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EXTENDED-ABSTRACT

Understanding the Formation of Human-Robot Rapport to Facilitate Positive Long-Term Human-Robot Interaction

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Abstract

As robots integrate into everyday settings, they must build positive relationships with people to ensure their long-term use. These relationships are characterized by "rapport," which involves mutual understanding and interpersonal connection. However, there are no effective scales that measure human-robot rapport in various scenarios, and there are few studies that explore how human-robot rapport is developed and sustained over time. We discuss our prior, current, and future works that operationalize human-robot rapport, understand factors that affect rapport across sessions, and test how robot behaviors can sustain rapport in the long term. In our prior work, we developed the Connection-Coordination Rapport (CCR) Scale to measure human-robot rapport. In our current work, we use this scale to investigate how a robot's social behaviors (empathy, self-disclosure) influence rapport in a three-session study. Finally, our future work will explore how a robot leverages prior conversations with the user to sustain rapport over three weeks.

CCS Concepts

• **Human-centered computing** → **HCI design and evaluation methods**; • **Computer systems organization** → **Robotics**; • **General and reference** → **Metrics**.

Keywords

social robots, human-robot rapport, scale development, robot empathy, robot self-disclosure, long-term human-robot interaction

1 Introduction

In recent years, robots have transitioned from factories to our everyday environments such as restaurants, hospitals, and nursing homes. The success of these social robots not only depends on their technical performance but also relies on their ability to interact smoothly with people and tailor to their needs. Building rapport during these human-robot interactions increases people's willingness to engage with the robots, thus enabling the robots to perform their tasks more effectively. Past literature in HRI has found that fostering human-robot rapport leads to a wide range of advantages, including enhancing customers' satisfaction [4], patients' overall well-being [19], and children's willingness to learn [25, 33]. Strong human-robot rapport also has the potential to sustain people's engagement with a robot after the novelty of the robot wears off [10]. Despite the importance of rapport, the field of HRI currently lacks a validated scale that could measure human-robot rapport in a variety of situations. Previous rapport scales often lack clear psychometric validation [11, 12, 16] or contain many reverse-coded scale items that increase respondents' misunderstanding [3, 35, 36]. They also often cannot measure rapport in varied settings [20, 28, 32] or capture rapport (which is an observable construct) from a third-person perspective [8, 13, 15]. To address these weaknesses, we are motivated to design a rapport scale with items that are forward-coded, applicable to different contexts, and measurable from both first- and third-person perspectives. With this rapport scale, we could easily evaluate how a robot's behavior affects rapport.

In addition to the lack of rapport measures in HRI, the field is also missing a scalable and replicable framework for the robot to generate rapport-building speech. Even though prior works have shown that robot small talk [24, 31], backstories [9, 17], and active listening [34] could lead to greater human-robot rapport, these prior approaches use pre-scripted robot speech and cannot scale or generalize. Furthermore, only a handful of studies (e.g., [18]) examine how robots' speech affects human-robot rapport over multiple sessions. To close this gap, in our current work, we systematically define generalizable methods to operationalize two fundamental aspects of robots' rapport-building speech (i.e., robot empathy and self-disclosure) and analyze their effect on human-robot rapport over three study sessions. For future work, we will continue exploring how robots' social speech behaviors can sustain long-term human-robot rapport outside of a lab setting. We plan to leverage the robot's interaction history with the user to deliver longitudinal rapport-building speech (i.e., longitudinal robot empathy and self-disclosure) to reinforce rapport in a three-week study conducted in a college dormitory.

In our prior, current, and future work, we seek to capture rapport, understand factors that could drive rapport, and investigate strategies to maintain rapport in the long term. Throughout our work, we seek to answer these research questions:

- **RQ1 (Prior Work):** How do we characterize rapport and measure it quantitatively?
- **RQ2 (Current Work):** How can a robot use its verbal behaviors to build rapport with people over time?
- **RQ3 (Future Work):** How can a robot sustain rapport with people in a long-term real-world setting?

2 RQ1: Measure Human-Robot Rapport

Since prior rapport scales cannot be applied across different contexts and from both first- and third-person perspectives, we developed and validated the 18-item Connection-Coordination Rapport (CCR) Scale in Lin et al. [23]. To create this scale, we first defined rapport as "*a feeling of mutual understanding and interpersonal connection among individuals developed through interactions*" and utilized this definition to extract terms from dictionary definitions of rapport, papers retrieved from Google Scholar with keywords of "rapport" and "rapport in human robot interaction", and the general population's view of rapport to measure human-robot rapport. We then conducted three studies to construct, evaluate, and validate our scale. In Study 1 ($N = 288$), we identified two factors through exploratory factor analysis (EFA): "Connection" and "Coordination", which we named based on the items' contextual meanings in each factor. Building on these two factors, we named our scale the Connection-Coordination Rapport (CCR) Scale. In Study 2 ($N = 201$), we showed the CCR scale has an acceptable fit via confirmatory factor analysis (CFA), retains high reliability ($\alpha = 0.97$, $\omega_{total} = 0.97$), and outperforms the Rapport Scale 4 from Gratch et al. [11] by a statistically better model fit. In Study 3 ($N = 44$), we confirmed the CCR scale's construct validity, as in-person participants reported significantly greater rapport with a responsive robot as opposed to an unresponsive one, and we again found the CCR scale to be highly reliable ($\alpha = 0.95$, $\omega_{total} = 0.96$). Our CCR scale consists of 18 items, which capture positive characteristics of an interaction (e.g., empathy, respect, engagement, attentiveness). These items are rated on a five-point scale from *Strongly Disagree* to *Strongly Agree*. The CCR scale allows us to quantify rapport, which addresses our RQ1.

3 RQ2: Understand Factors Contributing to Human-Robot Rapport Over Time

Given the shortage of scalable approaches for robots to build rapport with people, we are currently conducting a three-session study to analyze how a robot's empathy, self-disclosure, and their combination based on structured "formulas" affect human-robot rapport over repeated interactions. Empathy and self-disclosure are both core rapport-building speech strategies. Robot empathy is known to enhance relationships [2, 5, 30] while robot self-disclosure could increase trust [26] and engagement [14]. We also explore the interaction of robot empathy and self-disclosure, as we hypothesize it will have the strongest effect on rapport due to its two-way reciprocal rapport-building process. In our current work, we are conducting a 2x2 between-subjects study where college students would interact with a homework companion robot that delivers either empathy (*Empathy Condition*), self-disclosure (*Self-Disclosure Condition*), both empathy and self-disclosure (*Empathy + Self-Disclosure Condition*), or neutral statements (*Baseline Condition*).

During each 30-minute study session, students will be asked to work on their homework while the robot assists them by setting goals to complete their work and checking in on their progress. In the *Empathy Condition*, we designed the robot to display empathy using a structured formula fed into an LLM prompt that combines both affective empathy (understanding the student's emotional state) and cognitive empathy (taking the student's perspective and

drawing inferences about their thought), inspired by Park and Whang [29]. To keep the robot empathy plausible, the robot is restricted from presenting its emotions as stemming from its own lived experience, as if it has personally been through that. Below, we show the formula for robot empathy with an example:

- **Student:** *"I was nervous practicing my French pronunciation."*
- **Robot:** *"It's understandable to feel nervous when you're putting yourself out there with a new language."* (affective empathy) *"But it sounds like you're really pushing yourself, which is great."* (cognitive empathy)

In the *Self-Disclosure Condition*, we also designed our own structured formula (fed into an LLM prompt) to generate robot self-disclosures. This formula consists of a discourse marker (e.g., *"that makes me think of"*), affective alignment (sharing related emotions), and cognitive alignment (sharing related past experience). Since having a robot self-disclose an unbelievable personal story may lead to the uncanny valley effect [6], we developed believable backstories for the robot to reference as it self-discloses. We show the formula for robot self-disclosure with an example below:

- **Student:** *"I am catching up on my history readings. They feel really dry and hard to get through."*
- **Robot:** *"That reminds me of how discouraged I felt when I struggled to hear someone clearly."* (discourse marker and affective alignment) *"They grew impatient over time and raised their voice during the interaction."* (cognitive alignment)

In the *Empathy + Self Disclosure Condition*, the robot's speech will be a combination of its responses in the *Empathy Condition* and *Self-Disclosure Condition*. As for the *Baseline Condition*, the robot will just respond with neutral statements (e.g., "I see, so that's what you're spending your time on right now"). College student participants will complete three study sessions with the robot and evaluate their rapport using the CCR scale [23] after each study session. From our current work, we seek to understand how a robot can best build rapport through its speech with people over repeated interactions, answering our RQ2.

4 RQ3: Sustain Long-Term Rapport

Since robot personalization and adaptation with memory are keys to sustaining positive long-term user engagement [1, 7, 21, 22, 27], we plan to investigate whether a robot can utilize its past interactions with the user to give longitudinal rapport-building speech to maintain human-robot rapport in a three-week study. In our future work, we will integrate a homework companion robot into college dormitories where students will interact with a robot that memorizes transcripts of past conversation topics and responses. The robot will leverage retrieval-augmented generation (RAG) to reference conversation history and show either longitudinal empathy (i.e., empathy with references to the student's history of emotions) or longitudinal self-disclosure (i.e., self-disclosure about its new memory with the student). The students will work on their homework with the robot daily and assess their rapport with the CCR scale [23]. The results from our future work will inform us whether the addition of longitudinal speech is beneficial to sustain long-term rapport in a real-world setting and guide the design of long-term robots in broader contexts such as K-12 tutoring, workplace training, and in-home caregiving, which tackles our RQ3.

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