Investigating Mind Perception in HRI through Real-Time Implicit and Explicit Measurements

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ABSTRACT

Social robots have revolutionized social interaction and communication. This study explores our perception of robots, focusing on the factors influencing evaluations of Agency and Experience - two dimensions of mind perception. Three distinct aspects of our research include: investigating perceiver determinants alongside perceived agents and their actions, utilizing a naturalistic setup featuring live actions of both human and robot actors, and employing a comprehensive approach with both implicit and explicit measurements. In-person data were collected from 160 individuals across four generations. Future steps involve data analysis and result discussion. This study reevaluates the determinants of mind perception using a real-time paradigm, intending to contribute to the ongoing debate and deepen our understanding of mind perception in HRI.

CCS CONCEPTS

• **Human-centered computing → Laboratory experiments**.

KEYWORDS

social robotics, human-robot interaction, mind perception, implicit association test, ecological validity

ACM Reference Format:
Tuğçe Nur Pekçetin, Cengiz Acarturk, and Burcu A. Urgen. 2024. Investigating Mind Perception in HRI through Real-Time Implicit and Explicit Measurements. In *Companion of the 2024 ACM/IEEE International Conference on Human-Robot Interaction (HRI '24 Companion), March 11–14, 2024, Boulder, CO, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3610978.3638366

1 INTRODUCTION

In human interactions, mind perception is vital for effective communication, empathy, and meaningful connections. This capacity to attribute mental states extends to nonhuman entities, including technology [6, 41]. The rising presence of social robots has led to inquiries into their perception as "new members" of society. This investigation is crucial, shaping the roles and designs of social robots as well as providing insights into human social cognition [3, 9].

HRI '24 Companion, March 11–14, 2024, Boulder, CO, USA

ACM ISBN 979-8-4007-0323-2/24/03.
https://doi.org/10.1145/3610978.3638366

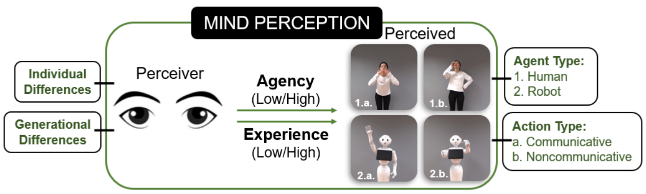

Figure 1: Representation of the current study, showing the parameters related to mind perception tested for perceiver and perceived. Inspired by Waytz et al. [41]

Extensive research, relying on self-reports and controlled laboratory experiments, has significantly contributed to understanding mind perception in Human-Robot Interaction (HRI). However, there is room for improvement in three key areas: *the validity of measurements*, often reliant on subjective verbal responses; *the ecological and external validity of experiments*, often limited to lab settings; and *the exploration of behavioral consequences*, requiring the development of methodologies to study the behavioral consequences. This study addresses these concerns by integrating insights from the intersection of Cognitive Science (CogSci) and HRI [33, 36].

Our research proposes a comprehensive and concurrent exploration of the role of determinants related to both the *perceiver* and the *perceived* in the context of the mind perception process. Specifically, we examine the dimensions of *Agency* (the ability to act) and *Experience* (the ability to experience sensations) as outlined by Gray et al. [12]. Our methodology combines *explicit measurements*, *implicit tasks*, and *interviews*, presenting a novel contribution. A distinctive feature of this doctoral research lies in the utilization of a *real-time* approach, incorporating *live* actors within a *naturalistic* co-located setting, all the while rigorously maintaining experimental control. With extensive pre- and post-study data, our goal is to reveal the origins and implications of attributing mental states to robots. Figure 1 provides a schematic representation of our study, inspired by Waytz et al.'s conceptual framework [41]. Subsequent sections delve into each module and relevant research questions.

2 DETERMINANTS OF MIND PERCEPTION

2.1 Parameters Related to the Perceiver

Individual Differences Previous research has explored the impact of human factors [7], including cultural background [35], motivation [42], and prior interactions with robots [5, 21], on mind perception induced by social robots. In addressing our **RQ1: How do individual differences modulate mental capacity attributions to robots in a real-time study?**, we explore whether specific individual traits can predict the extent to which participants attribute mental capacities to humans or robots. Drawing insights from Saltik et al.'s study [31], we administer seven individual difference scales [2, 22, 23, 29, 37, 39, 40] before participants see the actors and engage in real-time implicit and explicit tasks.

Generational Differences Previous research indicates varying levels of mind perception toward robots across different age groups [36]. Existing studies, relying mainly on self-reports and often comparing two groups such as children vs. adults, lack conclusive findings on generational differences. To address this gap, we pose **RQ2: Are there generation-specific patterns in mental capacity attribution?** In our real-time experiment, we included participants from four age groups (Young: 18-28, Adult: 33-43, Middle Age: 48-58, Elderly: 63-73), aligning with established generational classifications based on the age at which individuals first encountered technological innovations [20, 24]. With this representative approach, we aim for a nuanced understanding of mind perception patterns across generations, both implicitly and explicitly.

2.2 Parameters Related to the Perceived

Agent Type Past studies comparing robots with other agents or entities, as well as robots with diverse faces and body forms [4, 13, 45] consistently show a greater inclination to attribute mental states to humans than to robots, or to humanoid robots compared to computers. Furthermore, the presence of robots further increases this tendency [18]. To address **RQ3: What is the impact of agent type on mind perception when both agents are physically present and performing the same?**, we use real-time stimuli performed by two real actors: a human actor (see Figure 1, panels 1.a and 1.b) and Pepper, a programmable humanoid robot with extensive mobility capabilities (see Figure 1, panels 2.a and 2.b).

Action Type While some studies suggest that socially interactive robot behavior leads to greater attribution of mental capacities [1, 10, 30, 34, 44, 46], others find similar tendencies between social and nonsocial robot behavior [8, 38]. We propose that observing live robot actions when robots are physically present rather than through images or videos [32], is the optimal method for assessing the impact of robot behavior on mind perception. To address **RQ4: How does an agent's action type influence mind perception?**, both agents in our study performed identical sets of communicative (e.g., peek-a-boo, saluting, throwing a kiss, hand-waving, see Figure 1, panels 1.a and 2.a) and noncommunicative actions (e.g., shooting an arrow, jogging, drinking, driving, see Figure 1, panels 1.b and 2.b). Before integrating them into our real-time experiment, we normed and validated [15] our action stimuli through two online studies involving a total of 40 actions and 438 participants [25].

3 METHODS TO MEASURE MIND PERCEPTION

In response to the call for incorporating implicit measures into social cognition research [14], we employ a combined approach of implicit and explicit tasks to address **RQ5: Do implicit and explicit metrics align in mind perception results?** To present real-time stimuli, we have devised a specialized laboratory setup, thoroughly documented in our previous works as an article and a video clip [27]. An innovative and indispensable component of this setup is an OLED screen offering transparency during stimulus presentation and opacity during evaluation. This design eliminates modulation changes between stimuli and responses, facilitating accurate measurements. Subsequently, we provide a detailed overview of the implicit and explicit tasks employed in our study.

Implicit Measurements We focused on the Agency and Experience dimensions of mind perception [12], aligning with the binary structure of the implicit association task (IAT) [16]. We measured the High and Low ends of these dimensions similar to a recent study, which introduced the Mind Perception IAT (MP-IAT) [19]. Differentiating from previous works, in our Real-World IAT (RW-IAT) [28], we feature live human and robot actors while they perform various communicative and noncommunicative actions. The participants watch these actions when the screen is transparent, and when the screen turns opaque, they evaluate the actions by attributing High or Low ends of Agency or Experience and we record their responses, response times, and mouse trajectories to analyze hesitations [11, 43]. Similar to the action stimuli, we normed and validated the conceptual stimuli in an online study (*N=274*), as documented in our prior work [26]. We also thoroughly documented the details of our RW-IAT in a recent paper [28].

Explicit Measurements We created an explicit task as a counterpart to the implicit task, where participants rate agents and actions on Agency- and Experience-related mental capacities using a 1-7 Likert scale. This task involves six blocks, assessing both communicative and noncommunicative actions by alternate actors through 12 sentences, such as "This human/robot can feel hunger." Our goal is to examine the alignment or divergence between implicit and explicit measurements of mind perception, analyzing response times and Likert scale responses.

4 PROGRESS SO FAR AND FUTURE PLANS

We recently completed in-person data collection for this study with 160 participants, evenly distributed across four age groups. The participants' ages ranged from 18 to 73 and they had diverse backgrounds, which we hope would contribute to the generalizability of the findings in HRI [17, 36]. Regarding the procedure, after the training sessions, the participants first completed the RW-IAT task, followed by the Explicit Task, and were interviewed about their perceptions of the study and social robots.

In future work, we will conduct a thorough analysis of implicit and explicit task data, exploring the role of individual and generational differences. We will also analyze the interview data, which would provide insights into the implications of mind perception. By integrating comprehensive behavioral and self-report data, we aim to offer a holistic understanding of the dynamics of the mind perception process in the HRI context, from a CogSci perspective.

ACKNOWLEDGMENTS

This study is funded by The Scientific and Technological Research Council of Türkiye, TUBITAK (Project Number: 120K913). We thank Şeyda Evsen and Serkan Pekçetin for their collaborations in implementing the experiment and lab setup, Tuvana Karaduman for her acting, Gaye Aşkın, Aslı Eroğlu, Deniz Erdil, and RAs Badel Barinal, Jana Tunç, Gizem Çınar, Zeynep Koçak, Duru Naz Han, Melis Akdeniz, İdil Ece Karaosman for their contributions.

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