Inspector Baxter: The Social Aspects of Integrating a Robot as a Quality Inspector in an Assembly Line

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ABSTRACT
We are interested in the social implications of working alongside robots. In this paper we look at a humanoid robot quality inspector, acting alongside workers in an assembly line. This setting is viable in small scale assembly lines where human assembly workers provide flexible, rapid assembly. A robotic quality inspector could enhance the quality assurance process, but places the robot in a position of relative seniority to the assembly workers. We present the results of an initial in-lab pilot study designed with our industry collaborators. In our pilot, a humanoid robot visually inspected participants' assembled products in a shared workspace and provided critiques that follow simple models of robotic social feedback. Our findings suggest that people's opinions of the robot (trust, impression of intelligence, etc.) changed based on the robot's social behaviors while it is judging the participant's work. Additionally, people rated the robot more negatively if they disagreed with the robot's opinions of their work, regardless of the robot social behavior and the value of its critique.

Author Keywords
Human-robot interaction; human-robot collaboration; social robotics; Baxter.

ACM Classification Keywords
H.1.2 [**User/Machine Systems**]: Human factors

INTRODUCTION

Social human-robot interaction (sHRI) in an industrial setting is still in its infancy. Human-robot collaboration in industry is typically limited to humans and robots working in isolation from one another as a means to keep workers safe [2,13]. If we can surpass this limitation and treat robots as our co-workers instead of a tool [7] that should be caged and isolated, we can open opportunities for safe and efficient human-robot collaboration in industrial settings (e.g. Figure 1), enabling us to leverage the strengths of both people and robots. Such potential can already be realized with industrial robots such as Rethink Robotics' Baxter [18] which is designed to be safe for industrial human-robot collaboration in a shared space. However, integrating such robots into an industrial setting raises social challenges about how people perceive their robotic co-workers.

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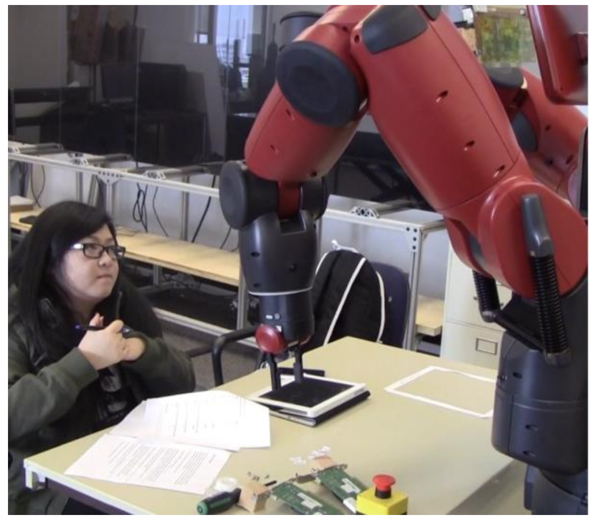

Figure 1. A participant watches a quality inspection robot evaluate the circuit board they assembled.

People are often concerned with their safety around robots, and this reaction is even stronger in safety-critical areas such as factories and assembly lines [2]. Robots can also replace people in the workplace, which may create animosity to robots that a person may work with. Other sHRI challenges include facilitating the non-disruptive introduction of robots into the workforce, building trust in robots to safely and correctly do their job [2], and improving communication between people and robots [7]. While robots that can collaborate with people may increase efficiency and safety in a factory, workers cannot be expected to have insight or knowledge in robotics, and may exhibit anxiety around new and unpredictable robots. Workers take time to accept and familiarize themselves with changes in their environment, challenging industries that cannot tolerate costly delays. Moreover, the risks of integrating a robot that may have negative social impact on its coworkers (e.g. feeling threatened, unneeded, confused) should not be ignored. We believe that these risks can mitigated by examining a social robot into an industrial setting as a sHRI design challenge.

In the formative phase of this project we worked with our industrial collaborator Dynamic Source Manufacturing to explore ways in which a humanoid robot could be integrated into their circuit assembly line. We searched for a task that would fulfill two criteria: clearly highlight the advantages of deploying a Baxter robot [18], and at the same time require sharing the physical workspace with the robot to provide ample opportunities for communication and collaboration between the assembly line worker and the robot. With our industry collaborator, we identified an assembly-line task that matched these requirements: inspection of the circuit boards produced by the workers. While printed circuit board (PCB) quality control is almost completely automated [20], inspecting the assembly of non-flat multifaceted products, especially in small to medium assembly lines, is still conducted visually by human inspectors who can manipulate the boards and inspect them from several angles. These inspectors are prone to becoming tired and making errors, making inspection a promising task for a humanoid robot. When it comes to Baxter's capability of providing precise and reliable visual quality assurance inspection, we expect Baxter to be far superior to a human quality assurance inspector. Baxter could use computer vision to match a correct template, providing accurate and reliable inspection, as Baxter will never tire, miss a detail or be bored by the repetitiveness of the task.

Quality inspection is a relatively senior position in an assembly line, and criticizing other people's work puts the robot in a socially and professionally sensitive situation; Baxter's quality inspection of an assembled product will relate directly to the quality of a person's work, and can result in a time cost in order to fix any problems Baxter finds, or, in case of repeated issues with the assembly of a specific worker, even in retraining. Our work begins to explore what is socially important in a robot for a factory worker to accept the robot as a quality inspector and to communicate and work effectively as a human-robot team.

To better understand the sHRI challenges of having a robot inspect someone's work, we conducted an in-lab pilot study that is set up as a mock circuit board assembly line to observe the actions and behavior of people when interacting with our humanoid robot, Baxter, in a shared space. We asked participants to perform simple, but valid, assembly tasks and to submit it to Baxter for quality assurance inspection. As Baxter reviews participants' work, we have it display social cues, such as displaying an affective facial expression (e.g. satisfied) and body language (e.g. nodding its head). After watching these social cues and reading Baxter's written report, participants rated the robot on a variety of measures such as trustworthiness and their own comfort level. Initial findings suggest that workers react positively to positive social behaviors, negative social behaviors have benefits, and behaviors can be interpreted in very different manners. We also observed how coworkers distrust the robot if the report disagrees with the worker's own opinion of their work, regardless of the social behavior and assessment result.

Our objective for this research is to better understand and improve social human-robot interaction in an industrial setting. We envision human-robot collaboration as an opportunity for factories to change the way they operate to benefit from the teamwork of humans and robots in a shared space. While our results here are preliminary, we view them as important to avoid potentially dangerous and costly problems when introducing a robot to a real assembly line. We further hope that our findings can benefit the sHRI aspects of other applications of robots in collaborative and repetitive work settings, such as an assistive rehabilitation robot reports patients' progress in an appropriate way.

RELATED WORK

Collaboration between people and robots presents many challenges and has been studied extensively. HRI researchers have studied robots working with humans during everyday tasks, such as handing an item to someone [5]. Robots have also been shown to be good team members when they predict how to help a human collaborator by preparing materials for them [13] and deciding when it is a good time to offer help [10]. This collaborative HRI research focuses on the challenge of real-time collaboration, while industrial settings often have individual workers (people, robots), working on separate tasks that are sequentially dependent. Our work follows the collaborative industrial HRI thread, and focuses on the social interactions during work evaluation.

Industrial robots are arguably the most common robots today, but they are typically behind safety cages and do not interact with people [2] - a desirable setting when robots are dealing with tasks that are unsafe for people [11]. However, robots can be integrated, in various industrial setting where they will be sharing workspaces with people (e.g., warehouse robots [21]), and where communication and understanding of coworkers can improve safety and efficiency [9]. The scenario we developed with our industry collaborator Dynamic Source Manufacturing has a collocated humanoid industrial robot overseeing the quality a worker's product, enabling some level of social awareness and interaction between the two; this setting allows us to investigate social factors of cooperation, such as trust and perceived friendliness, intelligence, and responsibility.

sHRI research has repeatedly shown that people treat robots as social entities, and that social behaviors are important design considerations that affect people's opinions of robots and how people react and interact with them (e.g., [3,17,22]). Teams of industrial robots and people have also been shown to benefit from sHRI techniques such as giving the robot dynamic facial expressions, and can actually improve the manufacturing process [15]. We leverage this by displaying our robot's state (its satisfaction with the board it is inspecting) with facial expressions while it is collaborating on an assembly task.

A quality assurance inspector in a factory line is an authority that can pass judgement over others' work. Existing work looks at how people perceive robots in positions of authority, or as a knowledgeable partner. For example, people have been shown to defer to robots that act as a moderator [12], or to robots who appear to be running scientific experiments [4].

However, misapplication of authority can have negative consequences [14]. Thus, it is important to carefully consider people's comfort and trust around a robot in an authoritative position [4,8]. We build on current research in robots and authority by looking at people's behaviors when their work is being evaluated by a robotic inspector that employs social behaviors in the context of an industrial assembly line.

In our work, we explore issues and opinions of people that may arise when they have their work judged by an inspection robot in a shared location. We draw on previous research that leverages social communication in an industrial setting to improve the interaction, and we extend the body of work on HRI collaboration by focusing on the rating of someone's work by the robot, rather than the assembly task itself. The quality inspection task connects us to the field of robotic authority, which inspired us to explore the opinions of users in terms of feelings like trust and comfort towards a robot that passes judgement on the assembler's work. We hope that our findings serve as a springboard for industrial sHRI.

INITIAL INVESTIGATION

Before integrating Baxter into a real circuit board assembly line for observation, we decided to first explore the social interactions with people by conducting an in-lab pilot study. Researchers have emphasized the importance of observing human-robot interactions in a context that is outside of a lab [19], and while we agree with this statement, we propose to first study industrial robots in the lab due to the high risk to safety and economical cost for implementing such a study in a real factory. In addition, our target application is multi-faceted, and potentially includes issues involving social interactions, workplace ethics, authority, physical and mental comfort, reaction to criticism, etc. Thus, the purpose of our pilot study was to explore the problem space and help develop targeted research questions for future work.

Our participants performed assembly tasks in a mock circuit board assembly line. The participant watches Baxter inspect their work, who reports the result back to the participant. During the inspection, Baxter employs social behaviors that indicate how correctly the work was done. We do this in 4 different conditions, combining facial expressions and body language during Baxter's inspection in each condition.

Participants are told they will be helping test a human-like industrial quality inspection robot, and are given a demo of the assembly process they will perform. Following the demo, they complete 4 different assembly tasks, and present each to Baxter for inspection before moving on to the next task. After each task, the participants filled out a questionnaire on eight Likert-like scales, measuring different impressions of Baxter. At the end, a semi-structured interview enabled participants to provide open-ended feedback.

For our initial pilot study, we had 5 participants (1 female), recruited from within our research lab (but they were not aware of our experimental objective). The order of the 4 conditions (of Baxter's expressions during inspection) were partially counterbalanced across participants (participants' actual assembly performance was ignored). Each participant saw one condition per assembled board (within-participant design) and were not told of the manipulation of Baxter's inspection until after the pilot.

Exploratory Questions

The questions that we aimed to explore during our pilot are:

1) What happens when Baxter evaluates someone's work to be unsatisfactory? How would this worker react?

2) How can a robot's social behaviors affect others' impression of the robot (e.g. trustworthiness, intelligence)?

3) What happens if workers think Baxter made a mistake?

The pilot study's purpose was not to come up with conclusive answers to these questions, but rather to explore the validity of our social behaviors and approach.

Instruments

At the beginning of the experiment, we supply the participant with all the tools necessary for the 4 conditions (Figure 2). The 4 circuit boards (2 large circuit boards, and 2 smaller circuit boards) are simply old PCI boards. Each board has a cube attached with an augmented reality tag for Baxter to easily detect and grip the board. There are also small wooden label mounts, labels, tape, screws, and a screwdriver. A finished assembled board can be seen in Figure 3.

Baxter the Humanoid Robot

Baxter is a humanoid robot that is designed to work in the manufacturing industry and to be safe while working alongside people [18]. In our study, we use Baxter to perform one of the tasks seen on a circuit board assembly line: inspecting the boards made by other workers for errors.

Baxter has a camera in his head and manipulators and thus can perform tasks that require him to pick up the circuit boards to inspect them at different angles. In our study, Baxter detects and manipulates the board automatically, but we fabricate the results of Baxter's inspection of the quality of work done on the board and the report that is given to the workers. In this Wizard-of-Oz setup we circumvent the 3D inspection problem and measure the sHRI as if the vision problem was solved.

Software

The experiment was performed with a Baxter Research Edition from Rethink Robotics which has collision detection and emergency stop features for participant safety. We communicated with Baxter via ROS Indigo, and our code was written in Python 2.7. Movement planning was performed by the "MoveIt!" library, and AR detection was handled by the "ar_track_alvar" ROS package

Assembly Task

Our assembly task is designed to require no specialized electronics knowledge: the tasks consisted of attaching components to the board with screws and tape. Each participant was asked to attach two logos on the large circuit boards (a completed version shown in Figure 3) and one logo on the small circuit boards and then submit their finished board to Baxter for inspection. To attach a logo to the circuit board, the participant must first screw on a flat wooden block to a certain corner of the board that has a hole, and then make sure that it is screwed tightly with the long side of the flat wooden block aligned parallel to the edge of the board. The next step requires the participant to stick the logo onto the flat wooden block using tape, and they are instructed to make sure that the logo is perfectly aligned in the center. They then submit their work to Baxter for inspection.

Participants perform the assembly while sitting in front of Baxter (Figure 1) and assemble the 4 boards, one at a time (Figure 2). After each board is assembled, participants place the board in a "completed" box where Baxter will automatically detect the board, and perform the inspection. The participants watch Baxter's inspection, and then receive the results in a report file on a nearby tablet.

Baxter's Inspection

In our implementation, Baxter detects completed boards via an augmented reality (AR) tag that is already attached (Figure 2) to the circuit boards. Baxter then picks up the board, and performs a thorough inspection by changing the board's position and orientation of the board in four distinct movements that we implemented (some of which are shown in Figure 5). We designed these board manipulations to be near Baxter's "face" (its head display and camera).

While Baxter is "inspecting," it displays a facial emotion and employs body language to express its satisfaction with the circuit board. The participant is asked to watch and wait for Baxter's report before moving on to the next board. Each condition in our pilot study combines a different facial expression with body language.

In addition to the social feedback of the facial expressions and body language, the participant receives a detailed report (also fabricated, but participants are told Baxter generates it from his inspection results), which arrives on a nearby tablet once Baxter places the circuit board down. This feedback is textual, and can include supposed participant errors (e.g., "First screw is too loose."), and success messages. We chose to have visual feedback (faces, gestures, and text) because manufacturing environments can be loud, and workers often wear hearing protection, making voice interaction difficult.

Baxter's Facial Expressions

Drawing from previous work that says robots with human-like expression can help people understand what robots are doing [15], we had Baxter use facial expression and body language to convey the robot's "feelings" about the inspection. The facial expression was displayed as a static image of the expression on the monitor that acts as Baxter's head (Figure 5). We created 3 expressions: neutral, satisfied, and unsatisfied (shown in Figure 4), using Ekman's Universal Facial Expressions as a reference [6].

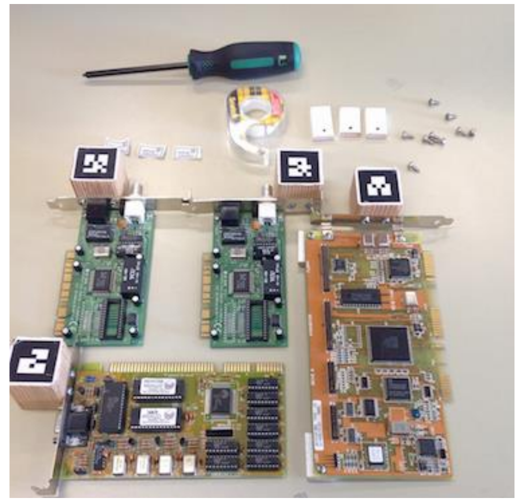

Figure 2: The tools, circuit boards, and labels given to the participant at their workstation

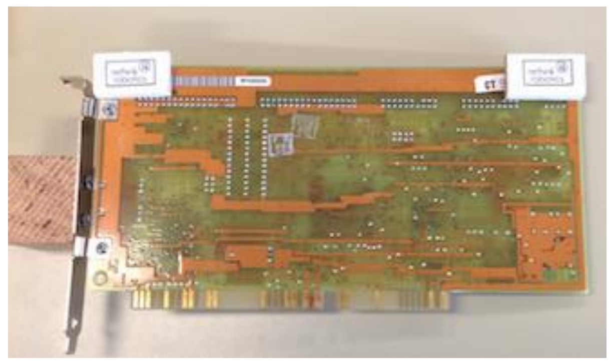

Figure 3: A finished circuit board with the logos attached to each of the two corners

Baxter's Body Language

For body language, we gave Baxter the ability to perform two head motions. The first head motion gives Baxter the ability to nod his head three times if the work done on the circuit board passes his inspection. The second head motion gives Baxter the ability to shake his head three times if he finds an error on the boards that was submitted to him. This enables Baxter to communicate to the worker the assessed quality of the work done on the board.

Experimental Conditions

The results of the inspection (Baxter's behaviors and the detailed report) were controlled, *regardless of participants' actual performance*. The inspection's result was manipulated over 4 conditions (1 per board, partially counterbalanced across participants).

Neutral Condition: Baxter displays a neutral face, shakes his head, and sends an email report that says: "Your alignment of the wooden block is off by 1cm."

Contradictory Condition: Baxter displays a satisfied face, shakes his head, and sends an email report that says: "Your alignment of the logo sticker is off by 0.5cm and is not centered properly."

Negative Condition: Baxter displays an unsatisfied face, shakes his head, and sends an email report that says: "The top screw is turned too much, you were off by 2 degrees."

Positive Condition: Baxter displays a satisfied face, nods his head, and sends an email report that says: "Circuit board is OK and is accepted."

The neutral, contradictory, and negative conditions focus on how negative reports, where people may be sensitive, should be handled by a robot. The positive condition is, in a sense, a baseline for how people evaluate a non-critical interaction from a robot, and could find biases against the robot itself.

Data Collection

In order to understand our participants' reactions to each condition, our participants rated the robot on a questionnaire after seeing Baxter's report. Our questionnaire was based on the Godpeed measures [1], with additional measures to better understand the participants' social acceptance of Baxter after working alongside it. They rated Baxter on eight measures on 5 point Likert-like scales (5 being the highest, with the questions structured so that higher numbers are associated with positive emotions): how *humanlike* Baxter seemed, how *nice* the robot was, how much they *liked* the robot, how *responsible* they thought Baxter was, how *intelligent* they thought Baxter was, how *comfortable* they felt around Baxter, how much they *trusted* Baxter to do his job, and how *likely they were to work with Baxter again* if given the option to. After the 4 tasks, each participant was interviewed by a researcher to give open-ended feedback (video recorded).

FINDINGS

We analyzed the questionnaires and the interview sessions with each participant to gain a better understanding of his or her experiences when interacting with Baxter. To help mitigate the effects of personal differences in ranking the robot, we looked at the within-participant relative difference; in other words we look at how much more or less a person rated the robot based on the condition. We performed this by subtracting the participant's average response for each measure across each condition. Thus, 0 in the following figures represents the average rating for that measure for that participant (Figure 6). A positive value in the figures represents the participant rated that measure higher than their average for that measure, and vice versa.

Quantitative Data

Likely due to our low participant numbers, repeated-measure ANOVAs found no significant results. However, our questionnaire data suggest a few trends that may be of interest for future work. In particular, we observed an increase in positive feelings in the positive condition (see Figure 6, *nice, likeable, humanlike, comfortable,* and *likely to work again*). This observation agrees with previous work showing that positive social interaction can improve a person's relationship with a robot [12].

When Baxter was negative and reported a negative result, we observed negative reactions in participants' rating of the robot (see Figure 6, *nice, like, comfortable,* and *likely to work again*). This could be related to the fear of being evaluated negatively [16]. However, in the negative condition, we also observed higher ratings for *humanlike* and *intelligence*, agreeing with work in human-computer interaction [17].

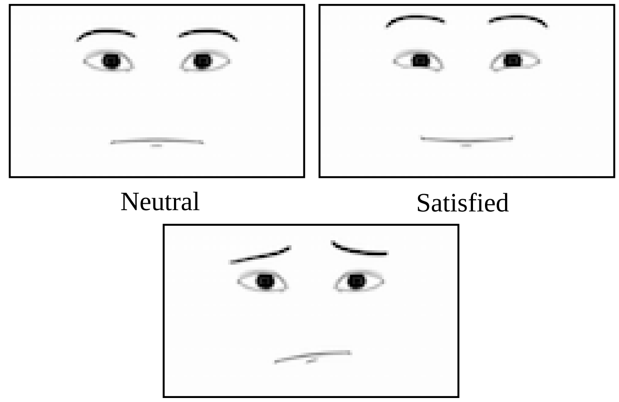

Figure 4: The three facial expressions that we used for Baxter.

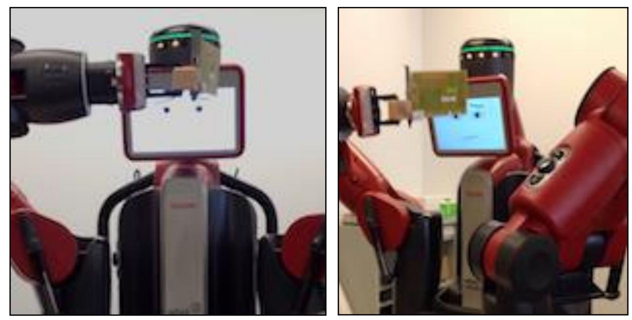

Figure 5: Two of the four close ups that Baxter does when he inspects the board

In the contradictory condition, where Baxter showed a satisfied face but reported a negative result, we observed small differences in being rated higher for *nice*, *like*, and *likely to work again*, suggesting some participants thought Baxter was trying to be nice, even while reporting mistakes.

Exploratory User Feedback

There was a variety of responses for our qualitative data that may be relevant to future work. In particular, we received feedback about physical and social comfort, reactions to Baxter's social behaviors, and observed more negative opinions when workers' opinion of their performance differed from Baxter's report. These results point to potential research directions for industrial sHRI.

Our participants often felt uncomfortable due to the large, mechanical nature of Baxter: "[It was] awkward to have large machine in front of me" (P2). Others, such as P3 mentioned Baxter was "scary and noisy," suggesting physical design cues for social robots in industry.

Social comfort was also an issue in much of the feedback, especially for the negative condition, where Baxter used

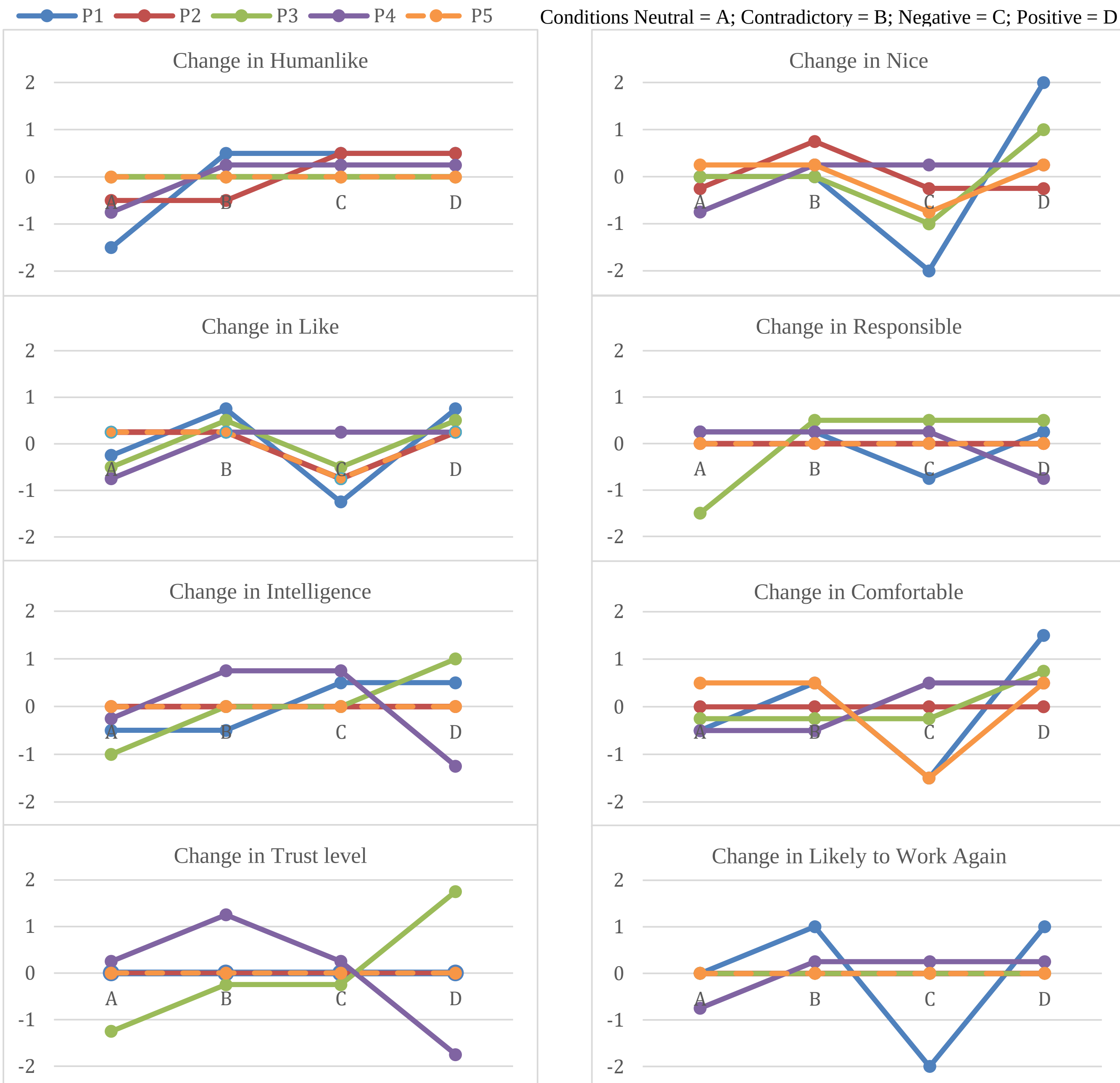

Figure 6: The average rating of the robot for each measure. Personal differences in ranking the robot were corrected by subtracting each participant's questionnaire response by their average response for each measure across each condition. N = 5.

negative facial expressions and body language along with a negative report. P5 elaborated, saying:

> *"[Baxter's] facial expressions made me feel uncomfortable because he wasn't happy" - P5*

There were also comments that directly criticized the social behavior of Baxter, saying the robot was "not nice" (P1), "not fun to work with" (P5), and they specifically disliked Baxter's "dissatisfied face during the critique" (P3). Such comments show that robot designers should also consider the social well-being of a robot's co-workers.

One participant had an interesting experience during the contradictory condition, where Baxter shows a satisfied face while shaking its head and reporting a negative result:

> *"When it shook its head, it had a smirk on its face as if it was mocking me" - P1*

Mockery is a complex human behaviour, suggesting that sHRI designers should be mindful of even these possibilities, and should not assume that positive behaviors such as happy faces will always have positive effects on the interaction.

Interestingly, participants often had their own opinions about the quality of their work, which sometimes differed from Baxter's report. For example, both P3 and P4 had the positive condition first. However, P4 did not think they performed adequately, and was surprised when Baxter said the board was correct, giving the robot a low rating on trustworthiness and intelligence. Their opinions improved in the next condition where Baxter rejected their board. Conversely, P3 was satisfied with Baxter's initial positive inspection. However, in the next conditions, Baxter reported mistakes, but the participant believed their work was correct and grew frustrated, saying they "did [the] same task as before", and commented that they are "not sure if [Baxter] knows what I am doing." We note that the other 3 participants stated they believed Baxter to be correct. These examples suggest that social industrial robots should consider their coworkers' opinions, providing extra explanation when they disagree.

DISCUSSION

Our exploratory design aimed to discover interesting avenues for future work. As a tradeoff for our exploratory breadth, we had many uncontrolled and overlapping variables, so we cannot draw specific conclusions. For example, people's reaction to the robot is conflated with Baxter's reported result (satisfactory or unsatisfactory), not just the social behaviors. Such interaction effects may be of great interest for future work. While our low sample size precludes strong conclusions, our pilot found potential considerations for sHRI designers that can benefit from targeted follow-up work. This includes addressing physical safety concerns, social comfort when the robot inspector is critical, multiple interpretations of the same social behaviors, building and breaking trust, and managing frustration due to differing opinions about the quality of work.

We observed negative trends when Baxter reported mistakes along with negative facial expressions and body language. It was interesting, however, to observe a possible positive trend in *intelligence* for the negative condition. While participants did not like the robot or think it was nice, they may also hold a grudging respect for finding mistakes they could not see themselves. The ability to appear intelligent while judging others' work may be a desirable quality in an inspection robot, in spite of the loss of other positive social attributes.

One participant thought the contradictory condition was mocking and mean. This participant (P1) still rated the robot highly, suggesting that existing questionnaires such as our modified Godspeed questionnaire may not cover complex social reactions to decisions made at work. This should be a caution to sHRI designers that social behaviors in robots with social power, such as an inspector, may have unintended interpretations that can make some people uncomfortable.

Other results seemed to have little average change, such as *responsible* (Figure 6). While we may simply not have had enough data to detect any differences, we noticed participants sometimes rated measures, such as *humanlike*, *trust level*, or *intelligence* consistently across conditions. This needs further study as robots may have qualities that make them more trustworthy, etc., regardless their actions.

As for physical design, many participants found Baxter to be an intimidating machine. Our participants are not industrial workers and may be less used to large machines, but large noises and intimidating physical designs may be less permissible for robots that interact socially with coworkers, and we suggest further research in this direction.

Finally, we would like to remind readers of our small sample size of 5, drawn from our lab. While sufficient for a pilot study, we cannot draw strong conclusions, but we hope our work inspires further research in industrial sHRI.

FUTURE WORK

In order to move sHRI into a real factory setting, we suggest that future work should aim to improve can be done to improve the ecological validity of experiments. For example, some participants were concerned when Baxter's report differed from their opinions of their own work, which may change by having a proper inspection with computer vision that can report actual errors on the circuit boards.

Social communication involves a wide variety of channels, and there is research on many of them; how people use and interpret them may change in an industrial setting. As such, it is important to continue to explore social cues (e.g., more faces for Baxter, use of gaze in factories, techniques to report mistakes). How Baxter delivers the report can also be explored from a social angle. For example, in quieter factories, voice may be a useful, but how a robot should talk to someone who questions the robot's decisions, or who is sensitive to criticism is an important direction.

Larger data sets will be necessary to draw more concrete conclusions. In particular, long-term interaction is of particular interest as a robotic coworker will be interacting with people for hours almost every day. Thus, longitudinal studies will help overcome sHRI challenges such as having people accept robots that may threaten jobs in their workplace (impossible in a lab with volunteer participants), and ways to introduce social robots without making current staff uncomfortable or incurring losses of productivity.

In particular, we suggest 5 targeted research directions:

1) What physical traits (shape, sound, speed, etc.) impact physical comfort during social interaction with a robot?
2) How does the result of a robotic inspection (satisfied, unsatisfied) affect people's opinions of the robot, without any social behaviors? How can specific social behaviors mitigate or affect this opinion?
3) How can we improve social comfort (reduce anxiety, frustration, etc.) when the robot reports mistakes?
4) Are nice and likeable robots perceived as more trustworthy in a workplace?
5) How can a robot deal with workplace conflict in a socially acceptable manner? For example, when a worker thinks the robot has made an error.

We believe all of these can be explored in a mock industrial setup, such as in this paper, and followed up with a study in a real manufacturing setting. Our sample task of circuit board inspection, while not representative of all manufacturing, may be a good starting point for these works as well.

CONCLUSION

Social human-robot interaction in an industrial setting remains relatively unexplored. To better understand human-robot interaction in a factory, we proposed to look at introducing Baxter into a circuit board assembly line where he performs quality inspection on the boards by other workers. We explored this in an in-lab pilot evaluation where we observed how people react to a robot being critical of their work while using social cues. We found people can interpret the same reporting style on a robot in very different ways (e.g. kindness vs. mockery), and that robots that report mistakes in a negative manner may be seen as more intelligent. Reporting methods that leverage social behaviors may, however, reduce the trust coworkers have in the robot if the report disagrees with their own opinions about their work. We imagine that the knowledge gained from this research can be applied to many industries that are shifting towards a workforce that encourages collaboration between humans and robots, and we hope that our work can serve as a springboard for future sHRI research.

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