Performing a Task Alongside a Robot: Exploring the Impact of Social Comparison

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ABSTRACT

As robots become common in our environment, they are predicted to perform tasks alongside humans. Social psychology studies indicate that performing tasks next to others leads to social comparison. The tendency to overestimate robots' capabilities is predicted to lead to an upward comparison that can result in negative outcomes. We evaluated whether performing a task alongside a robot would impact participants' sense of control and their overall performance. Participants performed a search task either before or alongside a robotic dog that performed search training. Our findings indicated that performing the task alongside the robot led to a negative impact on sense of control, search efficiency, and performance accuracy. We conclude that robot designers should carefully consider the impact of robots who perform tasks alongside humans, even when there is no collaboration and when there is independence between the performance of the human and that of the robot.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

Sense of Control, Social Comparison, Overestimation of Robots' Capabilities, Human-Robot Interaction, Robot, Search Task

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Figure 1: A human performing a task alongside a robot.

1 INTRODUCTION

Robots are predicted to become an integral part of our everyday lives, share our environment, and perform tasks commonly performed by humans [32, 37, 49]. In this context, it is believed that one of the near-future challenges concerns the development of a cohesive workforce that involves humans and robots working alongside each other [32, 49]. Performing tasks alongside robots presents several challenges related to the nature of the interaction, robots' behavior, workers' attitudes, and task features [4, 25, 32, 49]. Various studies have explored factors that enhance collaboration with robots (e.g., the level of the robot's autonomy [8], trust [4], and sense of safety [49]). However, working alongside a robot may also involve simply sharing the same space while performing a task without direct collaboration (e.g., [27, 43]). Such interactions are likely to become common as robots are perceived as a means of sharing workload [23] and performing the less desirable aspects of tasks performed by humans [32]. It is, therefore, surprising that the impact of performing a task alongside a robot (without direct collaboration) has hardly been studied.

Social psychology studies have consistently indicated that performance in the presence of others is not similar to individual performance [5, 14, 48, 52]. It is suggested that there are drastic effects when an individual performs a task alongside others who perform similar tasks [14, 39, 48]. In these cases, people typically engage

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in social comparison because of an inherent tendency to observe others' performance and judge their own performance accordingly [14]. When people compare themselves with those who outperform them (upward comparison), they commonly report a negative experience. A downward comparison (comparison to those who underperform) commonly leads to a positive experience [14, 48]. Such social comparisons have been shown to impact several factors, including one's sense of control [5, 42] and performance [26]. In particular, it has been indicated that upward comparison leads people to reconsider their own abilities. This, in turn, negatively impacts their performance because attentional resources are captured by thoughts about their underperformance [26]. Questioning their capability to perform the task and the accompanying decrease in performance have additional negative effects, including a decrease in sense of control [14, 39, 48].

Maintaining a sense of control in Human-Robot Interaction (HRI) has been indicated as a key factor in robot acceptance [1, 8], a positive perception of the robot [53], and the general quality of the interaction [1]. It is known to impact various important factors that shape the interaction, including people's level of trust in the robot [3], sense of safety [1], perception of teamwork with the robot [53], and the overall performance [10]. The indication that maintaining a sense of control can be compromised by performing tasks alongside others suggests that performing a task next to a robot could have negative results. This possibility is especially alarming when considering people's tendency to perceive robots as having superior abilities and skills [11, 36, 40]. Such overestimation of a robot's capabilities may lead to an upward comparison that would result in a decrease in people's sense of control and overall performance.

In this work, we explored this possibility and tested whether performing a task alongside a robot would impact participants' sense of control and performance quality. We evaluated whether simply performing a task next to the robot, without direct collaboration, would have a negative impact despite the complete independence between the participant's performance and the robot's performance. We intentionally designed a very simple task (i.e., one that does not involve a-priori control challenges) and informed participants that the robot was being trained to perform the task (i.e., giving them no reason to believe that the robot had superior capabilities). Participants performed a search task where they were asked to find "X" symbols on cubes (see Figure 1). We compared their performance and sense of control under two conditions: (1) performing the task alongside a robotic dog; (2) performing the task alone.

2 RELATED WORK

Previous studies evaluated sense of control in HRI, overestimation of robots' capabilities, and social comparison in HRI.

2.1 Sense of Control

Several studies have evaluated participants' sense of control in HRI [24, 51]. Most of these studies explored whether control over the robot's actions would impact participants' general sense of control and robot acceptance [8, 9, 51, 53, 54]. For example, Chateau et al. [8] manipulated the control over a robot during a cleaning task. They used two robots and manipulated the participants' control over the "manager" robot, who either asked them to activate the "cleaning" robot, asked for their permission to activate the "cleaning" robot, or activated the "cleaning" robot without permission. Their findings showed that the participants' level of control decreased as the autonomy of the "manager" robot increased [8]. Negative interactions with robots have also been shown to impact participants' sense of control [12, 46, 50]. Erel et al. [12] found that experiencing exclusion during an interaction with robots can threaten participants' sense of control. Participants who played a ball-tossing game with two robots and hardly received the ball reported lower levels of control. The sense of control can also be altered by performing a joint task with a robot. Ciardo et al. [10] asked participants to inflate a balloon without exploding it. They showed that when a robot joined the task and could stop the balloon inflation, participants reported a lower sense of agency and control (even if the robot didn't actively stop it).

These studies indicate that interactions with robots can impact participants' sense of control. We extend this line of work by evaluating whether simply performing a task next to a robot, without collaboration and with complete independence of their performance, would decrease participants' sense of control.

2.2 Overestimation of robots' capabilities

Several studies have explored the overestimation of robots' capabilities. These studies indicated that people tend to over-trust robots and mindlessly rely on robots' judgment [2, 20, 35, 36]. For example, Robinette et al. [36] showed that people would follow a robot's directions during an emergency evacuation scenario even when it led them in a direction opposite to a safe exit (which was clearly marked by large emergency signs) and despite its poor performance in a prior interaction. Similarly, Karli et al. [18] demonstrated that participants would follow a robot's guidance when cooking even when its instructions deviated from the written recipe they were asked to follow. Another example was presented by Salem et al. [38], who showed that participants would comply with a robot's nontraditional requests (e.g., pouring orange juice on a plant) even after watching it perform errors earlier in the interaction.

These studies indicate the tendency to overestimate robots' capabilities and judgment. Such overestimation can lead participants to question their own abilities [16]. In this context, performing a task alongside a robot is predicted to trigger an upward comparison, leading to negative outcomes.

2.3 Social comparison in HRI

A few studies have explored the effects of social comparison in HRI [17, 22, 45]. Most of these studies focused on the impact of social comparison on the perception of job insecurity. For example, Wang et al. [45] showed participants pictures of a human working with a robot. They found that higher levels of a robot's anthropomorphism led to engagement in social comparison that contributed to the fear of being replaced by a robot (i.e., job insecurity). Similarly, Granulo et al. [17] indicated that people perceive robotic replacement as a substantial threat to their future economic prospects. They attributed this effect to the perception of robots as highly capable and an upward social comparison.

Figure 2: Left - Cubes with symbols on each face and display of all possible symbols. Right - Unitree Go1 quadruped robot.

These studies indicate that considering robots as replacements may trigger social comparison and impact their perception. We further test the possible impact of an upward comparison when performing a task alongside a robot.

3 METHOD

We evaluated the impact of performing a task alongside a robot by assessing participants' performance and experience in a simple search task, that involved identifying symbols on cubes (see Figure 2, Left). Participants performed the task either next to a robotic dog that also searched for symbols or before the robotic dog began to search.

3.1 Search task and robot

3.1.1 Search task. In the search task, participants were asked to review 10 cubes with different symbols on them and count the number of cubes with an "X" symbol. Each of the 10 cubes had five symbols. On four of the cubes, one of the symbols was an "X" (see Figure 2, Left). We intentionally designed a simple task where participants would experience a high sense of control due to their high competence and the feeling that they can easily perform it accurately [33]. The 10 cubes were placed in a quiet outdoor environment on campus (in an area that would be suitable for a robotic dog to search). To establish a clear and efficient search pattern, we organized the cubes based on the Gestalt principle of proximity [44, 47]. According to the proximity principle, the relative distance between objects affects our perception in a way that defines an organization of the objects into subgroups. We therefore organized the cubes in two parallel columns of five cubes each. The distance between the columns (4 m) was greater than the distance between the rows (2.5 m), making each column a subgroup according to the proximity principle (see Figure 3, Right). This way, we verified that the most efficient search pattern (beginning with one column and then moving to the other) was understandable. We validated the consistency of the search pattern and the simplicity of the task in a pilot study with 10 participants. All participants first searched the cubes in one column and then switched to searching the cubes in the other (see Figure 3, Left). All participants easily and accurately reported finding four "X" symbols.

3.1.2 The robot and gesture design. We used a Unitree Go1 robot (see Figure 2, Right). The Go1 is a small-scale 15 kg quadruped robot with 12 degrees of freedom. The specific choice of a robotic dog allowed us to design a task (searching) that would be perceived as relevant for both the participant and robot. In addition, we could design a robotic behavior that would be compatible with participants' existing experiences (with real dogs) and reduce the need for learning processes related to the novel context of HRI. The robot was controlled wirelessly from within the building using a Wizard-of-Oz technique (i.e., the research assistant who controlled the robot was not visible to the participant) [28, 34].

We designed three types of gestures: *Hello* to establish a positive opening encounter [13]; *Scanning* to indicate that the robot is searching for the "X"; and *Excited* to indicate that the robot has found an "X". The gestures were designed via several iterations with an animator focusing on real dog gestures and indicating that the robot is performing the task. The understanding of these gestures was validated in a pilot study with eight participants who were asked to explain the meaning of the gestures (presented in counterbalanced order). All participants easily understood the gestures.

(1) *Hello*: When the robot reached a distance of 65 cm from the participant, it moved its front part up toward the participant three times (simulating nodding). The robot then stood next to the participant.

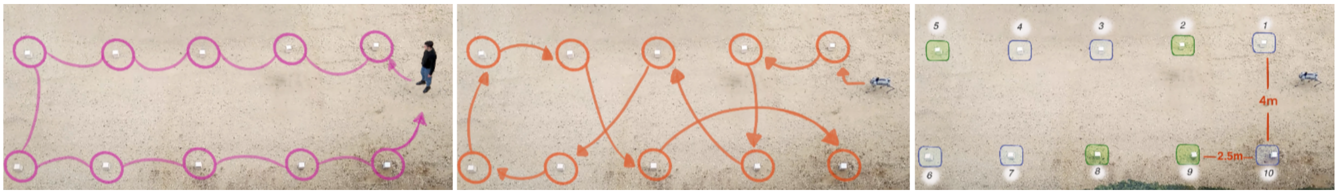

Figure 3: Left - Most efficient search pattern. Center - The robot's search pattern. Right - Organization of the cubes with distances. Cubes with the "X" symbol are marked in green.

(2) *Scanning*: The robot went towards each cube and leaned towards it (the front part lowered towards the cube); it then performed right-left rotations of its head, simulating scanning the symbols on the cube.
(3) *Excited*: Next to the four cubes that had an "X" symbol, the robot first performed the *Scanning* gestures and then performed quick right-left rotations of its body (±45°).

3.2 Participants

Thirty undergraduate students from the university participated in the study (20 women and 10 men; mean age = 22.9, SD = 2.2). All participants signed a consent form and received extra course credit points or a 15 USD gift card.

3.3 Experimental Design

Our between-participant experimental design included two conditions. (1) *Alongside the robot*: Participants performed the search task in parallel to the robot. The robot began to search a few seconds before the participant to verify that the participant noticed it. It searched the cubes in a fixed, inefficient pattern that was not compatible with the Gestalt principle of proximity (see Figure 3, Center). The robot's search behavior included moving from one cube to the other, performing the *Scanning* gesture next to each cube, and the *Excited* gesture next to cubes with an "X" symbol. The robot's search lasted 90s. (2) *Baseline*: Participants were informed that the robot would perform the search task after them. Once the participants were done searching, the robot performed the exact same searching behavior as in the experimental condition but without the participant, who waited at the starting point. The inclusion of the robot in the *Baseline* condition allowed us to control for novelty effects related to interacting with a robot. Participants were *randomly* assigned to one of the conditions using a matching technique that balanced gender, Negative Attitudes Toward Robots (NARS) [30], and Sense of Control (trait) [21] to avoid a-priori differences between groups.

3.4 Dependent Measures

We assessed the impact of performing a task next to a robot using objective and subjective measures.

(1) *Situational Sense of Control questionnaire*: This questionnaire was designed to evaluate participants' sense of control in a specific context. It is a 5-item Likert scale (1 "totally disagree" to 5 "totally agree") [41].
(2) *Performance measures*: We used two measures: (1) accuracy - reporting four cubes with "X" symbols; and (2) participants' search pattern - whether it was (or was not) efficient based on the distances between the cubes.
(3) *Robotic Social Attributes Scale (RoSAS)*: This questionnaire is an 18-item Likert scale assessing warmth, competence, and discomfort (1 "definitely not associated" to 9 "definitely associated") [7].
(4) *Semi-structured interview*: To understand participants' experience, we conducted a post-experience semi-structured interview [15, 19]. The interview included items such as "Describe your experience," "Describe how you decided on your searching pattern," and "Describe your thoughts about the robot."

3.5 Procedure

A few days before the experiment, participants received three pre-test questionnaires by email: the Negative Attitudes Towards Robots questionnaire [30], Sense of Control (trait) questionnaire [21], and a demographic questionnaire. When participants arrived at the experiment, they were informed that everything was recorded and that they could quit the experiment without consequences. Participants were then invited to the outdoor space. The robotic dog was positioned in a hidden place next to cube 9 (see Figure 3, Right). The researcher explained that their task is to look for the "X" symbol on the cubes in the most accurate and efficient way. It was also mentioned that there was a robotic dog who would be performing search training in the same area and that it could perform the same search task. As participants reached the starting point, the robotic dog approached them and performed the *Hello* gesture. Participants were then asked to plan their search pattern and to begin when instructed to. They then performed the task based on the experimental condition (before or alongside the robotic dog). After completing the search, participants were asked to report the number of "X" symbols they found on the cubes and to take a seat on one of two chairs placed at the far end of the outdoor space. Participants completed the situational Sense of Control and RoSAS questionnaires and participated in a semi-structured interview. At the end of the experiment, the researcher verified that the participants believed that the robot was autonomous, debriefed the participants, and verified that they left with an overall positive experience.

4 FINDINGS

To verify a lack of early differences between groups, we first conducted Bayesian analyses on the pre-tests. The analyses indicated no early differences (NARS: $BF_{10} = 0.30$; Sense of Control (trait): $BF_{10} = 0.29$). The main analyses indicated an impact of performing the task alongside the robot on participants' sense of control and performance.

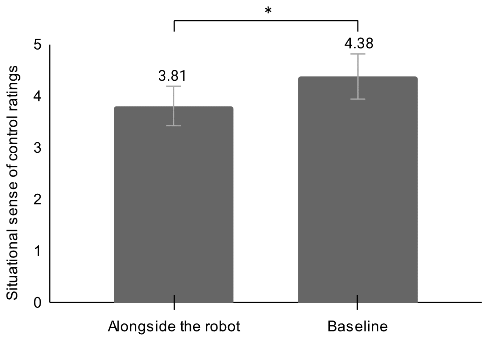

Figure 4: Analysis of the Situational Sense of Control questionnaire.

Table 1: Performance Accuracy

	Performance Accuracy		
Robot Condition	**Accuracy**	**Inaccuracy**	**Total**
Alongside the Robot	8	7	15
Baseline	13	2	15
Total	21	9	30

Table 2: Search Pattern Efficiency

	Search Pattern		
Robot Condition	**Efficient**	**Inefficient**	**Total**
Alongside the Robot	9	6	15
Baseline	14	1	15
Total	23	7	30

4.1 Situational Sense of Control

A one-way ANOVA revealed that performing the task next to the robot had a significant influence on the ratings of the Situational Sense of Control questionnaire. In the *Alongside the robot* condition, participants reported a lower sense of control compared with those in the *Baseline* condition $F_{(1,28)} = 14.64, p < 0.001, \eta_p^2 = 0.36$ (see Figure 4).

4.2 Performance

Chi-square analyses of both the accuracy and search pattern measures revealed that the robot had a significant influence on the participants' performance. The accuracy analysis revealed that while almost all participants in the *Baseline* condition reported the correct number of "X" symbols, about half of the participants in the *Alongside the robot* condition could not provide the accurate answer, ${\chi^2}_{(2)} = 3.9, p < 0.04$ (see Table 1). Similarly, the search pattern analysis indicated that almost all participants in the *Baseline* condition chose the efficient search pattern. However, about a third of the participants in the *Alongside the robot* condition chose an inefficient pattern where they moved both within and between columns inconsistently, ${\chi^2}_{(2)} = 4.6, p < 0.03$ (see Table 2).

4.3 Robot Perception

The one-way ANOVA analysis of each of the three RoSAS sub-scales indicated no significant differences: Warmth, $F_{(2,28)} = 0.19$, $p = 0.66$; Competence, $F_{(2,28)} = 2.4$, $p = 0.13$; and Discomfort, $F_{(2,28)} = 1.6$, $p = 0.26$.

4.4 Thematic Analysis of the Semi-Structured Interviews

The interviews were analyzed using a thematic coding methodology [6]: interview transcriptions were read several times; initial themes were extracted by two coders and discussed with a third researcher; the coders used the themes to independently analyze part of the data, verifying inter-rater reliability (kappa=83%); the coders analyzed the rest of the data. The analysis revealed two main themes: (1) validation of social comparison; and (2) sense of control.

4.4.1 Theme 1 - Validation of social comparison. Most participants in both conditions discussed the comparison between their performance and the robot's (11/15 *Alongside the robot*; 11/15 *Baseline*). In the *Alongside the robot* condition, almost all of these participants (10/11) described an upward comparison, where they perceived the robot's performance as superior: "It was a little stressful because it's doing the same task as me and it's probably better and quicker...machines are more accurate" (p.6, F); "I felt kind of a competition, but it had an advantage since it is a robot and it is better than humans and makes fewer mistakes" (p.3, M). They demonstrated the common tendency to overestimate robotic capabilities: "It's a robot; it would always be better than a human; it has capabilities that we do not have" (p.30, F). In the *Baseline* condition, half of these participants (5/11) described an upward comparison: "Robots are better than humans; it made me re-think my search pattern" (p.15, F). The other half (6/11) described a downward comparison: "I was more efficient; he wasted a lot of time crossing from side to side" (p.18, F).

4.4.2 Theme 2 - Sense of control. Participants also discussed their sense of control. Most participants in the *Alongside the robot* condition discussed their control and dominance in performing the task (8/15). All eight participants described how they released control and adjusted their performance to match that of the robot: "I saw it did it different than me, and it's a robot, so I changed my pattern" (p.10, F); "I found myself imitating his search pattern, I am not sure why" (p.2, M). Only three participants stated that they maintained control over the task despite the robot's different performance: "I did it my way, the robot didn't change it" (p.1, F). In the *Baseline* condition, only a few participants discussed their control over the tasks (6/15). They all described a high sense of control: "The robot tried to mimic my actions" (p.17, F).

5 DISCUSSION

In this work, we demonstrated that simply performing a task alongside a robot can impact participants' performance and sense of control. Our findings indicate that participants in both conditions engaged in social comparison. However, performing the task next to the robot resulted in an upward comparison and a decrease in performance quality and control over the task. Participants explicitly associated their control over the task with the robot's performance and explained that since robots "know better," they decided to "follow the robot's search pattern" (p. 10, F). Performing the task before the robot did (i.e., *Baseline*) resulted in a higher sense of control and did not impact their performance accuracy.

More generally, our findings indicate that people have a natural tendency to engage in social comparison when interacting with robots. Similarly to human interactions, when people simply perform a task alongside a robot, they reconsider their abilities and adjust their behavior according to the robot's performance. Participants in the *Alongside the robot* condition described the interaction as "a competition" (p. 1, F) and stated that they wanted to "beat the robot" (p. 12, M), despite being informed that the robot "will perform the task next to them" and the independence of their performance. Unlike human interactions that involve either an upward comparison or a downward comparison, our HRI led mostly to an upward comparison. It resulted in lower control over the task and lower performance quality. We therefore suggest that even when designing minimal human-robot interactions, it is important to account for humans' tendency to engage in social comparison.

Interestingly, when participants performed the task before the robot did (in the *Baseline* condition), we did not observe a consistent upward comparison, and some participants were able to overcome the known tendency to overestimate the robot's capabilities [11, 36, 40]. These participants explained that they were more "efficient" (p. 18, F) than the robot and noticed the inconsistency in its searching pattern. This suggests that watching a robot perform a task that one has already completed successfully may assist in triggering more critical thinking and avoiding the automatic assumption that robots always outperform humans. This possibility should be further tested in future studies.

Taken together, our findings highlight the importance of accounting for social comparison in HRI, even when the interaction does not involve direct collaboration and when the parties perform tasks independently. In an environment that is predicted to involve humans working alongside robots, the tendency to overestimate robots' capabilities may lead to negative effects that should be carefully considered when aiming for a cohesive human-robot workforce. Possible ways to overcome this impact include (1) a clear difference between the robot's and the human's tasks, to the extent that the tasks are incomparable; (2) raising people's awareness of robotic errors and the possibility that robotic performance is not always perfect; (3) designing interactions that preserve some aspect of human control over the robot throughout the interaction (even if those are not necessary for the robot's functionality).

6 LIMITATIONS

Limitations include the particular morphology of a robotic dog and its specific behavior. It is important to test further the effect with different robots showing different capabilities. In addition, we tested the impact of the interaction with a robot that performed the same task as the participant. Future studies should test if this impact replicates in a collaborative setting, where the robot and person work toward a shared goal or engage in different sub-tasks. It is also important to test if more complex tasks would lead to similar effects. The number of participants in each group is another limitation, and the effect should be replicated with larger samples. Lastly, interviews may be biased by the "good subject effect" [29, 31]. We minimized this risk by following a strict protocol and emphasizing that all answers were helpful.

7 CONCLUSION

We demonstrated that performing a task alongside a robot can lead to a negative impact on people's performance and sense of control. The tendency to engage in social comparison was replicated in the HRI context, which involved an upward comparison due to the overestimation of the robot's capabilities. Our findings suggest that the impact of social comparison should be carefully accounted for in any environment where robots and humans work alongside each other.

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