

The Role of Trust in Human-Robot Interaction: A Perspective on Factors Influencing Trust Development

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Abstract - Trust is a fundamental determinant of successful human-robot interaction (HRI), shaping user acceptance, reliance, and collaboration with robotic systems. This paper examines trust development in HRI through the lens of Social Exchange Theory (SET), emphasizing key influencing factors such as reliability, transparency, predictability, and social behavior. Trust plays a pivotal role in various domains, including healthcare, manufacturing, and autonomous systems, where user confidence in robotic performance is crucial for effective adoption. By analyzing empirical research, this study highlights strategies to foster trust and mitigate challenges associated with human-robot collaboration. Recommendations for designing transparent, consistent, and socially intelligent robotic systems are provided to enhance trust and usability in different sectors.

Keywords: Trust, Human-Robot Interaction, Social Exchange Theory, Reliability, Transparency, Autonomy.

I. INTRODUCTION

Background of the study

The integration of robots into various sectors, including healthcare, manufacturing, and customer service, has highlighted the importance of trust in human-robot interaction (HRI). Trust plays a crucial role in determining how individuals perceive, accept, and collaborate with robots in different settings. Without adequate trust, users may resist adopting robotic systems, which can impede technological progress and operational efficiency (Hancock et al., 2021). Trust influences whether individuals feel comfortable delegating tasks to robots, relying on their decision-making capabilities, and interacting with them in both personal and professional environments. The development of trust in HRI, therefore, requires a comprehensive understanding of various contributing factors, including robot-related, human-related, and situational elements.

Human-robot interaction has gained significant attention as advancements in artificial intelligence (AI) and robotics have led to increased human-robot collaboration. Trust in HRI

is a multifaceted construct influenced by several factors, such as the reliability, competence, transparency, and ethical considerations associated with robotic systems (Xu & Yanco, 2022). For instance, a robot's ability to perform tasks accurately and consistently builds trust, whereas system failures or erratic behavior may lead to distrust. Transparency in robotic decision-making, including clear communication of capabilities and limitations, further strengthens trust. Ethical concerns, such as data privacy, fairness in algorithmic processes, and the potential for biased decision-making, also play a role in shaping human perceptions of trust in robotic systems.

Research has shown that trust in HRI varies depending on the application of robots, whether in medical surgeries, autonomous vehicles, or industrial settings (de Visser et al., 2020). In high-risk environments like surgery or autonomous driving, trust is particularly critical because the consequences of failure can be severe. Studies suggest that individuals are more likely to trust robots in structured and predictable environments than in highly dynamic or unpredictable settings (Hancock et al., 2021). Additionally, prior experience with robots and overall technological literacy can impact an individual's willingness to trust and engage with robotic systems. Cultural attitudes toward automation and AI further shape the degree of trust people place in robots across different societies.

Understanding the dynamics of trust development is essential for designing robots that are not only functional but also acceptable and reliable in human-centered environments. Engineers and developers must consider both technological and psychological factors to enhance trust in HRI. Designing robots with user-friendly interfaces, providing clear explanations for their actions, and incorporating mechanisms for human oversight can improve trust and adoption.

Statement of the Problem

Despite the growing prevalence of robots in various industries, trust remains a significant barrier to their widespread adoption. Many individuals are hesitant to rely on robotic systems due to concerns about reliability, security, and

ethical implications (Madhavan & Wiegmann, 2021). Fear of malfunction, particularly in high-risk environments such as healthcare and autonomous driving, can create resistance to robot-assisted operations. Ethical concerns, including data privacy, job displacement, and algorithmic bias, further contribute to mistrust. Additionally, a lack of transparency in how robots make decisions or process information may lead users to question their accuracy and fairness, ultimately impacting their willingness to engage with robotic systems.

Another critical factor affecting trust in robots is their consistency and ability to display social cues that facilitate human-like interactions. Studies have shown that people tend to trust robots more when they exhibit predictable and consistent behavior over time (Robinette et al., 2020). However, inconsistencies in robotic responses or errors in decision-making can quickly erode trust, making users skeptical of their reliability. Moreover, the absence of social cues such as facial expressions, gestures, or verbal explanations can hinder human-robot rapport, as people naturally rely on these elements to assess credibility and intentions in human interactions. Addressing these issues requires designing robots that can communicate effectively, adapt to user needs, and demonstrate dependable performance.

This study seeks to explore the factors influencing trust development in human-robot interaction (HRI) and identify strategies to enhance trust in robotic collaborations. Understanding how transparency, predictability, and ethical considerations impact trust can help inform the design of robots that foster greater user confidence. Strategies such as improving explainability in robotic decision-making, incorporating human-like social behaviors, and ensuring consistent performance can strengthen trust in robotic systems. By addressing these challenges, researchers and engineers can develop robots that are more widely accepted and integrated into various industries, enhancing human-robot cooperation and efficiency.

Objectives of the Study

1. To examine the key factors influencing trust development in human-robot interaction.
2. To analyze how robot-related attributes (e.g., reliability, transparency) impact trust.
3. To investigate human-related factors (e.g., personality, familiarity) affecting trust in robots.
4. To evaluate situational and contextual factors that influence human trust in robotic systems.
5. To provide recommendations for improving trust in human-robot interaction.

II. LITERATURE REVIEW

Trust Theory

Trust Theory, introduced by John D. Lee and Katrina A. See in 2004, provides a comprehensive framework for understanding how humans develop, calibrate, and adjust trust in automated systems, including robots. Specifically, the theory outlines three critical dimensions that govern trust in automation: performance, process, and purpose. Firstly, performance refers to the system's reliability and its ability to fulfill its intended function. Secondly, process pertains to how transparent and understandable the system's operations are, thereby enabling users to predict and interpret its behavior. Lastly, purpose involves the perceived alignment between the robot's goals and those of the human user. Lee and See (2004) succinctly define trust as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (p. 51), thereby highlighting both the psychological and situational aspects of trust.

Furthermore, Trust Theory holds particular significance in the domain of Human-Robot Interaction (HRI), where interactions frequently occur under conditions of uncertainty—such as in healthcare, emergency response, or assistive technologies. In these contexts, users must decide whether to rely on the robot or monitor its behavior closely. According to Hancock et al. (2011), trust serves as a crucial mediator in such collaborations, directly influencing user engagement, task efficiency, and overall system effectiveness. In fact, robots that consistently demonstrate high performance, communicate their actions clearly, and appear to have benevolent intentions aligned with user goals are significantly more likely to be trusted. Supporting this, Hancock et al. (2011) conducted a meta-analysis which revealed that robot performance and behavioral consistency were among the strongest predictors of trust development in HRI.

Moreover, numerous scholars have expanded upon or supported Lee and See's model within robotic systems. For example, Desai et al. (2012) emphasized the importance of process transparency, noting that a robot's ability to explain its actions plays a vital role in establishing calibrated trust, especially in collaborative environments. Similarly, Robinette et al. (2016) investigated how robot explanations of intent—which relate to both process and purpose—can sustain or even rebuild user trust following system failures. Additionally, Waytz et al. (2014) demonstrated that when users perceive robots as having a social purpose aligned with their own, they are more likely to trust and accept the robots. Collectively, these studies reinforce the idea that trust is influenced not only by technical reliability but also by how effectively a robot communicates and socially aligns with human users.

In the context of the current study; *The Role of Trust in Human-Robot Interaction: A Perspective on Factors Influencing Trust Development*—Trust Theory serves as a valuable analytical lens. For instance, performance-based trust is evident in the work of Salem et al. (2015), where users expressed greater trust in robots that operated reliably and with fewer errors. In addition, process-based trust is enhanced when robots provide clear, understandable explanations for their actions, thereby reducing uncertainty and increasing confidence, as shown in the findings of Wang et al. (2016). Equally important, purpose-based trust becomes critical when robots engage in socially meaningful behaviors—such as offering apologies or demonstrating empathy—which users interpret as signals of shared intention or moral alignment (Eyssel & Hegel, 2012). Therefore, by applying these three dimensions, researchers can more precisely assess whether a robot's trustworthiness is rooted in its functional capability, its behavioral transparency, or its socio-emotional resonance with users.

In conclusion, Trust Theory, as articulated by Lee and See (2004), offers a nuanced and multidimensional approach to understanding trust in human-robot relationships. It underscores that trust is not a singular, static construct but rather one shaped by a robot's functionality, clarity of behavior, and alignment of goals. Within this study, the theory provides a critical framework for evaluating how various design and interaction elements ranging from technical performance to emotional expression affect user trust. Ultimately, it encourages a broader understanding of trust that extends beyond mere reliability to include perceptions of fairness, transparency, and shared purpose as key components in the design of trustworthy robotic systems.

Social Exchange Theory

Social Exchange Theory (SET), first developed by George C. Homans (1958) and later expanded by Peter M. Blau (1964), provides a sociological framework for understanding how individuals form and sustain relationships based on perceived costs and benefits. At its core, the theory posits that human interactions are guided by the pursuit of rewards and the avoidance of punishments or losses. Trust, under this model, emerges when individuals perceive that the benefits of engaging in a relationship outweigh the risks or uncertainties involved. Though originally designed to explain interpersonal relationships, SET has been increasingly applied to technology-mediated interactions, including those involving robots.

In the context of Human-Robot Interaction (HRI), Social Exchange Theory helps explain how trust develops based on users' evaluation of the robot's behavior and the outcomes of

their interactions. Trust in robots is not solely a product of their technical competence; rather, it also involves the perceived *reciprocity* of the interaction. When a robot provides assistance, performs reliably, communicates transparently, or offers social cues (like apologies or empathy), users are likely to perceive the exchange as fair or beneficial, thereby increasing trust. Conversely, if users feel the robot is unhelpful, opaque, or behaves erratically, trust may erode as the cost of the interaction is perceived to outweigh the benefit.

Supporting this perspective, researchers such as Hancock et al. (2011) emphasize that trust in robots is sensitive to both performance and social behaviors. Their meta-analysis showed that consistent performance, combined with clear, socially engaging communication, enhanced trust significantly. Similarly, Robinette et al. (2016) found that trust could be recovered after failure when robots provided context-sensitive apologies or explanations—suggesting that users appreciate and reciprocate emotionally meaningful gestures, even in artificial agents. These findings align closely with the assumptions of SET, where mutual benefit and perceived fairness drive trust over time.

Moreover, Eyssel and Hegel (2012) demonstrated that users were more likely to trust robots that exhibited socially appropriate behaviors and emotional intelligence. From a Social Exchange Theory viewpoint, such behavior increases the relational value of the robot, making users more willing to engage and accept potential risks, especially in collaborative or assistive tasks. The emotional and cognitive “returns” provided by the robot such as respect, empathy, or understanding are interpreted as valuable social exchanges that foster trust.

In relation to the current study—*The Role of Trust in Human-Robot Interaction: A Perspective on Factors Influencing Trust Development*, Social Exchange Theory offers a compelling framework for understanding the underlying psychological mechanisms. Performance-based trust, as seen in studies like Salem et al. (2015), reflects a cost-benefit analysis where reliable robot behavior minimizes user effort and anxiety. Process-based trust, influenced by a robot's transparency and communication, provides informational value that reduces uncertainty and cognitive load, thus increasing the perceived benefit of the interaction. Purpose-based trust, evident when robots align with user goals or display emotional sensitivity, enhances the relational depth of the exchange offering affective rewards that reinforce user commitment and reliance.

Ultimately, applying Social Exchange Theory to HRI highlights the importance of designing robots that are not only functionally effective but also socially aware and emotionally

intelligent. By fostering interactions where users perceive mutual respect, reciprocity, and fairness, designers can create robotic systems that naturally cultivate trust through ongoing positive exchanges.

Empirical Review

In this study, the researchers examined how robot anthropomorphism and the type of failure affect human trust in both attitudes and behaviors. Firstly, they conducted two controlled laboratory experiments. In Experiment 1, participants interacted via voice commands with either an anthropomorphic robot or a purely technical-looking one. Subsequently, Experiment 2 introduced failure scenarios with the technical robot, featuring either information-processing errors or action-implementation errors (ScienceDirect, 2024). The sample comprised adult volunteers, likely university students, although the exact number was not specified. For the analysis, mixed ANOVAs were utilized to investigate the interaction effects of robot appearance and failure type on trust attitudes and behaviors, followed by post-hoc tests to explore differences in trust dissolution. The results revealed that the technical robot inspired significantly more trust than its anthropomorphic counterpart. Additionally, failures related to information acquisition led to a greater decline in trust compared to action-related errors. Interestingly, while participants' trust attitudes fluctuated across trials, their behavioral trust did not significantly change even after encountering failures.

The second study explored how a robot's emotional expression and apology impact user trust and acceptance. Specifically, a within-subject design was used, exposing participants to three conditions: a perfectly performing robot, one that erred without apologizing, and one that made errors but expressed apology with a sad facial expression. Participants engaged in a cooking task by making an omelet with the robot's assistance (Wired, 2016). The sample consisted of 21 adult participants, predominantly from U.K. universities. For the data analysis, chi-square or McNemar's tests were applied to assess participants' final binary preferences. Results showed that 15 out of 21 participants preferred the apologetic robot despite its slower performance. These findings highlight that emotional recovery mechanisms, such as apologies, effectively restored trust and likability and remarkably, some participants admitted lying to the robot to avoid hurting its "feelings".

The third study examined how a robot's physical presence and anthropomorphic features influence emotional and cognitive trust. To that end, the researchers employed a survey-based design, utilizing instruments such as the Negative Attitudes toward Robots Scale (NARS) and specific

trust questionnaires. Participants viewed hypothetical interaction scenarios and responded to trust- and emotion-related prompts. The sample included Japanese university students in the initial phase and U.S.-based participants in follow-up studies. Analyses involved correlation and regression to investigate associations among attitudes toward robots, tangibility, anthropomorphism, and trust levels. The findings indicated that individuals with stronger negative attitudes toward robots exhibited lower functional trust. Moreover, the effect of physical tangibility was mixed—some participants found tangible robots engaging, whereas others experienced discomfort or fear. Finally, anthropomorphism elicited complex emotional responses, ranging from warmth to unease.

Overall, these studies collectively indicate that trust in robots is shaped by design elements, error type, and emotional expression. Firstly, technically styled robots tend to foster greater trust in task-oriented contexts compared to anthropomorphic designs, likely due to enhanced perceptions of competence. However, anthropomorphic traits may increase likability but also erode trust by reducing perceived professionalism or triggering discomfort. Furthermore, the nature of robot errors significantly influences trust: cognitive errors lead to sharper declines than physical ones. Importantly, emotional recovery strategies such as apologies can mitigate trust erosion. Finally, trust manifests in both emotional and cognitive forms: emotional trust is heavily influenced by social cues and design, while cognitive trust is grounded in reliability and predictability.

III. DISCUSSION

Research consistently highlights that predictability and consistent performance are primary determinants of trust in human-robot interaction (HRI). Users are more likely to trust robotic systems that function reliably over extended periods, demonstrating stable and expected behaviors (Lee & See, 2004). From the perspective of Social Exchange Theory (SET), trust is cultivated through repeated positive exchanges, where individuals develop confidence in the reliability of an entity based on its consistent delivery of expected outcomes (Blau, 1964). For instance, in healthcare settings, robotic assistants that consistently perform tasks such as medication dispensing without errors foster a sense of dependability among medical personnel (Hancock et al., 2011). Similarly, in industrial automation, robots that exhibit consistent precision in assembly lines instill trust in operators and decision-makers, reinforcing SET's premise that trust strengthens over time with reliable interactions.

Studies have shown that robots equipped with human-like attributes such as eye contact, voice modulation, facial

expressions, and natural gestures are perceived as more trustworthy compared to purely mechanical robots (Fong et al., 2003). This aligns with the principles of SET, which emphasizes the importance of interpersonal behaviors in fostering trust. Human-like cues create a sense of familiarity, making robotic systems appear more predictable and emotionally engaging (Groom & Nass, 2007). For example, companion robots designed for elderly care, such as PARO, leverage social and emotional cues to establish rapport with users, thereby strengthening trust in their functionality (Broadbent et al., 2013). The ability of robots to mimic social interactions fosters a relational exchange, where users reciprocate trust based on perceived positive engagement.

Transparency in robotic decision-making is another crucial factor influencing trust development in HRI. Users are more likely to trust robots when they can understand the reasoning behind their actions, reducing uncertainty and perceived risks (Wortham et al., 2017). Transparent robotic systems that provide real-time feedback, rationale for decision-making, and user-centered explanations enhance user confidence in automation. This finding supports SET's assertion that predictable and reciprocal exchanges foster trust. In autonomous driving, for instance, trust in self-driving cars increases when the vehicle communicates its intended actions, such as lane changes or braking decisions, through visual or auditory cues (de Visser et al., 2020). Similarly, in AI-powered diagnostic systems, providing interpretable explanations for medical recommendations enhances trust among healthcare professionals and patients alike.

While trust in HRI can be cultivated, several challenges hinder its development, including machine errors, ethical concerns, and automation bias. Trust can be fragile and easily eroded by a single failure or inconsistency (Sheridan, 2016). Unexpected errors, even minor ones, can cause users to become skeptical of a robot's overall reliability, leading to reduced adoption and engagement. Ethical concerns, particularly in AI-driven decision-making, also impact trust, as users may question the fairness, bias, or accountability of robotic systems (Madhavan & Wiegmann, 2007). Furthermore, automation bias—where users over-rely on robotic systems without critical evaluation—can result in misplaced trust, potentially leading to catastrophic consequences in safety-critical environments such as aviation or healthcare (Parasuraman & Manzey, 2010). These challenges highlight the complex nature of trust in HRI, emphasizing the need for continuous improvements in reliability, transparency, and ethical AI practices.

Recommendations

- To achieve consistent performance, developers must prioritize robust hardware design, high-quality sensors, and advanced control algorithms that minimize operational variability. Regular software updates and maintenance protocols should be integrated to address performance degradation over time.
- Transparency in robotic decision-making is crucial for building trust and facilitating user acceptance. Robots should be designed with explainability features that allow users to understand how decisions are made and why certain actions are taken.
- Humans are naturally inclined to trust entities that exhibit familiar social behaviors and cues. Research indicates that robots equipped with human-like attributes such as facial expressions, voice modulation, gestures, and body language are perceived as more trustworthy and relatable.
- Trust in robots can be severely undermined by system failures, security vulnerabilities, and ethical concerns. Developers must implement robust safeguards to prevent technical malfunctions, unintended behaviors, and potential misuse of robotic technology. These safeguards should include a combination of fail-safe mechanisms, ethical AI guidelines, and cybersecurity measures.

IV. CONCLUSION

Building trust in human-robot interaction requires a multifaceted approach that prioritizes consistency, transparency, social intelligence, and security. Robots must be designed for reliable and predictable performance, ensuring that users feel confident in their functionality. Explainability and user feedback mechanisms should be integrated to enhance transparency and accountability. Human-like interaction capabilities should be developed to foster familiarity and emotional engagement, making robots more relatable and trustworthy. Finally, robust safeguards must be in place to prevent failures, ethical dilemmas, and cybersecurity risks. By addressing these factors, developers can enhance trust in robotic systems, leading to higher adoption rates and more effective human-robot collaborations across various industries.

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Citation of this Article:

Adeniyi, A.O. (2025). The Role of Trust in Human-Robot Interaction: A Perspective on Factors Influencing Trust Development. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 9(6), 112-118. Article DOI <https://doi.org/10.47001/IRJIET/2025.906013>
