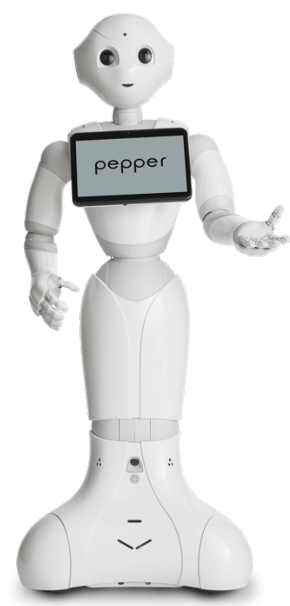
School of Humanities and Digital Sciences

Research Traineeship Program 2022-2023

1. Title of the project

Can a Social Robot be a Creative Partner? Effects of Perceived Robot Intelligence on the EEG Correlates of Brainstorming



2. Coordinators

Dr. Maryam Alimardani (DCA)
Dr. Mirjam de Haas (DCA)
Dr. Alwin de Rooij (DCC)
Dr. Jan de Wit (DCC)

3. Project description

Background:

Creativity, the creation of novel yet useful solutions to ill-defined, complex, or novel problems, is a highly sought-after skill [1]. Creativity often happens in collaboration with others as it is a multi-dimensional construct requiring both internal and external resources [2]. People can facilitate each other's creative thinking through brainstorming, a commonly used protocol where people are encouraged to produce and share as many unusual ideas as they can, while not judging each other's ideas [3]. However, the potential advantages of group work are often not achieved, e.g., when people do not build on other's ideas due to doubts about others' capabilities and dwindling engagement [4]. **An alternative solution is to involve interactive technologies such as social robots to maintain collaboration and facilitate the creative task.**

Social robots can be programmed to communicate ideas and facilitative cues with their users through their verbal and non-verbal social behavior [5]. Previous research provides examples of social robots used to spark creativity in activities such as collaborative drawing [6], Japanese Zen garden making [7], storytelling [8-10] brainstorming [5] and programming [11]. These studies generally suggest that compared to other technologies, social robots can facilitate creativity among users. However, little is known about the factors that shape human perceptions of robots as creative collaborators. **More research is required to understand the behavior and form factors that contribute to human-robot brainstorming.**

Human-robot collaboration follows the same guidelines as human-human interaction. Participants reward a robot's cooperative behavior and punish its selfishness as they do for a human collaborator [12], or they lose confidence and refuse to follow robot's instructions when it makes mistakes [13,14]. **Thus, perceived robot intelligence is an important factor for it to be trusted as a peer for collaboration [14, 15].** People perform better when collaborating with someone that is perceived as more skilled than them [16]. However, it is unclear whether such social comparisons also occur when collaborating with a social robot. Therefore, this research aims to investigate the impact of users' perception of a robot's intelligence on their engagement and performance during collaborative brainstorming with the robot.

We plan to manipulate the robot behavior so that it is perceived in two ways; as an intelligent brainstorming partner that comes up with relevant ideas in real-time, allegedly based on the ideas of the user, or as an unintelligent partner that draws ideas from a previously collected dataset without considering the user's input. We then evaluate the impact of the robot's framing on users' perception and collaboration with it on a brainstorming task. More importantly, in addition to subjective questionnaires, which are often used as the primary and sole evaluation tool in human-robot interaction (HRI) research, **we intend to integrate measurement of EEG brain activity during human-robot collaboration to obtain an objective measure of creative performance [17, 18] and user engagement with the robot [19]**.

Our research question is:

How does perceived robot intelligence influence human-robot brainstorming performance and engagement?

Methods:

We plan to recruit 30 participants to conduct a brainstorming task with a Pepper robot in a within-subject experiment. They will be asked to generate ideas together with the robot for two different but comparable ideation problems in two conditions: 1) where the robot displays intelligent behavior by generating relevant ideas in real-time, and 2) when the robot displays un-intelligent behavior by providing random ideas during the interaction (see Fig. 1). The ideas are selected from the same dataset in both conditions but they are communicated in different context and timing. The conditions and tasks are counterbalanced.

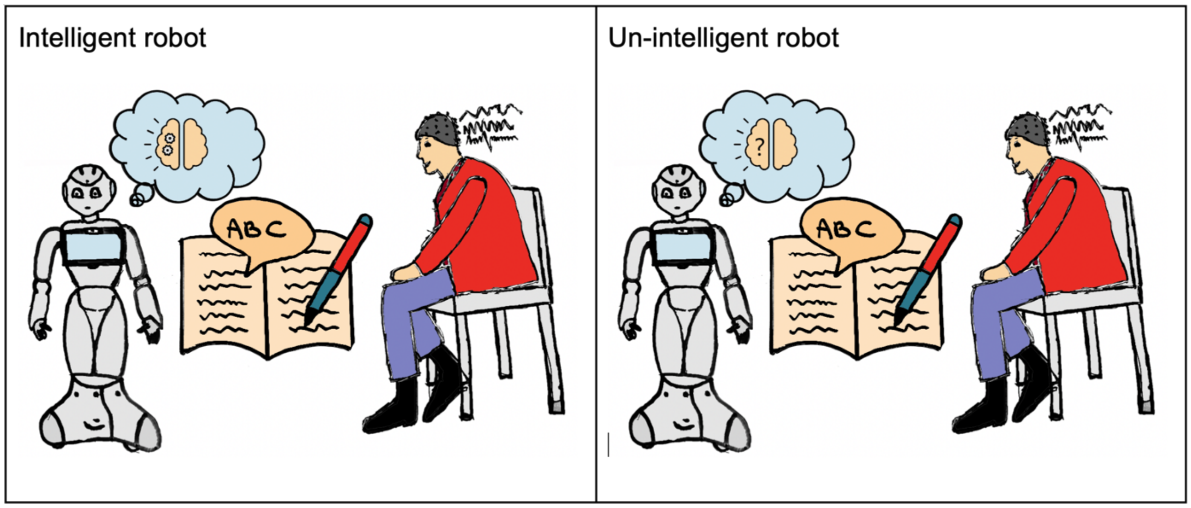


Figure 1. Participants will brainstorm with a social robot under two conditions; 1) the robot is framed as intelligent and 2) the robot is framed as un-intelligent.

The idea generation task will be a brainstorming task where people are asked to generate as many unusual ideas as they can for a given problem together with the robot [5, 20]. EEG brain activity will be collected using a wireless EEG cap (available at MindLabs, see Fig. 2) before (baseline) and during the idea generation task in each condition. Using the obtained signals in the frontal electrodes (F3, Fz, F4), we will compute EEG Engagement Index as a measure of user's engagement in the task [19] and Gamma-band power as a measure of creative brainstorming performance [17, 18].

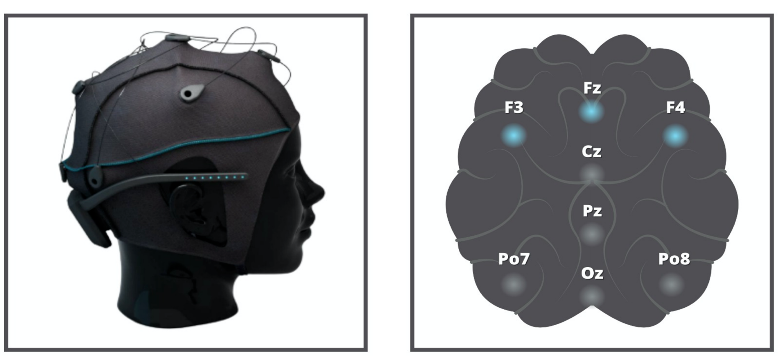


Figure 2. EEG Brain activity will be collected using the Unicorn Hybrid Black device.

Additionally, multiple questionnaires will be collected before the experiment and after each interaction condition to evaluate users' attitude and perception of the robot, engagement and acceptance. These include: Negative Attitudes towards Robots Scale (NARS) [21], God-speed questionnaire [22], Persuasive Robots Acceptance Model (PRAM) [23] and the short form User Engagement questionnaire [24].

The experiment will produce a rich dataset for exploration that will help drive future work. We will compare the following variables between the experimental conditions:

1) Subjective ratings of Perceived Intelligence (God-speed questionnaire) [22], User Engagement and Perceived Usefulness (PRAM) [24].
2) Collaboration performance on the brainstorming task (number of generated ideas and semantic similarity between robot's and user's ideas) [5, 20].
3) EEG Engagement Index and EEG Gamma band power [18, 19].

Additionally, correlation analyses will be performed on the EEG features, collaboration performance and subjective ratings.

Impact

The resulting knowledge from this study could unravel the causal mechanisms of the user's perception of a robot on their interaction quality and collaborative performance in HRI. It could also prove critical for designing robots that optimally maintain or even enhance the advantages of creative collaboration. Furthermore, the study introduces novel methods of measurement in HRI settings, that is neurophysiological indicators of engagement and creativity as quantified by EEG brain activity.

4. Project timeline

September 01, 2022	Open vacancy for recruitment of the trainees
October 01, 2022	Kick-off project with the hired trainees
November 15, 2022	Finish literature review, Finalize study design
December 23, 2022	Trainees finish preparation and develop all experiment materials (robot codes, questionnaires, EEG collection and analysis protocol, etc.)
January 15, 2023	Kick-off experiments (Ethical approval has already been obtained and is valid until Dec 2022. Amendment for extension will be requested before December)
March 15, 2023	Finish data collection and start analysis
May 31, 2023	Finish data analysis and start writing up
July 31, 2023	Termination of the project, send paper to HRI-related conferences, data management, and planning the follow-up

5. Collaboration

Our team consists of 4 researchers with expertise in the domains of creativity and psychology, social robotics, human-computer interaction and cognitive neuroscience. This enables us to look at the problem from various angles. The integration of social robots as a brainstorming support tool is a relatively new direction within the HRI domain that has received little attention so far. On top of that, employment of neurophysiological measures in HRI is scarce and to the best of our knowledge has never been done in past robot-creativity research. Therefore, this collaborative study is very promising both in terms of scientific publication in the fields of interest as well as paving the way for future research and larger grant applications.

6. Research Trainee profile

This project is open for both international and Dutch students.

Trainee 1 is an Ma or Ba student who has knowledge -or is interested- in cognitive science, brain imaging techniques and social robotics. The research trainee will collect EEG signals during the experiment and will perform feature extraction and data analysis. S/he will assist Trainee 2 in the development of the robot experiment. Therefore, a certain level of programming skills is required and experience with signal processing is a plus. This research theme is particularly suitable for students enrolled in the CSAI program.

Trainee 2 is an Ma or Ba student who has knowledge of – or is interested – in social robotics and ideally in creativity and design research. The research trainee will design the creative task and develop robot behavior for interaction experiments. Therefore, a certain level of programming in python and design skills is necessary. S/he will be required to assist data collection during experiments so an interest in EEG is a plus. S/he will be also responsible for the analysis of questionnaire data. This research theme is therefore particularly suitable for the new media design students enrolled in the CIS program.

7. Recruitment of trainees

At the beginning of September, an open vacancy call will be announced on the Canvas page of the relevant bachelor or master programs. Applicants should send a CV and a motivation letter to Maryam Alimardani (m.alimardani@tilburguniversity.edu).

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