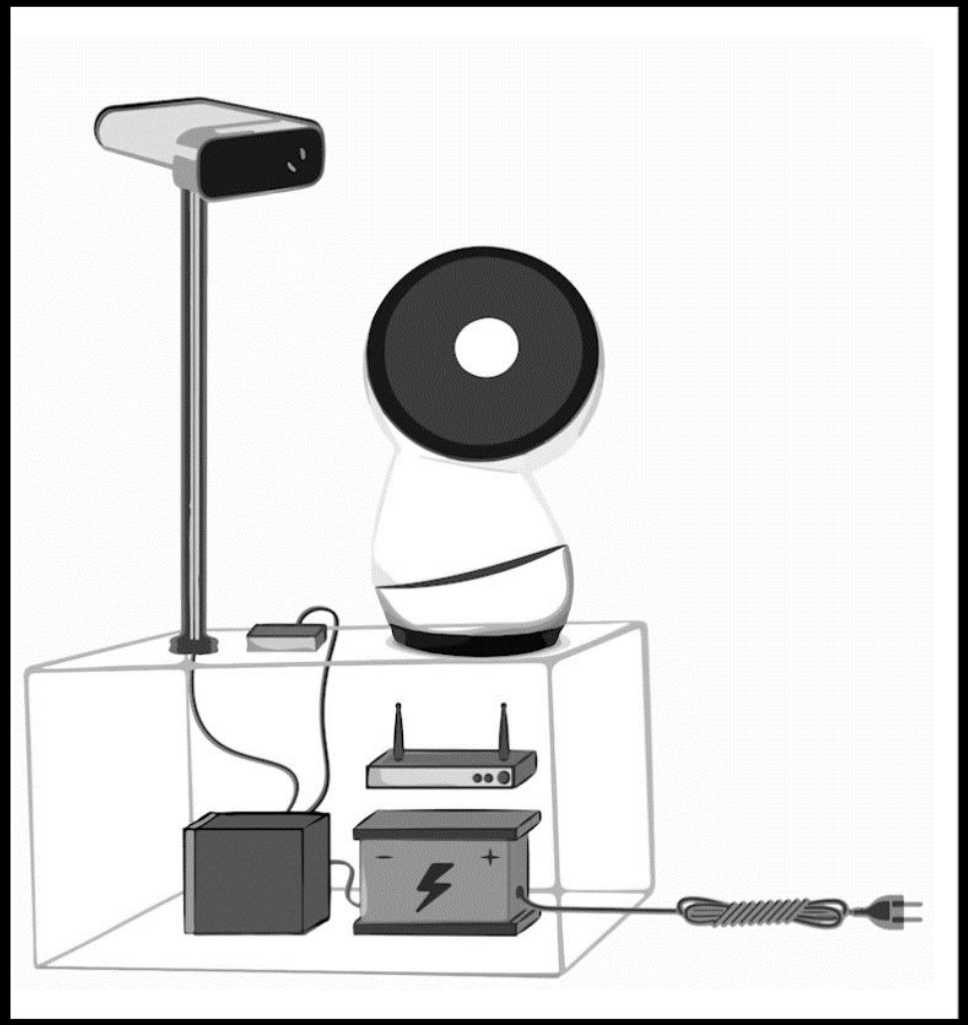


Interruption Lag

Resumption Lag

ISTAR

Yale
SOCIAL ROBOTICS LAB



We present the **Interruptions Skills Training and Assessment Robot** (ISTAR).

ISTAR is an in-home autonomous robot that provides training by allowing users practice handling work-related interruptions.

Sample Population and Metrics

- 10 participants
  - 8/2 male/female, Ages: 20-42 (Mean = 26.3, SD = 6.9), 80% college/vocational.
  - 10-14 days
- Resumption Lag
- Interruption Lag
- Handling Different Types of Interruptions*

*Cades, D.M., et al. (2011). Mitigating disruptive effects of interruptions through training: What needs to be practiced?. Journal of Experimental Psychology: Applied, 17(2), 97.

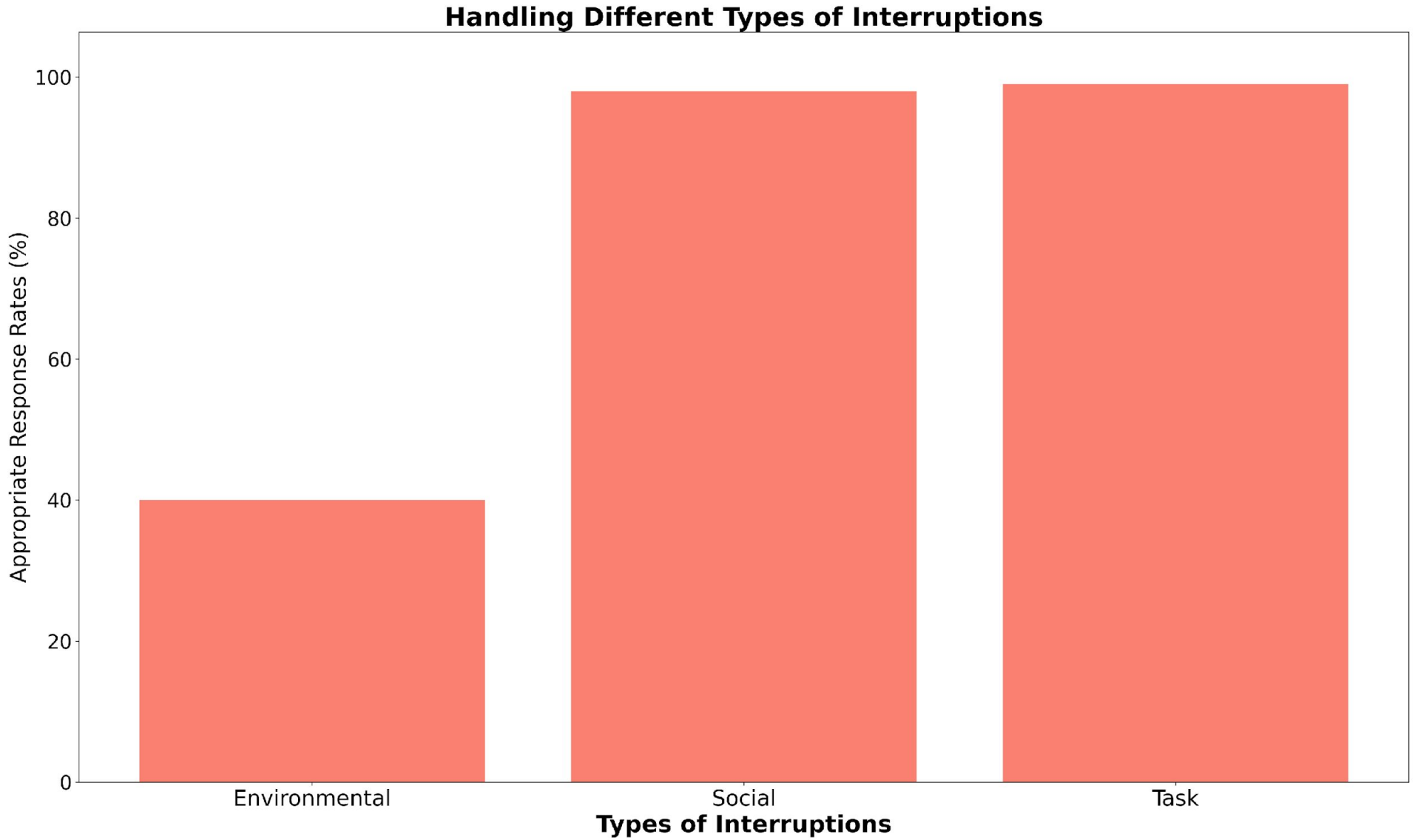
Yale SOCIAL ROBOTICS LAB

Interruption Management and Responses to Types

- Interruption Management
  - Predicted reduction in interruption lag
    - 0.01 seconds for each additional interruption experienced ($p=0.01$)
  - Predicted reduction in resumption lag
    - Decrease associated with specific interruption types (reduction of 11.1 seconds, $p \leq 0.001$)

Yale
SOCIAL ROBOTICS LAB

Interruption Management and Responses to Types



Yale
SOCIAL ROBOTICS LAB

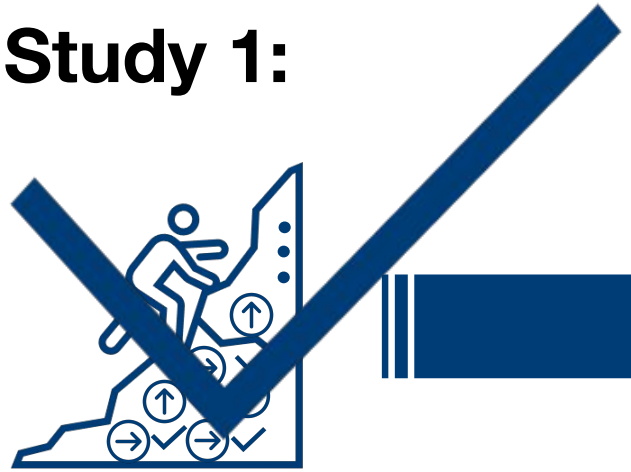
Takeaways

- Operate in the home.
- Fully autonomous system.
- Operates over weeks.

Yale
SOCIAL ROBOTICS LAB

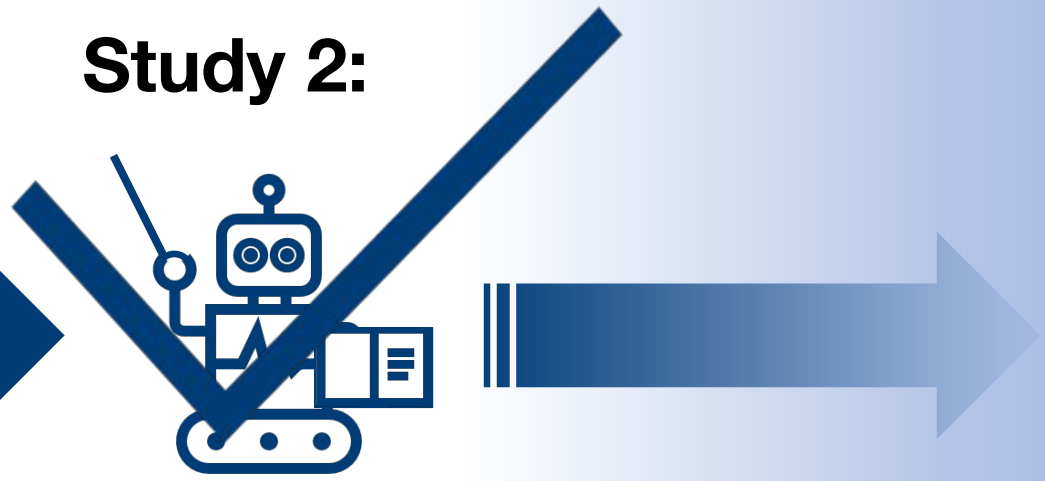
Outline: Robotics and Human Adaptivity

Study 1:



Modeling the Effects of Interruptions*

Study 2:

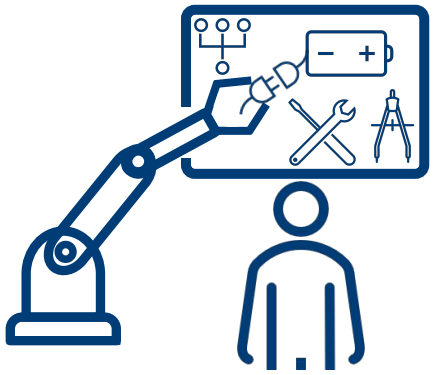


Robot-Assisted Interruption Training for ASD Adults

*Levy, Eliat Chen, Sheizaf Rafaeli, and Yaron Ariel. "The effects of online interruption pace and richness on task performance." Atlantic Journal of Communication (2024): 1-15.

Supporting Recovery from Distraction

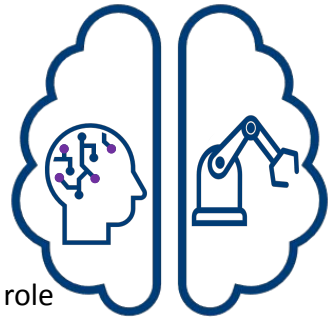
Enhancing Performance and Outcomes Amid Interruptions with Interactive Methods



Yale
SOCIAL ROBOTICS LAB

Hard Problems

- Key Challenges:
  - Real-time Processing of Multimodal Data.
  - Designing recovery support actions.*
  - Methodology for Evaluating Task Complexity.



* Piątkowski, K., et al. (2024). Forgetting during interruptions: The role of goal similarity. Journal of Cognitive Psychology, 1-16.

Yale SOCIAL ROBOTICS LAB

Hypothesis: Supporting Recovery from Distractions

Implementing robotic assistance* will significantly improve the management of interruptions during technical troubleshooting tasks via the following measurable outcomes:

H-1: Longer interruptions leading to quicker resumption of primary tasks.

H-2: The imposition of a time cost by interruptive tasks leads to an increase in errors.

H-3: Robotic assistance more significantly reduces errors in complex tasks.

*Atman Uslu, N., Öztüre Yavuz, G., & Kocak Usluel, Y. (2023). A systematic review study on educational robotics and robots. Interactive Learning Environments, 31(9), 5874-5898.

Yale SOCIAL ROBOTICS LAB

Method: Study Design Overview

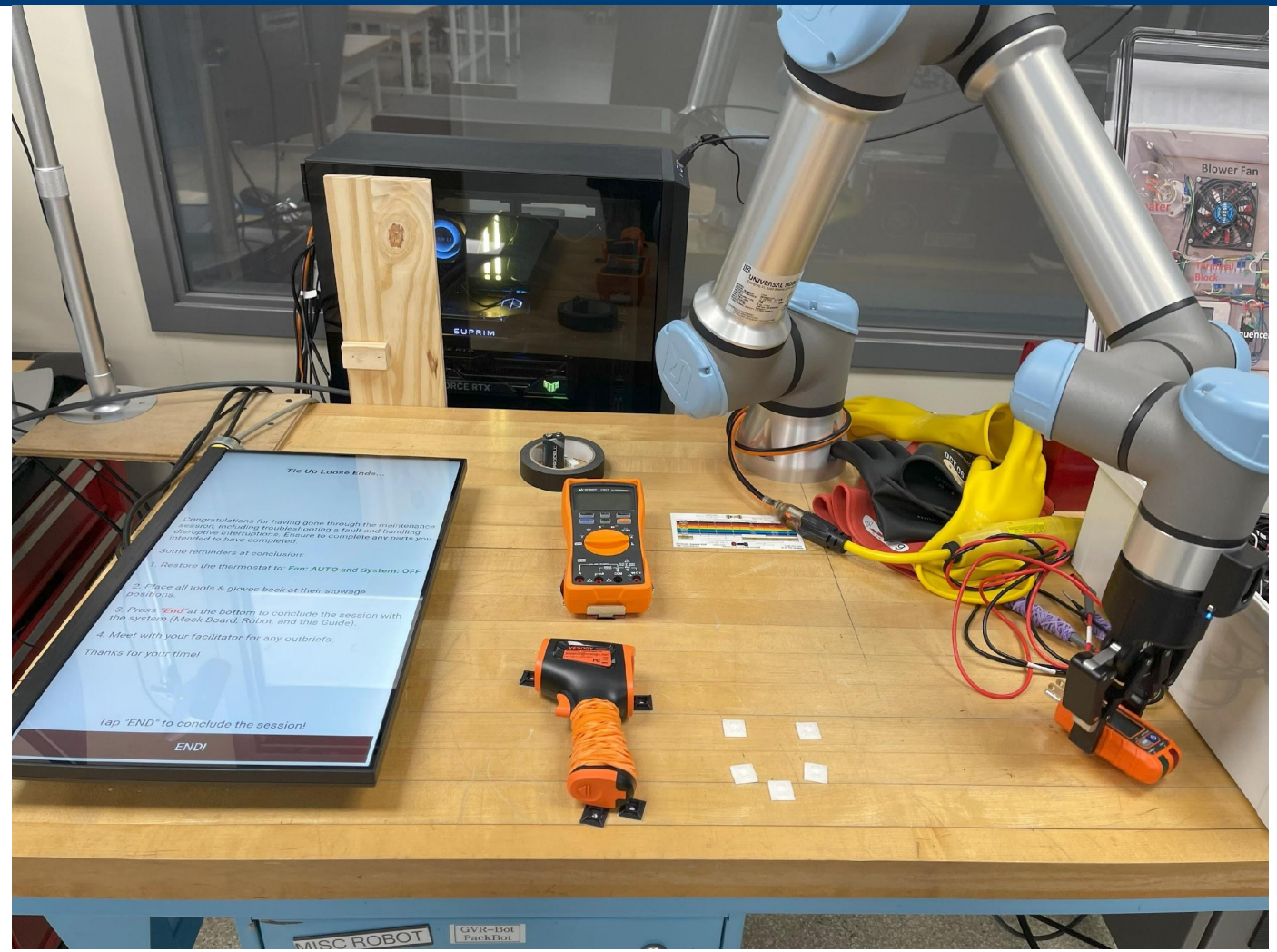
- Scenario:
  - 4 Maintenance tasks
    - Temperature, Fan, Cooling, and Heating
    - 2 interruptions per participant

Group	Robot Assists (Task 1)	Robot Assists (Task 2)	Complexity (Task 1)	Complexity (Task 2)	Task 1	Task 2
1	Yes	No	Simple	Simple	Identify faulty Condenser Fan	Identify faulty Compressor
2	Yes	No	Complex	Complex	Identify faulty Wire from Contactor Relay	Identify faulty DPDT Relay
3	No	No	Simple	Simple	Identify faulty Condenser Fan	Identify faulty Compressor
4	No	No	Complex	Complex	Identify faulty Wire from Contactor Relay	Identify faulty DPDT Relay

Yale
SOCIAL ROBOTICS LAB

Objectives of the Study Design

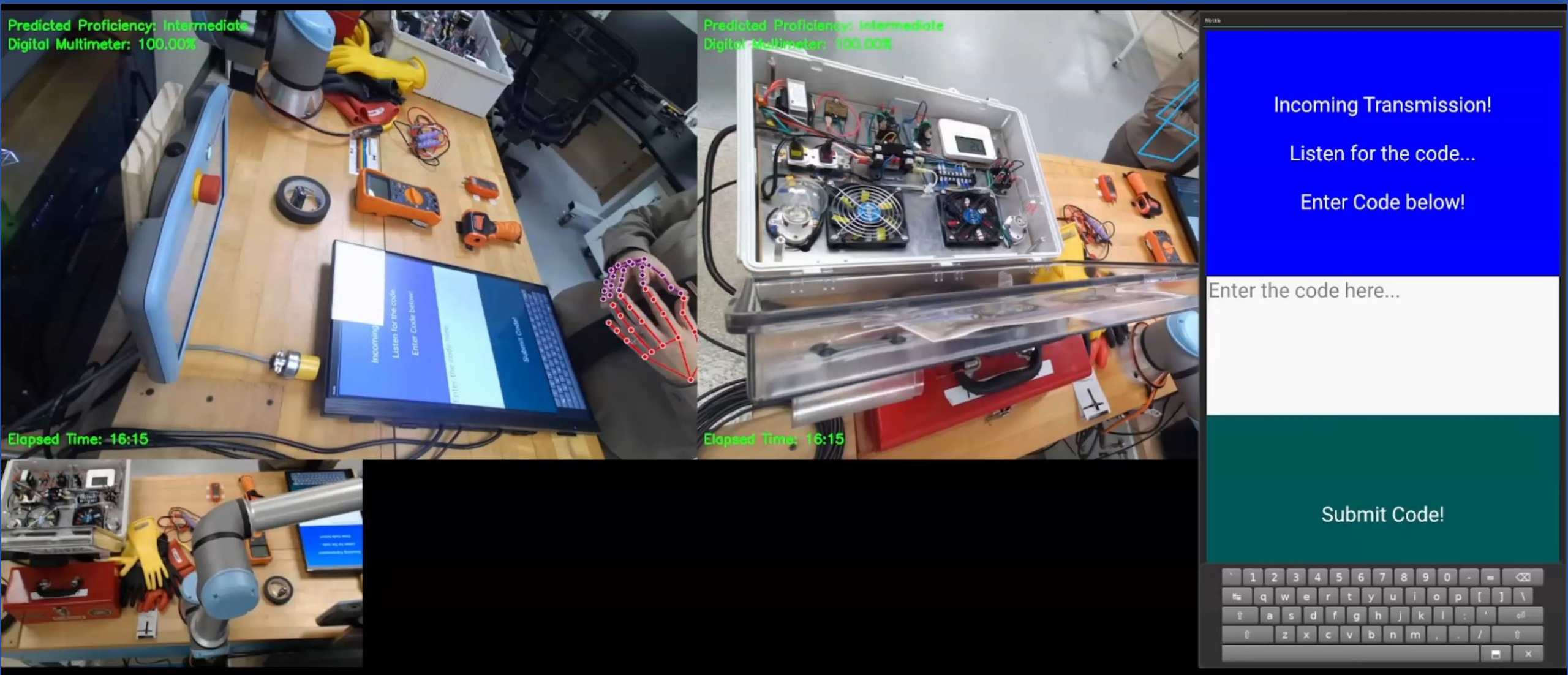
- In Laboratory
  - Technical Subject
  - Embedded Learning
- Robot Features:
  - Contextual Cueing
  - Intuitive Guidance*
  - Targeted Indication
- Further Aims:
  - Adaptive Learning Paths
  - Engagement and Motivation



*Norton, A., et al. (2022). Metrics for robot proficiency self-assessment and communication of proficiency in human-robot teams. ACM Transactions on Human-Robot Interaction (THRI), 11(3), 1-38.

Yale SOCIAL ROBOTICS LAB

Contextual Cueing



Cue Recognition

Intuitive Guidance

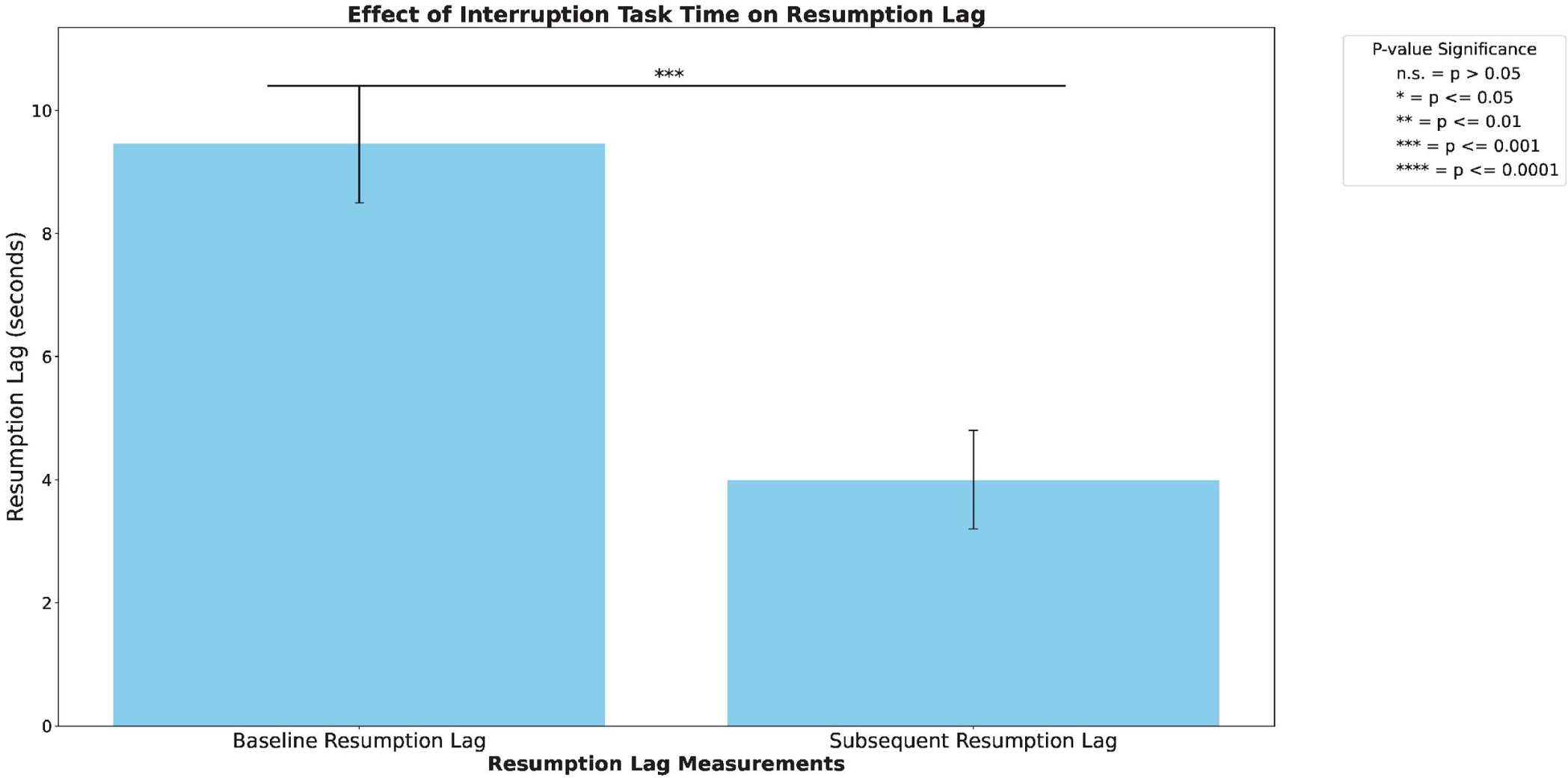
Sample Population and Metrics

- 65 participants
  - 55/10 male/female, English-speaking, no color blindness or auditory impairments.
- Interruption Response Time
- Task Resumption Time
- Errors
- Time-on-task Efficiency*

*Magrabi, F., et al. (2010). Why is it so difficult to measure the effects of interruptions in healthcare?. In MEDINFO 2010. IOS Press, 784-788.

Yale SOCIAL ROBOTICS LAB

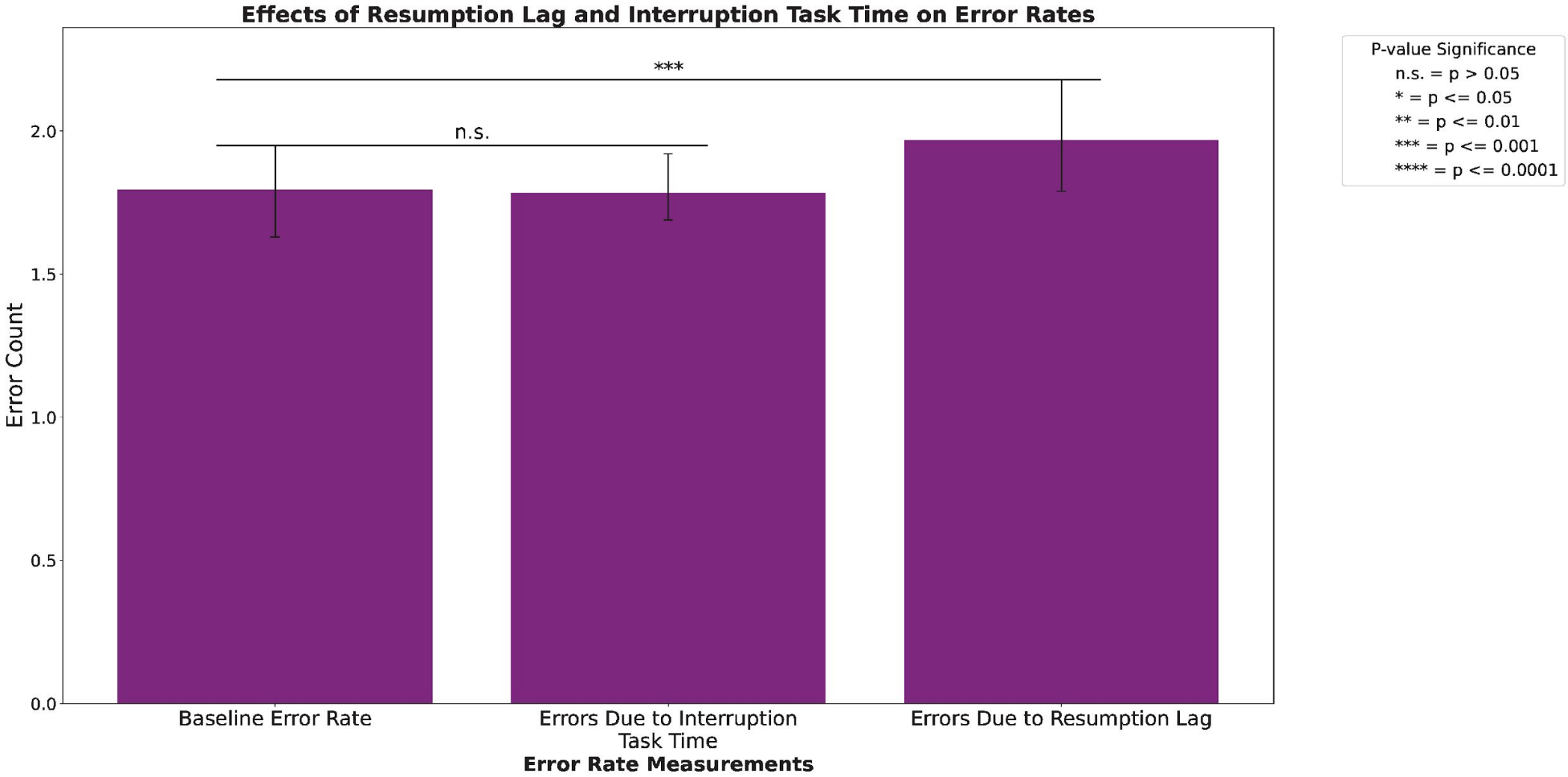
Findings: Supporting Recovery from Distractions



These results support **H1**: Longer interruption tasks time inversely affect resumption lag, leading to faster primary task resumption.

Yale SOCIAL ROBOTICS LAB

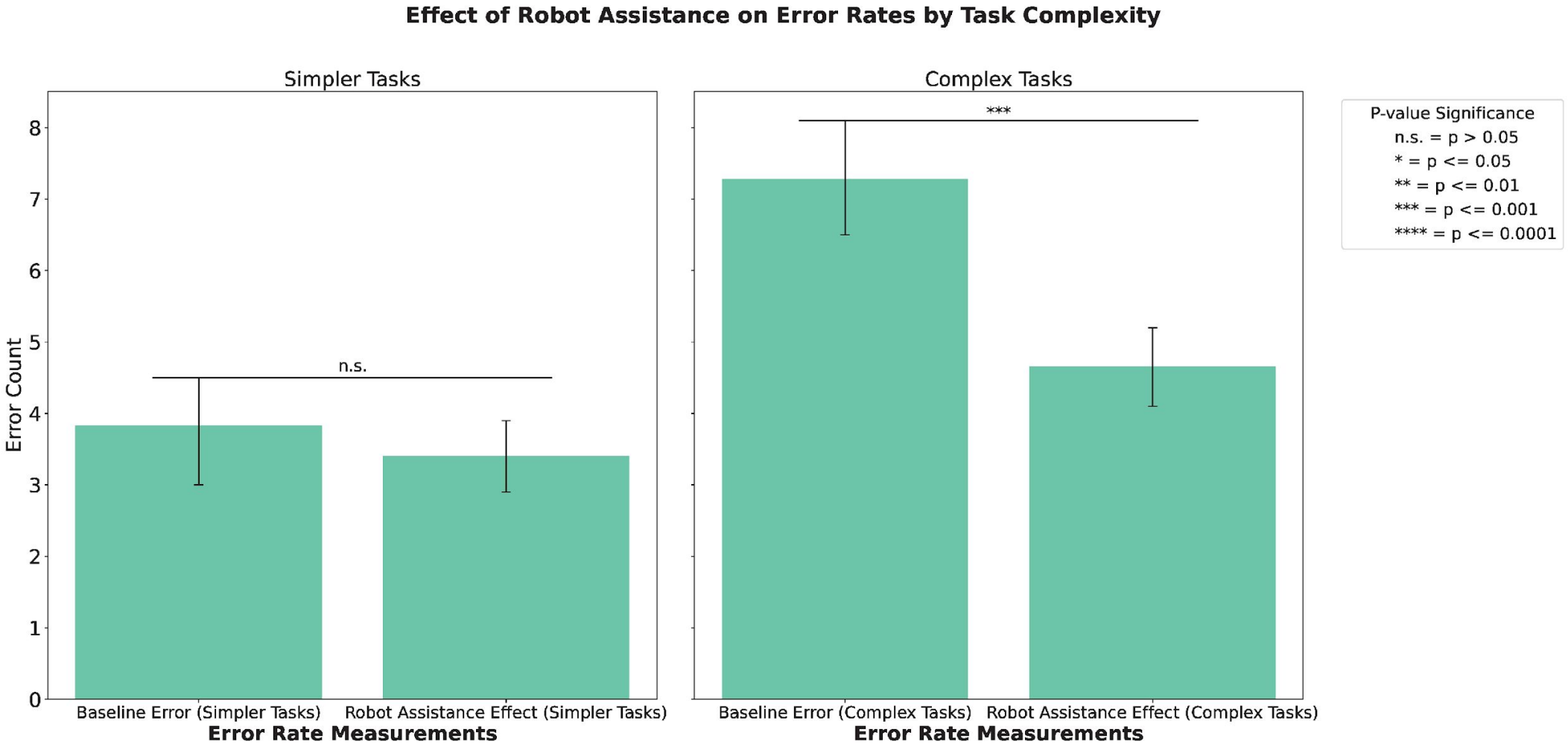
Findings: Supporting Recovery from Distractions



These results partially supported **H2**: Time-intensive interruptions increase errors in primary task.

Yale SOCIAL ROBOTICS LAB

Findings: Supporting Recovery from Distractions



These results support **H3**: The impact of robotic assistance on mitigating errors varies task complexity, with more complex tasks showing a greater benefit from robotic intervention.

Yale SOCIAL ROBOTICS LAB

Takeaways

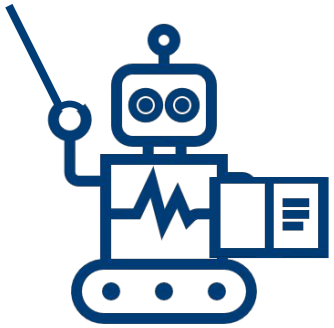
- Expansion to diverse educational settings.
- Strategic use of environmental cues.
- Evidence of differential impact based on task complexity.
- Enhanced technical education through robotic interplay.*

*López-Belmonte, J., et al. (2021). Robotics in education: A scientific mapping of the literature in Web of Science. Electronics, 10(3), 291.

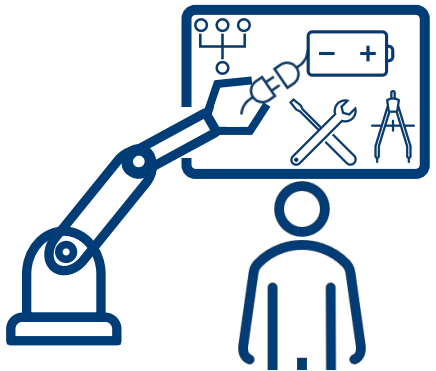
Yale SOCIAL ROBOTICS LAB

Integration of Findings: Key Insights

- Study 1: Interruption and Task Performance
  - Interruptions impact task performance, emphasizing the need for effective attention management strategies.



- Study 2: Robot-Assisted Interruption Management
  - Tailored robot assistance reduces interruption impact, enhancing task management and learning in training.



- Study 3: Supporting Recovery from Distractions
  - Robotics boost task performance and learning outcomes, bridging abstract and technical knowledge effectively.

Yale
SOCIAL ROBOTICS LAB

Q&A

Yale
SOCIAL ROBOTICS LAB