Addressing Trust and Negative Attitudes Toward Robots in Human-Robot Collaborative Scenarios: Insights from the Industrial Work Setting

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ABSTRACT

Recent advancements in Human-Robot Collaboration (HRC) have brought to light the significance of ethical, psychological, and attitudinal factors in advanced work and industrial settings, whereby collaborative robots assist humans in work tasks. In these environments, individual factors, attitudes, and trust beliefs of human workers towards robots have a direct impact on the perceived efficiency and safety of HRCs, contributing to worker well-being in the workplace. However, most of the existing research on these topics has been concentrated on social robots and much less on industrial ones. This study aims to fill this gap by exploring the relationships between Negative Attitudes toward robots (NARS) and Trust in industrial HRC. Results demonstrated how, while the overall correlation between NARS and Trust was non-significant, unexpected trends also arose. Gender-dependent dynamics added complexity, with women exhibiting stronger correlations between emotional attitudes and trust. Men, on the other hand, demonstrated a link between stronger NARS and enhanced trust, particularly in robot motion speed perceptions. These intricate findings emphasize the need for tailored design considerations in cobot development, acknowledging the nuanced interplay between dispositional attitudes and trust in shaping human perceptions of robotic technologies in practical scenarios.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

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1 INTRODUCTION

The study of human attitudes and perceptions is gaining increasing attention among researchers and practitioners of advanced industries. Among the factors that sparked interest in understanding human dynamics in this technical field, there is the recent evolution of the human roles in industry, which are transitioning from being kept at a distance from robotics due to safety concerns to being allowed to approach and manipulate them within more natural collaborative frameworks. In these frameworks, thanks to the progress in robotics, Artificial Intelligence (AI), and sensing technologies, humans can actively collaborate with robots, sharing spaces and tasks in a fluid and seamless manner [24]. The robotic technologies enabling these collaborative frameworks are called collaborative robots (cobots), and they are revolutionizing the work settings of various industrial applications [18].

1.1 Negative Attitude Towards Robots (NARS)

To allow seamless integration of cobots into daily working activities, it is crucial to understand which attitudes and perceptions can foster their incorporation and acceptance, and which can instead disadvantage this process. Among the factors investigated in the literature, the negative attitude toward robots (NARS) is surely worthy of attention [21]. Particularly, NARS decline into Negative Attitudes toward Situations of Interaction with Robots, toward the

Social Influence of Robots, and Emotions in Interaction with Robots. The first aspect, namely the Negative Attitudes toward Situations of Interaction with Robots, refers to the negative attitudes toward the practical aspects of using robots, such as operating robots in public or being given a job involving robots. The second aspect, namely negative attitudes toward Social Influence of Robots, refers to the aversion to the idea of robots being socially integrated agents, and the fear of negative consequences if robots develop further. Finally, the negative attitudes toward Emotions in Interaction with Robots refer to those feelings of unease or comfort associated with the idea of robots having emotions and the potential for forming emotional connections with robots. According to [21] these aspects collectively provide a nuanced understanding of individuals' NARS by capturing discomfort in various interaction scenarios, concerns about societal implications, and emotional aspects of human-robot interaction.

According to a recent investigation conducted in the European Union countries between 2012 and 2017, attitudes toward robots are becoming more negative, especially regarding workplace robots [10]. Furthermore, those who held more positive views were men and white-collar workers. This is a warning bell that highlights the importance of better understanding dispositional attitudes and whether they can affect Human-Robot Collaboration (HRC), making the transition toward cobots more or less welcome in industries. However, robots can be quite different in their appearance and functionality, and the attitude demonstrated by humans interacting with them can vary depending on these aspects [11] [28]. For instance, [1] showed how, when analyzing attitudes toward service robots, realistic robots elicited both explicit and implicit negative reactions, indicating a tendency to reject them in frontline service settings. Differently, less human-like robots received more positive attitudes and were nearly as accepted as human employees in hospitality and tourism settings. [26] reviewed the social acceptance of robots in various occupational fields. They reported that respondents considered robots suitable for various work tasks, with telepresence robots receiving high approval from healthcare staff. Furthermore, and quite interestingly, an increased occurrence of positive attitudes was observed in studies where participants were directly exposed to robots. Another aspect that was demonstrated to lead to increased attitudes towards robots is their representation, which is also changing with time in our culture [4]. Specifically, as people start seeing robots as essential parts of the ever-growing ICT ecosystem, the old notion of robots as metal objects with communicative functions is fading. Instead, a new perspective is emerging, suggesting that robots will become a normal part of our everyday lives and eventually be welcomed for tasks related to various work sectors. These pieces of evidence, together, suggest that NARS may depend on the robot's application, appearance, functionality, and socio-cultural context and therefore, need to be studied in circumscribed applied settings distinctively.

1.2 Trust toward Human-Robot Collaboration (HRC)

Another factor that can have a great influence on the robots' integration into practical settings is trust toward robots. Lee and colleagues [15] defined trust as an attitude that an agent (a robot, in this case) will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability. Trust is generally understood as a multidimensional psychological attitude encompassing beliefs and expectations about trustworthiness [14], and was also proposed to have both cognitive and affective features that influence human decisions about using automation [16]. While trust towards automation may, therefore, in part be a dispositional attitude, it has also been suggested that it may change according to one's experience with it. Sanders and colleagues [25] pointed out that prior experience with a robot is decisive in establishing user trust. Similarly, other studies have highlighted that the type of interaction with the robot, as well as the interaction output, have the potential to shape trusting behavior both positively [29] and negatively [2]). While there is a recognized relationship between experience and trust development, the influence of dispositional attitudes, such as NARS, on this dynamic is less explored. Studies in the social robotics sector, where computer anxiety and social and emotional factors can have a greater impact, have delved into the relationship between attitudes and trust [19]. In contrast, exploring these dynamics in the industrial and work context is limited. However, the literature on collaborative robotics has emphasized how fostering trust in collaborative robots, or cobots, is critical to improving system performance, promoting fluency in human-robot teams, and improving the overall quality of manufacturing processes [23].

As awareness of the importance of trust in cobots within the industrial sector grows, efforts have been made to investigate influencing factors, such as their reliability, predictability, size, appearance, and movement [27]. Consequently, specialized tools have been developed [6] to evaluate human perception of these aspects when interacting with robots. These evaluation tools prioritize the concept of Safe Co-operation, encompassing both the sense of mental safety (impacted by the size of the cobot) and physical safety (preventing injuries) perceived during the collaboration between humans and industrial robots. The second point of assessment revolves around the Motion and Pick-up Speed of the robot, capturing the human perception of its movement and the speed of its picking actions, factors closely linked to the predictability of the robot and the ability to anticipate its actions [13] [17]. Finally, the third evaluation point focuses on the perception of the Robot and Gripper's Reliability, which represents aspects of performance, in particular the robot's ability to manipulate components and interact with the human partner in collaborative tasks.

1.3 Gender role in Human-robot collaboration (HRC)

Several works have revealed gender-based differences in attitudes towards robots. For instance, Bloch and colleagues [3] utilized the NARS in a Norwegian context, uncovering a pronounced gender disparity where females generally held less favorable views of social robots than males, potentially influencing their interactions with robotic systems. Similar results were found in the study of Nomura and colleagues [21]. They demonstrated how, in a Japanese student cohort, both genders exhibited similar attitudes towards the social influence of robots and emotional responses in HRC, although women displayed heightened negative attitudes towards interaction scenarios with robots.

Further exploring the gender dynamics in HRC in the industrial sector, Wagner and colleagues [30] investigated how task complexity affects acceptance and trust, noting significant gender and age-related variations. Their research indicated that women found interaction tasks more useful and satisfying than men, with younger women displaying a higher level of trust than their male counterparts. Similarly, Gallimore and colleagues [8] focused on gender-based trust in an autonomous security robot, finding that women exhibited greater trust and perceived the robot as more trustworthy than men, highlighting intrinsic gender differences in trust. Interestingly, Ghazali and colleagues [9] highlighted a nuanced aspect of gender dynamics in human-robot interaction (HRI). They observed that women exhibited more positive attitudes towards a male robot compared to a female robot. This observation underscores the multifaceted nature of gender factors in HRI, especially in contexts where robots do not inherently possess features that suggest a specific gender, such as in industrial settings. Additionally, it is noteworthy that most of these investigations focus on social robotics, thereby leaving a notable gap in our comprehension of gender dynamics in different contexts, such as in industrial settings.

1.4 Our Study

In this work, we cover these topics in the industrial work sector by systematically reporting relations between dispositional NARS and trust toward HRC. Our sample, including both females and males, underwent a collaborative assembly task with an industrial robotic arm (i.e., UR10e) and related to their perceived trust afterward. These first data are gained in the context of a larger project that aims at evaluating various psychological and cognitive factors in HRC. We thus report and discuss our first data exploring whether a pronounced dispositional NARS relates to the levels of trust developed during an actual and realistic collaboration with an industrial robot. More specifically, our research questions can be outlined as follows:

RQ1. Relations between Dispositional NARS and Trust in HRC: Are individuals' dispositional attitudes toward robots related to the level of trust they perceive in an industrial HRC task?

RQ2. Relations between Social, Emotional, and Situational Attitudes with Trust in HRC: Among the various dimensions of dispositional attitudes toward robots, such as social, emotional, and situational aspects, is there a specific dimension that has a stronger relation with the level of trust during HRCs?

RQ3. Relations between Social, Emotional, and Situational Attitudes with Speed, Safety, and Reliability Perceptions: Digging deeper, do the dimensions of dispositional attitudes toward robots—social, emotional, and situational aspects—have distinct relations with the perception of the robot's motion speed, safe cooperation, and robot and gripper reliability specifically?

RQ4. Gender dependent dynamics: **RQ4.1**: Do men and women exhibit different relations between their dispositional NARS and the level of trust perceived in HRC tasks? **RQ4.2**: Are there distinct aspects of NARS that relate to trust perception differently between men and women in the context of industrial HRC? **RQ4.3**: Do dispositional attitudes toward robots, specifically in social, emotional, and situational dimensions, demonstrate distinct relations with the perception of robot motion speed, safe cooperation, and reliability of the robot and gripper, depending on whether the user is a woman or a man?

2 METHODS

2.1 Sample

We tested 17 participants, 9 women and 8 men (Mage = 26,82, SDage = 1.98). The sample included participants who did and did not have prior experience with cobots and consisted of university students who volunteered to participate in the study by signing an informed consent. Inclusion criteria ensured participants had no present or past neurological or psychiatric issues. The study's experimental protocol gained approval from the local ethics committee (protocol number 2023_212R1), and the research adhered to the principles of the Declaration of Helsinki.

2.2 Technical setup

Participants collaborated with a UR10e collaborative robotic arm featuring 6 degrees of freedom and a payload capacity of 12.5 kg. This arm was mounted on an assembly workstation, adjustable in height (Figure 1). The cobot was programmed in Polyscope (version 5.11). The workspace was outfitted with various components placed in five boxes on the worktable, including screws, bolts, two types of masks (black and transparent), and metal puzzle pieces varying in shape and color. Additionally, four metal plates were also provided. The experimental setup included a DELL PC (XPS 2720 model, with an Intel Core i7-4790S processor, and 16 GB RAM) used by participants to complete the questionnaires. All data processing and analysis were performed in R Studio [22].

2.3 Task, procedure and measures

The entire experimental procedure lasted approximately one hour and a half. First, participants responded to questionnaires about their demographics and their dispositional attitudes (i.e., NARS questionnaire [21]). In the training phase, participants were taught safe and unsafe interactions with the cobot. Afterward, they were asked to perform a collaborative assembly task with the cobot. More specifically, they had to assemble a metal plate with various components (screws, bolts, plastic masks, puzzle pieces, and plates), for which they executed various operations, such as pick-and-place, manual screwing, manual composition, and using an industrial screwdriver. The assembly task was previously tested for its feasibility, realism, and ecological validity of the lab-based setting [20]. All participants repeated the assembly task under varying mental load levels (i.e., single-task, and dual-task, created via concurrent execution of mental arithmetic operations). The latter aimed at simulating the working conditions of factory operators, who often operate under two degrees of mental fatigue [5]. The same assembly task was repeated 6 times in total, and afterward, the participants rated their trust toward robots in the HRC questionnaire [6]. The NARS questionnaire [21] administered before collaborating with the cobot encompassed a scale from 1 to 5, probed into three distinct dimensions: the nature of interactions with robots, the social impact of robots, and the emotional responses during interactions with robots. The level of trust in Industrial Human-Robot Collaboration (HRC) was assessed using the psychometric scale developed by [6], with responses ranging on a scale from 1 to 5. This questionnaire specifically evaluates three main dimensions: the robot's movement and pickup speed, safe cooperation, and the reliability of the robot and its gripper.

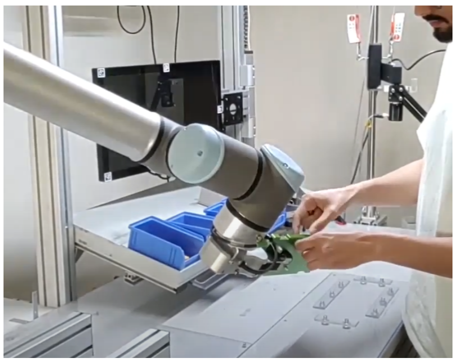

Figure 1: Technical set-up

2.4 Statistical analysis

We computed several Spearman rank correlation tests. Particularly, we were interested in exploring the following relations: a) between the NARS questionnaire and the trust toward industrial HRC questionnaire scores; b) between each of the NARS questionnaire dimensions (i.e., Situations of interaction with robots, the Social influence of robots, and the Emotions in interaction with robots) and the overall score at the trust toward industrial HRC questionnaire; c) between each of the NARS questionnaire dimensions and the single dimensions of the trust toward industrial HRC questionnaire (i.e., Robot's motion speed, Safe co-operation, Robot and gripper reliability); d) the same relations independently computed in the women and men sub-samples.

3 RESULTS

3.1 RQ1. Relations between Dispositional NARS and Trust in HRC

The Spearman rank correlation coefficient (rho) was 0.35, indicating a moderate positive correlation between the variables. However, the test did not reach statistical significance (S = 527.4, p-value = 0.1637).

3.2 RQ2. Relations between Social, Emotional, and Situational Attitudes with Trust in HRC

Results relative to RQ2 are reported in Table 1 and depicted in Figure 2.

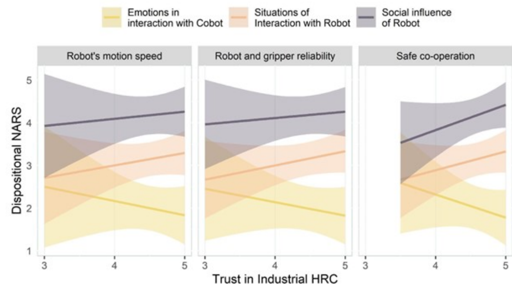

Figure 2: Relations between the dimensions of NARS (i.e., emotions in interaction with robots, Situations of interaction with Robots and Social influence of Robots) and Trust in industrial HRC

3.3 RQ3. Relations between Social, Emotional, and Situational Attitudes with Speed, Safety, and Reliability Perceptions

Results on the distinct influences of dispositional attitudes toward robots—specifically examining social, emotional, and situational aspects—on the perception of robot's motion speed, safe cooperation, and robot and gripper reliability are resumed in Table 1.

3.4 RQ4. Gender-dependent dynamics

As regards RQ4.1, men and women exhibit different relations between their dispositional NARS and the level of trust perceived in HRC tasks, as indicated by Spearman correlation tests. For women, there was a non-significant positive correlation (rho = 0.172, S = 99.308, p = 0.6573), suggesting a weak relationship. In contrast, men show a significant positive correlation (rho = 0.755, S = 20.556, p = 0.03024), indicating a stronger and significant association between their dispositional NARS and perceived trust in HRC tasks. These results are also depicted in Figure 3.

Furthermore, results responding to RQ4.2 and RQ4.3 are resumed in Table 1 and depicted in Figure 4

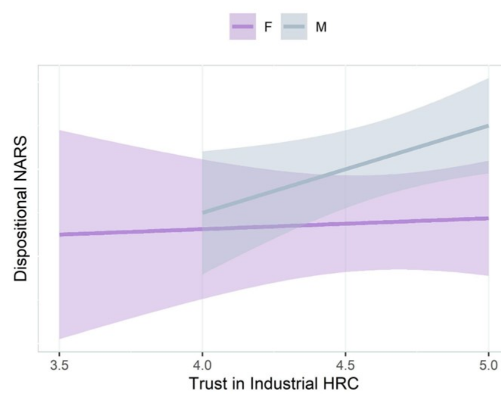

Figure 3: Relations between the overall NARS score and Trust in industrial HRC in men (M) and women (F)

Item		Women		Men		Aggregated	
NARS Subscale	**Trust Subscale**	**Rho**	**p-value**	**Rho**	**p-value**	**Rho**	**p-value**
EIC	Trust-tot	0.088	0.821	-0.615	0.1046	-0.429	0.08586
	RMS	-0.127	0.5266	**-0.439**	**0.03178**	**-0.297**	**0.03447**
	SC	**-0.604**	**0.0008389**	-0.240	0.2584	**-0.386**	**0.005206**
	RGR	**-0.385**	**0.0474**	-0.271	0.20003	**-0.307**	**0.02857**
SIR	Trust-tot	-0.296	0.4395	0.060	0.887	-0.101	0.6988
	RMS	-0.355	0.06954	**0.490**	**0.01512**	0.201	0.1567
	SC	0.196	0.3266	0.363	0.08158	**0.279**	**0.04764**
	RGR	0	1	**0.442**	**0.03042**	0.232	0.1006
IR	Trust-tot	-0.155	0.6905	0.207	0.6228	-0.012	0.9633
	RMS	0.148	0.4607	**0.674**	**0.000306**	0.151	0.2913
	SC	**0.515**	**0.005966**	0.370	0.07486	**0.423**	**0.001985**
	RGR	0.134	0.5062	0.226	0.2886	0.229	0.1068

Table 1: Results on the Spearman Correlation tests between questionnaire items. Significant correlations ($p < 0.05$) are highlighted in bold. Acronyms: Trust-tot (Aggregated score of Trust questionnaire), EIC (Emotions in Interaction with Cobots), SIR (Situations of Interaction with Robot), IR (Social Influence of Robot), RMS (Robot Motion Speed), SC (Safe Cooperation), RGR (Robot Grip Reliability)

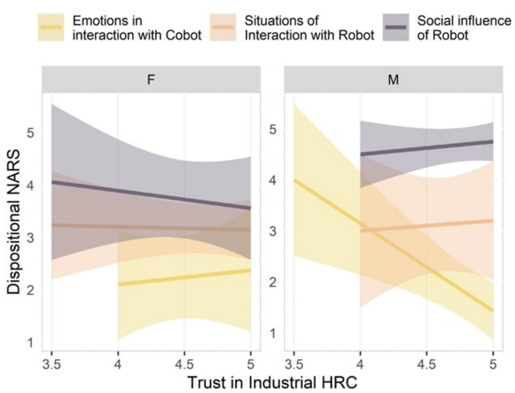

Figure 4: Relations between the dimensions of NARS (i.e., emotions in interaction with robots, Situations of interaction with Robots, and Social influence of Robots) and Trust in industrial HRC in men (M) and women (F)

4 DISCUSSION AND CONCLUSION

With this work, we aimed to unfold possible relations between the dispositional NARS and the levels of trust perceived after directly collaborating with an industrial robotic arm. Our results evidenced how, on a general level, this relationship did not emerge in our sample, and therefore, having a more negative attitude towards robots was not directly related to a lower level of trust built during close collaboration with these technologies. This result aligns with literature suggesting that human-related factors are not as determinant as other factors (e.g., performance- or attribute-based factors) in influencing trust [12].

Furthermore, a more detailed investigation into the relationships between the sub-scales of Trust and NARS revealed some trends that deserve attention. In particular, we identified negative correlations between the NARS sub-scale "Emotions in Interaction with Cobot" and various functional aspects of the robot, including motion speed, safe cooperation, and reliability. This suggests that individuals who harbor negative emotional attitudes towards robots tend to perceive cobots as less effective in these key functional areas. Since industrial robots do not typically suggest emotional features, this relationship is quite surprising. The only aspect that might somehow recall proximity in cobots, is that they involve close and direct interaction with the human operator, with whom they share space, tasks, and objectives. Despite these features might trigger feelings of closeness during the collaboration, the relation between attitudes toward emotional aspects of robots and trust in functional features (i.e., speed, safety, reliability) requires further investigations.

Similarly, the results showing positive correlations between Safe Cooperation and the two NARS sub-scales, "Situations of Interaction with Robot" and "Social Influence," are somewhat counterintuitive. Conventionally, one would expect decreased intolerance towards robots to correspond with increased perceived safety during collaboration. However, a potential explanation for these findings could be that individuals who experience greater discomfort with the idea of robots being integrated into our society engaged in safer behaviors towards the cobot. Such cautious behavior could have enhanced their perception of safety. However, a deeper analysis of human behavioral strategies would be necessary to prove this assumption.

When unfolding gender-dependent dynamics, we mostly observed trends consistent with the aggregated data. For instance, a greater attitude toward the idea of robots as emotional agents significantly correlated with higher trust in HRC. This effect appeared to be stronger in females, suggesting they attributed emotions to the cobot during the collaboration. Literature suggests that women generally exhibit a greater sensitivity and expressiveness in recognizing and expressing emotions compared to men [7]. This could imply a heightened propensity in women to attribute emotional states to non-human entities, even to cobots, relating to higher trust in their more functional aspects. What differs between men and women is that only for men, having stronger NARS was correlated with greater trust in HRC, while the same effect was not observed for women. Furthermore, when looking at the single relations between the NARS and trust dimensions, women's NARS correlated more with the Safe cooperation dimension, while men's NARS correlated more with motion speed perceptions. These results, despite deriving from small samples, provide valuable preliminary insights that highlight the complexity of these dynamics and suggest that cobot features may need to be tailored based on gender.

Overall, in this study, we aimed to explore the relationship between dispositional NARS and levels of trust during collaboration with an industrial robotic arm. The emerging insight appears that NARS may not necessarily translate to lower trust in practical HRC scenarios. However, further investigation is essential to confirm the reliability and implications of this trend, and to better explain the unexpected relations we observed. Indeed, nuanced findings emerged when examining specific trust dimensions and NARS sub-scales. These findings underscore the need for continued exploration into the intricate interplay between dispositional attitudes and trust in HRC, paving the way for tailored design considerations and further investigations to elucidate the evolving dynamics shaping human perceptions of robotic technologies in practical scenarios.

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