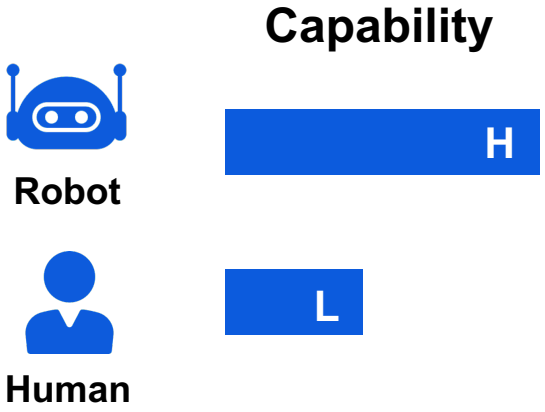
Assessing the Decision-Making Process in Human-Robot Collaboration Using a Lego-like EEG Headset

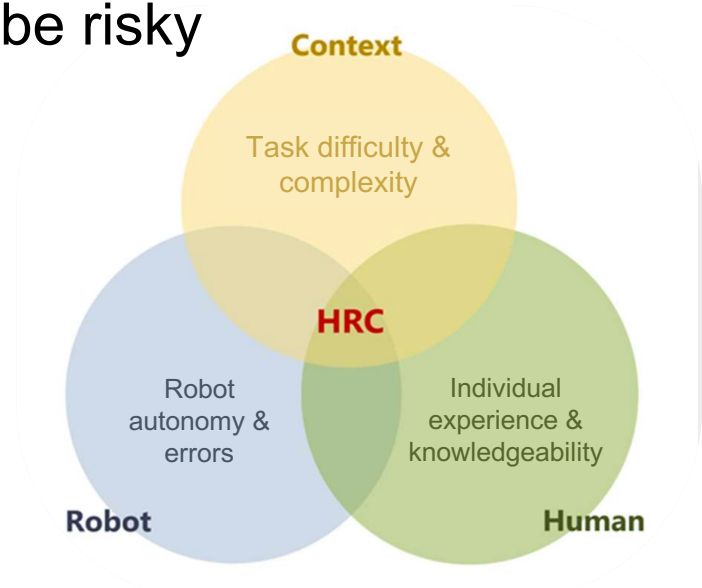
Ching-Chih Tsao[1], *Hao-Hsiang Chuang*[1], *Tzu-Han Tsao*[1], *Cheng-Yi Tang*[1], *Yu-Wen Chang*[1], *Chih-Ling Chu*[1], *Chi-Chien Sung*[1], *Cheng-Lin Hsieh*[1], *Yuan-Pin Lin*[2], *Shih-Yi Chien*[1]

[1] National Chengchi University, Taiwan, [2] National Sun Yat-sen University, Taiwan

Motivation

- **Trust** in automation is critical
- Highly autonomous robot can enhance HRI performance
- But there is no perfect automation in reality
- Inappropriate trust in a robotic agent can be risky



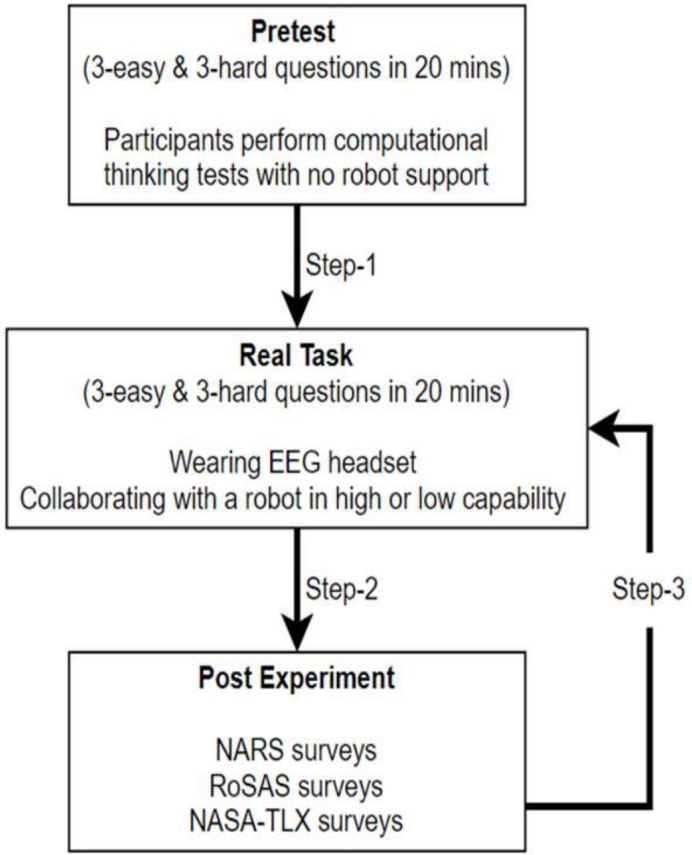


Research Question

1) **Do an individual's knowledge levels affect her reliance on a robot's suggestions?**

2) **Do a robot's capabilities affect user acceptance of the provided aids?**

Experimental Procedures

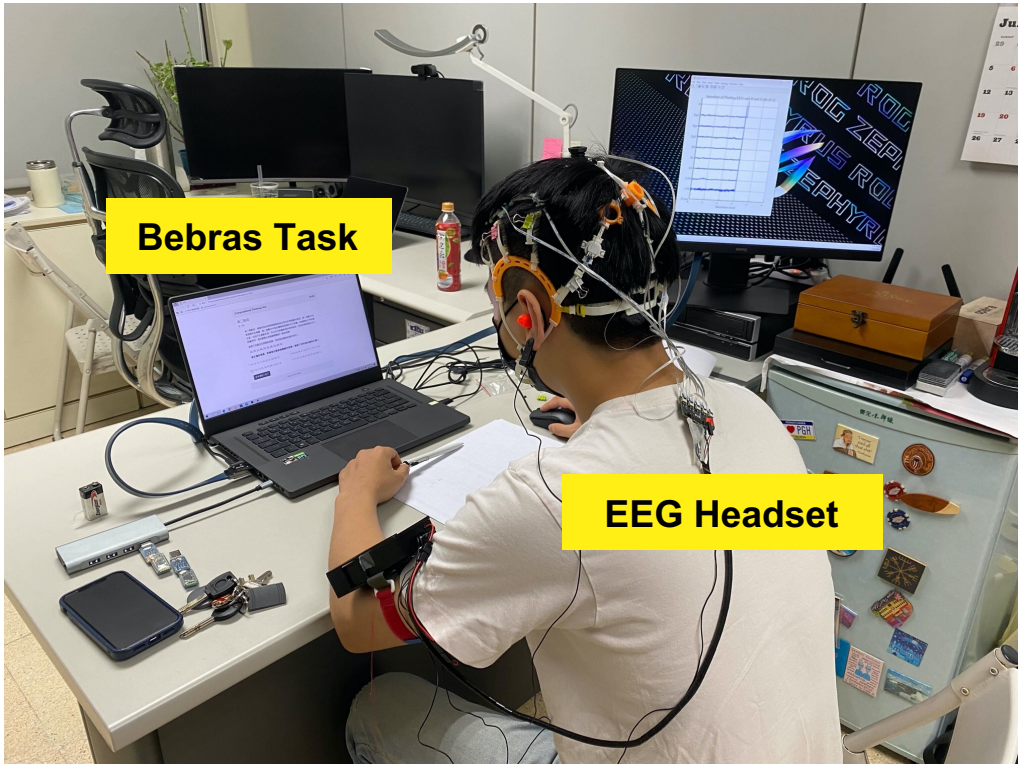


Six participants were divided evenly into two groups (high CT vs. low CT) based on their test score

Team with two robots in two rounds
Low capabilities: 33% correct rate
High capabilities: 66% correct rate

Measure the perceived task load and human intentions toward the robotic agent

Experimental Procedures (Cont'd)



Experimental Tasks: The Bebras Computing Challenge

- Organized in over 50 countries
- Aim to introduce computational thinking (CT) to students
- Participants answer questions that focus on computational and logical thinking

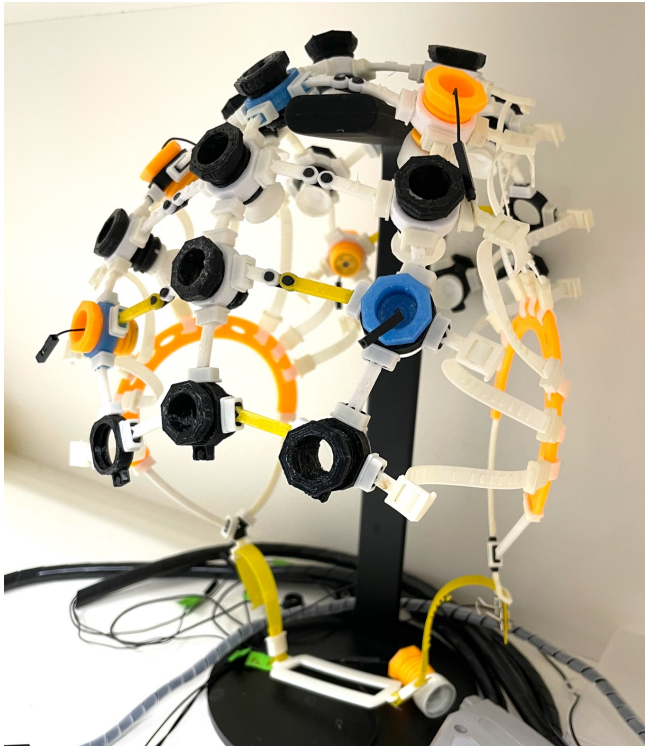
18 questions were selected
6 questions × (1 pretest + 2 rounds of real tasks)

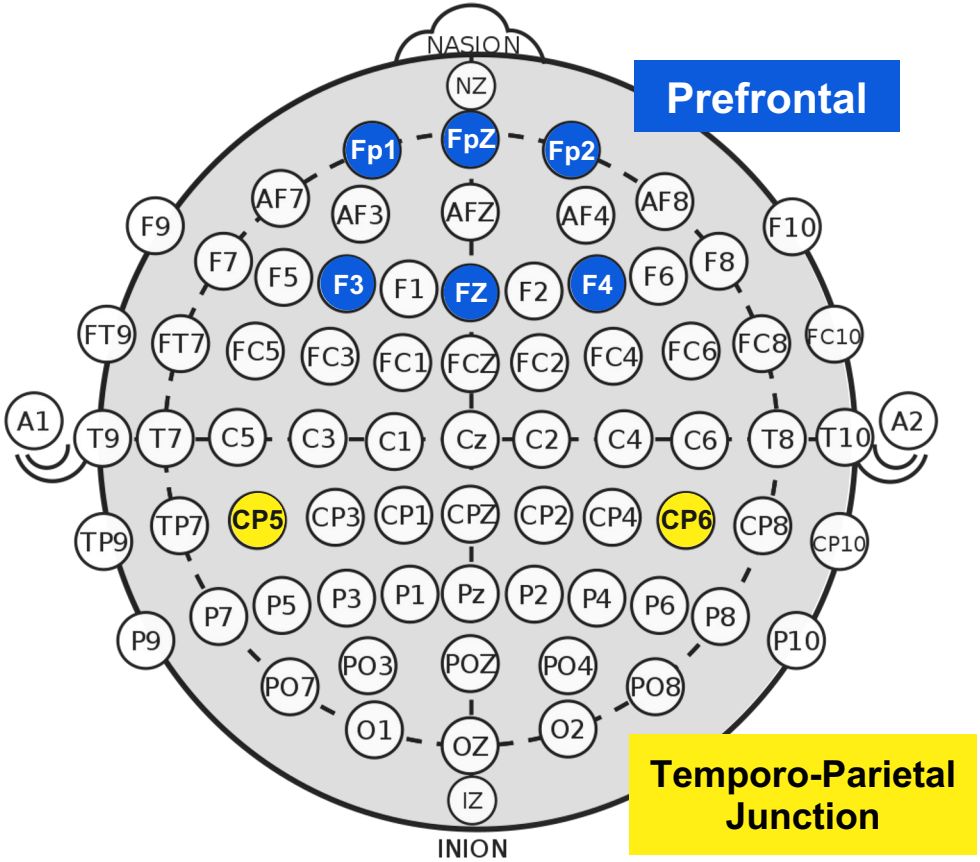
Easy: correct rate > 50%
Hard: correct rate < 50%

	Correct answer	**Incorrect** answer
Easy question	+6	-2
Hard question	+12	-4

What is Bebras. Retrieved December 30, 2022, from https://www.bebras.org/

EEG Headset

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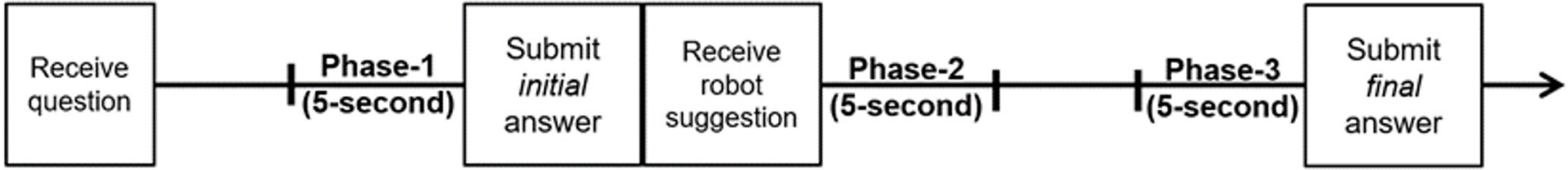
INION
Prefrontal
Temporo-Parietal Junction

Methodology: EEG Analysis



Phase 1

Brain activities before submitting the initial answer

Phase 2

Perceptions after receiving the robot recommendation

Phase 3

Brain activities before submitting the final answer

Frequency Band	Activities
Alpha 8~12 Hz	Relax and recharging
Low Beta 12~15 Hz	Quiet, focused, and introverted concentration
Mid Beta 15~20 Hz	Increases in energy, anxiety, and performance
High Beta 18~40 Hz	Significant stress, anxiety, paranoia, high energy, and high arousal

Result: Survey Results Overview

	NARS (range: 14~70)		RoSAS- Competence (range: 9~54)		NASA-TLX (range: 0~100)	
	High capability	**Low** capability	**High** capability	**Low** capability	**High** capability	**Low** capability
High CT	35.00	34.00	47.33	42.67	68.11	70.00
Low CT	30.33	33.33	36.67	31.33	69.00	69.67

High CT Participants have slightly more negative attitudes toward the high capability robot.

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High CT	35.00	34.00	47.33	42.67	68.11	70.00
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Participants were able to identify the difference of robot capability.

Result: Survey Results Overview

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The workload of working with low capability robot is slightly higher than collaborating with high capability robot.

Result: High CT vs. Low CT Task Performance

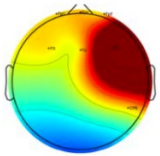
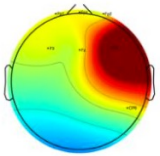
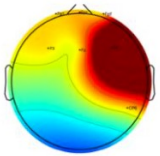
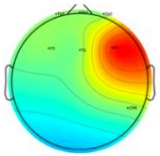
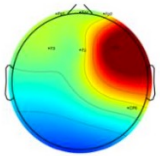
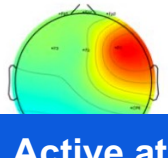
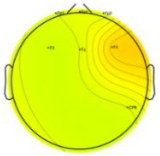
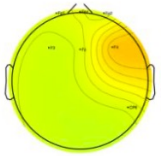
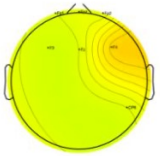
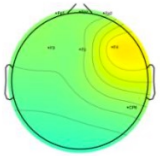
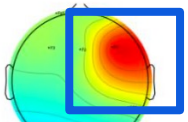
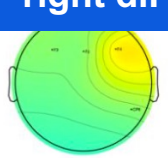
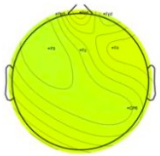
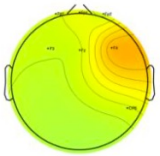
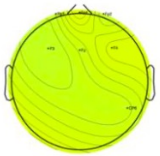
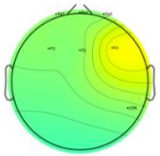
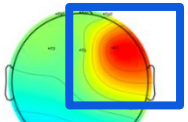
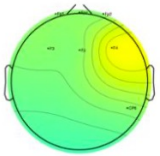
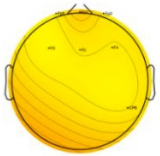
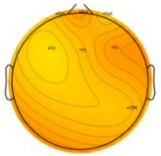
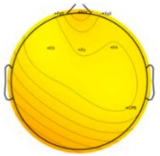
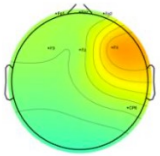
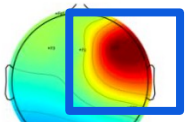
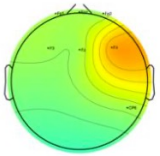
	High robot capability		**Low** robot capability	
	Initial answer	Final answer	Initial answer	Final answer
High CT group	24.67 points	27.33 points	16.67 points	6.00 points
Low CT group	10.00 points	12.67 points	-2.00 points	-2.00 points

Performance

The high CT group outperformed the low CT group regardless of the robot capability.

Overtrust

Robot with low capability significantly decreased the task performance

	Low CT Ability			High CT Ability		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
Alpha (Relax)						
Low Beta (Focus)						
Mid Beta (Increased Energy)						
High Beta (Stress)						

Active at the right dlPFC

Result: Overtrust vs. Appropriate Trust

	High robot capability		**Low** robot capability	
	Initial answer	Final answer	Initial answer	Final answer
Participant #2	22 points	22 points	30 points	-2 points
Participant #3	22 points	38 points	22 points	22 points

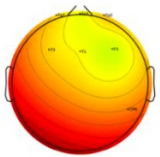
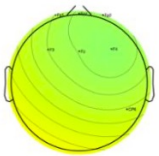
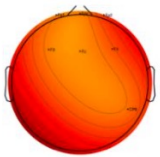
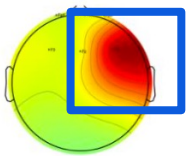
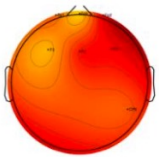
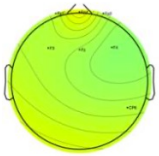
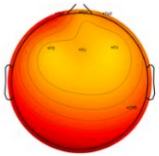
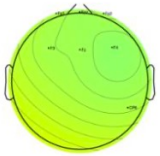
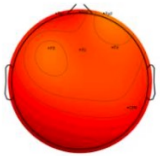
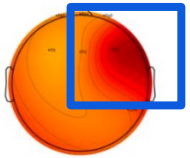
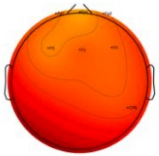
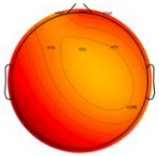
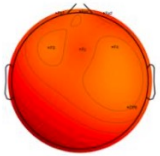
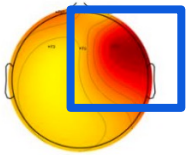
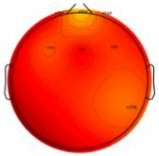
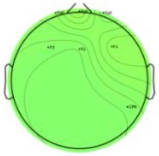
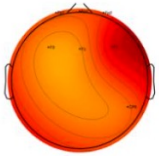
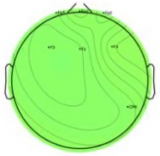
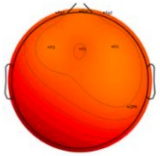
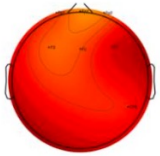
High CT

Participant #2 + Low Capability Robot ⬇ **− 32 pt**

Participant #3 + High Capability Robot ⬆ **+ 16 pt**

Overtrust

Appropriate trust

	P#2: Accept Suggestion & Submit **Wrong** Ans			P#3: Accept Suggestion & Submit **Correct** Ans		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
Alpha (Relax)						
Low Beta (Focus)						
Mid Beta (Increased Energy)						
High Beta (Stress)						

Preliminary Results

- The low capability robot's aid had a negative effect on the task outcomes for the high CT participants
- Better decisions are made when the brain generates **active beta waves** at the right prefrontal cortex
- Appropriate trust toward robotic agent’s suggestions requires a **longer decision process**

Summary

- The EEG topographic maps explained the differences in participants' **reliance behaviors**
- The Bebras task is capable to assess an individual's **CT ability**
- The differences of **robot capability** heavily affected the task outcomes
- More participants will be recruited in our formal study, which would allow us to develop robotic agents of **different capabilities** that can best support the participants with **diverse expertise**