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The Robot Makers: An Ethnography of Anthropomorphism at a Robotics Company

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This paper is an ethnographic exploration of robot anthropomorphism at a robotics company. It draws on a 10-month participatory ethnography between a robotics company, an anthropologist and a social robotics research lab. In contrast to psychological methods, our participatory ethnography integrates all stakeholders' insights, offering holistic understandings of robots' in-situ operations throughout the fieldwork, data-sharing, interviews, and analysis. In particular, this paper unravels employee social constructions of the company's self-driving factory transport vehicles, "the robots." These robots are deployed across a variety of warehouses and factories in North America. Our results involve an assessment of six teams at the robotics company's headquarters: those testing robots, those developing their hardware and software, and those working with customers. We unpack trends of anthropomorphism for each of these teams, and across the company.

CCS Concepts: • **Computer systems organization → Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

Additional Key Words and Phrases: Collaborative industrial robots, minimal social robots, robot anthropomorphism, social intelligence, human-robot social interaction, robot sociability, legibility, expressive motions, ethnography in HRI, collaborative manufacturing, social robotics

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1 INTRODUCTION

> **Test Team member:** The developer versions [of the robots] have nervous breakdowns on a regular basis... [They] are **little kids who've been given way too much sugar**... And the pre-released version are **the teenagers**. They're kind of cool, they don't care, but every once a while they still get into trouble. I think we [Test members] almost think of them as **kids we are taking care of** because our job is to spend a lot of time with them to completely understand how they behave and all the little caveats, particularly related to behaviors.

As we see increasing numbers of mobile robots in factories and workplaces, one might imagine them fading into the background as people get used to them, like dishwashers or drone wedding photography. But what we actually see in this paper is that people operating closest to these robots frequently use anthropomorphic language, extending previous findings of one-on-one bonding between people and robots in factories [1] to entire

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Fig. 1. At factories and warehouses, the OTTOs work closely with people and other automated technologies as they load up the OTTOs at one location and then the OTTOs travel to another location, where people or automated life unload them.

teams at a robot manufacturing facility. This is significant because increasing numbers of collaborative robots have been integrated into factories and warehouses where they work closely with their operators [1–3]. This paper extends also previous ethnographic results of human-robot interaction, e.g., ethnographies of robots in domestic settings [4], by presenting the results from an ethnographic study conducted at a robot manufacturing company in stages spanning a 10-month period in 2018.

Specifically, we observed a range of employee teams – including mechanical designers, software developers, test engineers, customer service, product development, and sales – interacting with their robotic products: low flat boxed-shaped robots used for point-to-point transport in factories (Fig. 1). These robots are used in factories and warehouses at over a 100 facilities in North America, often operating side-by-side with or near people. We employed qualitative participatory ethnography [5–7] to blend the insights and know-how of the three entities – a robotics company, an anthropologist and a social robotics research lab – facilitating holistic understandings of robots' in-situ relationships with people. Thus, the primary contribution of this paper is the detailed analysis and findings resulting from this in-situ observational study.

The results of our analysis indicate that employee job role plays a strong moderating role in employee uses of anthropomorphism. For example, the Test Team used anthropomorphic language, dressed the robots up at holidays, and played tricks on each other via the robots. Referencing these team sub-cultures, a Mechanical Engineer indicated he was "bilingual"; using anthropomorphic language to talk to the Test Team, but switching to more abstract technical descriptions in discussions with software. On the other hand, the Software team was proudly de-anthropomorphic, speaking of robots as machines. Software indicated that they considered robots to all behave in the same way (a perspective the Test team disagreed with), perhaps because they typically work with aggregate robot datasets at a distance from the physical robots. We also discovered strategic uses of anthropomorphism by the Sales and Services teams relative to their customers. For example, Sales said they described the robot as a coworker to underscore the unique collaborative offerings of their robot and decrease people's concerns about robots taking their jobs. On the other hand, Services frequently took the opposite approach, encouraging the customers to de-anthropomorphize the robots in order to convey the limitations of robot capabilities relative to what a person could do.

Our findings more generally point to the importance of designing robot capabilities with human expectations in mind. Because of people's tendency to judge robot capabilities relative to humans, our results indicate that improving robot performance relative to human expectations would likely improve human-robot collaboration, safety, and trust. Anthropomorphic descriptives are an efficient way for people operating closely to the robot to communicate about and reflect on robot capabilities. Moreover, making positive use of robot anthropomorphism can be used to build camaraderie within teams, and potentially even humanize a work day, by placing the worker relative to a robot social actor (e.g., when someone logged into to remotely check on the robots with their children over the weekend). Finally, they suggest important areas for research and technology development: e.g., (1) designing perception systems that keep robots from getting stuck in situations that people would find easy to resolve, (2) constructing path generation systems that handle unexpected phenomena in a way that seems socially intelligent, and, (3) developing legible robot communications with common social indications in mind.

In summary, this paper presents one of the first extensive in-situ qualitative investigations and analyses of how various employees at a robot manufacturing company apply anthropomorphic expectations and interpretations to the robots that they develop. Our results indicate that such uses of anthropomorphism are most common among those operating closest to the robots, but also present across the company, even if not all the teams liked to admit it. This paper also illustrates ways in which anthropomorphism can be used strategically by robot makers toward customers to clarify robot behaviors and manage their expectations. Finally, it illustrates the great appetite people have – even those working in industrial robot applications – for robots that act, perceive, and make decisions in a way that maps intuitively to human-human equivalents.

2 RELATED WORK

This section first reviews the role of people's anthropomorphism of robots to robot technical innovation, particularly in connection to socially operating robots. Next, it identifies technological ethnography with a focus on uses of ethnography in social robotics, followed by a theoretical elaboration of participatory ethnography. Finally, we review existing works investigating collaborative robots in organizations to establish the identification of the two variants of the company's self-driving vehicles as collaborative industrial robots.

2.1 Anthropomorphism in Social Robotics

The presence of robot anthropomorphism in industry would mean that such robots could utilize prior design findings in social robotics. Social robotics is a field predicated on the assumption that people treat robots like other social entities. For example, previous studies have examined the benefit of legible actions in the situation of human-robot collaboration. Dragan et al. [8] supported that planning motion enables the collaborator's inferences on the success of physical collaboration and suggested legible motion, planned to clearly express the robot's intent, leads to more seamless collaborations. Strabala et al. [9] examined the value of legible action in human-robot collaboration with a particular focus on the situation of a handover collaboration, which requires complex skills of interaction as actors are supposed to coordinate in time and space to transfer control of an object.

The ability of people to interpret robot intentions via socially-inspired actions, perceptions, and modulated behavior, were originally established by Breazeal et al [10, 11]. It has demonstrated the ability of simple form robots to expressively navigate around and communicate with people [12–15]. It has also demonstrated the potential for robot expressive motion to aid communication and collaboration with people [8, 13, 16]. These studies suggest that robots can legibly communicate their intentions when designed to reflect human understandings and expectations. These findings are echoed by prior work on human theory of mind attributions [17–19]. People anthropomorphize the motion of even very simple shapes [17], which establishes if the robot behaves with a legible goal, human make attributions regarding the robots' minds, relationships and actions [18, 19]. This expressive potential can also benefit from the use of complementary channels, such as light and sound [20].

In a similar vein, there also are existing works examining social impacts of robots regarding agency of computers as social actors [21–25], which are also related to the topic of this paper as well. For example, Groom et al. [21] showed how the act of people making the robot themselves can influence their responses to it, Lee et al. [22] suggested robot breakdowns hurt people's expectation, and Lee et al. [26] reported how different individual orientations influence people's sense-making in response to breakdowns. In addition, Takayama [23] suggested that perceived agency is fluid and one individual can perceive a varying level of agency depending on context. The contribution of this work is the evaluation of robot anthropomorphism in a novel setting.

2.2 Collaborative Robots in Organizations

Previous studies uncovered the role of social factors (e.g., job roles, workflows, physical closeness, and social dynamics) in shaping a variety of the robot sociability with different groups of people. For example, Sauppe et al. [1]'s ethnography of a collaborative industrial robot in manufacturing factories showed that workers at factories regarded their robot as a social entity and interacted with the robot relying on its non-verbal cues to understand its actions, which was critical for the perceived safety; their study also revealed that operators who were spending more time with the robot in the production line showed a higher level of anthropomorphism with metaphors such as son, grandkids and team players than workers in managerial team who were rarely working with the robot. Similarly, Mutlu et al. [27]'s ethnographic study of a mobile transport robot in hospitals uncovered social and organizational factors that shape workers' different reactions and attitudes towards the robot; their results showed significant differences between members in medical and post-partum units in experiencing and understanding the integration of the robot into their workflows because of their different job goals, patient types, team cultures and physical environments. Their findings regarding the workers' different interactions with robots inform design implications and recommendations for their increased sociability, that is, to improve the robots' algorithms to become more socially acceptable (e.g., matching perceived safety and actual safety, minimizing interruptions) and to add better communication and social skills (e.g., adding customizable voices, signals and language functions) that could fit different stakeholders' expectations.

2.3 Uses of Ethnography in Social Robotics

Originating from anthropology, ethnography is a set of qualitative and/or mix-research methods used to study people's cultural values and social behaviors [28]. It features researchers' self-engagement in study sites and active creation of social relationships with research participants as study opportunities [29–31]. In contrast to more scientific and clinical approaches to human behaviors which seek universal truths through objective experimentation, studies self-identified as ethnography often draw on an idea that the world is subjective and multivocal, foregrounding researchers' cultural interpretation and experiential interaction with their participants [32].

Hence, ethnography is particularly useful in human-in-the-loop technical development (e.g., customized robot social intelligence innovations) providing the 'native's point of view'(e.g., real-world experiences of the robot), synthetic analysis of distinct stakeholder groups (e.g., mediating developers, designers and users) and holistic understandings of integrated technologies (e.g.,mapping separate but connected multiple social contexts through which a robot platform is developed and operated)[33–36]. Similar to participatory design [37], it seeks to highlight various stakeholder perspectives, however, the end product is not a specific technological concept but rather sociocultural understandings of people's relationships, throughout processes, and expectations around technology. This unique utility of ethnography in social theory-building has motivated many large tech companies to hire trained anthropologists to understand workflows of their teams as well as their customers' desires for their products[38, 39]. As such, ethnography has been known as an effective method of discovering complex real-world human-technology social networks in the technology field [40–44].

Even through the number is still limited, there has been appreciation of ethnography in HRI and social robotics [45–49]. Existing ethnographic studies have examined sociability of robots as home assistants [50–54], caregivers [55–58] and coworkers [1, 27, 59], establishing usefulness of the method in understanding the particulars of real-world adaptability of socially intelligent robots.

Yet, there also are shortcomings found in the previous uses of ethnography in the field. Typical limitations include restrictions of researchers' direct participation to field sites and participants' engagement in the analysis process [45], which possibly hinders dynamic and productive collaborations between the researcher and the researched in creating insights into the future technical development. Extending previous works' methodological appreciation of ethnography, participatory ethnography used in our study maximizes the collaborative and interpersonal nature of ethnography by giving voices to all stakeholder groups in the study [5–7, 41] rather than limiting it. Drawing on anthropological theories, we further provide an epistemic background of participatory ethnography in the following.

2.4 Participatory Ethnography

Participatory ethnography is a method designated to maximize a philosophical foundation of ethnography which foregrounds researchers' self-engagement in their study sites and their communicative interaction with their researcher participants as study opportunities [6]. We utilize this method in this work because it encourages participants' articulation of their own needs and know-hows regarding study subjects throughout the whole research process [7]. Unlike controlled user studies and more objectivist ethnography, participatory ethnography facilitates interactions and collaborations between the researcher and the researched in the course of research process including study design, data collection, analysis and practical implementation of findings.

Ethnography does not only comprises data collection and analysis techniques (e.g., fieldwork and triangulation) but encompasses epistemology (i.e., how we know what we know) [60]. Participatory ethnography particularly draws on the ethnographic concept of reflexivity [45, 61] which establishes that ethnography is not simply a set of techniques used in examining a social process but also a social process by itself, sensitive to both researchers and participants' standpoints and relationships to one another. Hence, incorporation of participatory ethnography within social robotics facilitates to involve multiple parties' know-hows and insights in in-situ knowledge-building and robot behavior design process all together, allowing sustainable collaborations. Our study benefits from integrating concerns of the company teams, the anthropologist and the research lab – what is dedicated, needed, wanted, and possible to create. It keeps reflexive and communicative abilities of human groups as well as the social abilities of the robot in-the-loop, so as to develop socially-cognizant and more widely applicable collaborative robots.

The version of participatory ethnography used in our study is similar to Sauppe et al. [1]'s week-long onsite observation of the Baxter collaborative robot, with an expanded set of data channels and timeline and the most importantly, a higher emphasis on the productive effect of stakeholder collaborations. Previous ethnographic works have mostly employed fly-on-the-wall technique as a means of observation corresponding to psychological clinical methods. For example, Sabelli et al. [55]'s study used a 3.5 month participant observation in an elderly care center to assess a conversational robot. Fink et al. [52] also conducted a 6-month ethnography of a vacuum cleaner robot and a 10 month study of autonomous delivery robot deployed in hospitals [27]. Those existing works did integrate interviews as well as observation, however, they did not emphasize active interactions among all stakeholders and robots in order to create social and technical insights [45]. In this sense, a methodological

Fig. 2. A trained anthropologist (the first author) is making face-to-face interactions with company employees as well as their robots at the company's test facility during her conducting of 3 week on-site visit

innovation in this project is its use of participatory ethnography to facilitate on-going and future collaborations in the development of socially-acceptable collaborative robots.

3 METHODS

3.1 An Overview of the Methods

For a productive application of ethnography, this project was conducted through an anthropologist (first author)'s dedicated cooperation throughout the entire research process (Fig. 2). She conducted 10-month ethnographic fieldwork and analysis of the company employees' overall sociality and anthropomorphic attitudes towards their own robots in tandem with the social robotics research lab and the company (Fig. 3). As the related work illustrated, the incorporation of ethnography into studies of HRI in social robotics helps to clarify different groups of individuals (e.g., developers, end-users and bystanders)' latent needs and desires for socially intelligent robots. Thus, our ethnographic approach allowed the three stakeholders to work together to systematically study on social members' cultural values and practices. As such, our primary intention in the use of ethnography was to accomplish three-party-collaboration in this project: the integration of the anthropologist's methodological know-hows, the company teams' real-life knowledge of their own robots, and the technical/social expertise of the research lab.

In the following subsections, we explain our use of *fieldwork*, a central aspect of ethnography, involving data collection strategies such as in-depth interview, participant observation, and document collection, through which ethnographers themselves become part of the culture under study. These multiple data sources obtained through fieldwork leads to another strength of ethnography, *triangulation*, the integration of three data sources to increase validity of concepts (i.e., patterns in the qualitative data) using qualitative analyses such as *grounded theory* coding. We also present a visualized timeline which includes each event of data collection and analysis taken place in this 10 month collaboration in section 3.3.

Across all stages of this research, the guiding anthropomorphic concepts can be summarized by the following:

- Team variations in the trends of robot anthropomorphism
- Company-wide trends of robot anthropomorphism
- Employees desire for socially intelligent robots appeared in those trends

Finally, on-going conversations between the anthropologist, the social robotics research lab and the company teams regarding the technical development have taken place during the period of data analysis. At every stage of our analysis, those three parties shared and discussed over our drafts all together over and over again. Each time comments were gathered, we kept to edit our tentative drafts, which finally results in this paper. Conducting such long-term collaborations at the interfaces of academia and industry as well as different academic disciplines, we could achieve a profound interpretation of detailed real-world robot sociability rather than a monolithic explanation aiming at the development of more socially adaptable collaborative robots.

3.2 Fieldwork Timeline & Description of Activities

Referring to ethnographic data collection, fieldwork indicates ethnographic researchers' conducting of a set of data collection strategies such as interviews and participant observation by directly engaging themselves to their study sites [62]. For example, during participant observation, researchers can make observations and ask questions while participants can directly inform of their pain points in particular situations of interaction. Fieldwork is a pivot of ethnography that makes the method particularly useful in discovering real-world human-technology interactions [43, 44, 63, 64].

3.2.1 1st Site Visit: Pilot Research. The first site-visit included a tour of a couple of factories where the robots were integrated into as well as the robotics company building in which the employees work on/with the robots. Prior to the anthropologist' fieldwork, two robotics researchers in the social robotics research lab (the second author and a member of the research lab) visited the company and their customer sites to meet people working with the robots in the course of research design. An aim of the first site-visit was the authors' face-to-face participation to the employees' daily workplace routines involved in working on/with their own robots, in addition to gathering individual employees' stories with their robots. We also initiated face-to-face connection with the user experience (UX) design team members at the company who would continue to work with us throughout the project.

3.2.2 Ongoing Stakeholder Dialogs. This pilot research conducted through the lab and the company members' collaboration helped seed the ongoing data sharing, interviews, and communication of perspectives across the three stakeholder groups. For example, the initial field visit spurred the creation of customized interview questions for company employees, that was later expanded on by the anthropologist into a company-wide survey. Ongoing research talks occurred weekly between the robotics lab and two company UX designers who work across teams and facilitated interviews with a broad range of company team members. The company CTO also participated in monthly research checkins. Finally, this ongoing dialog facilitated our planning and goals for the second site-visit.

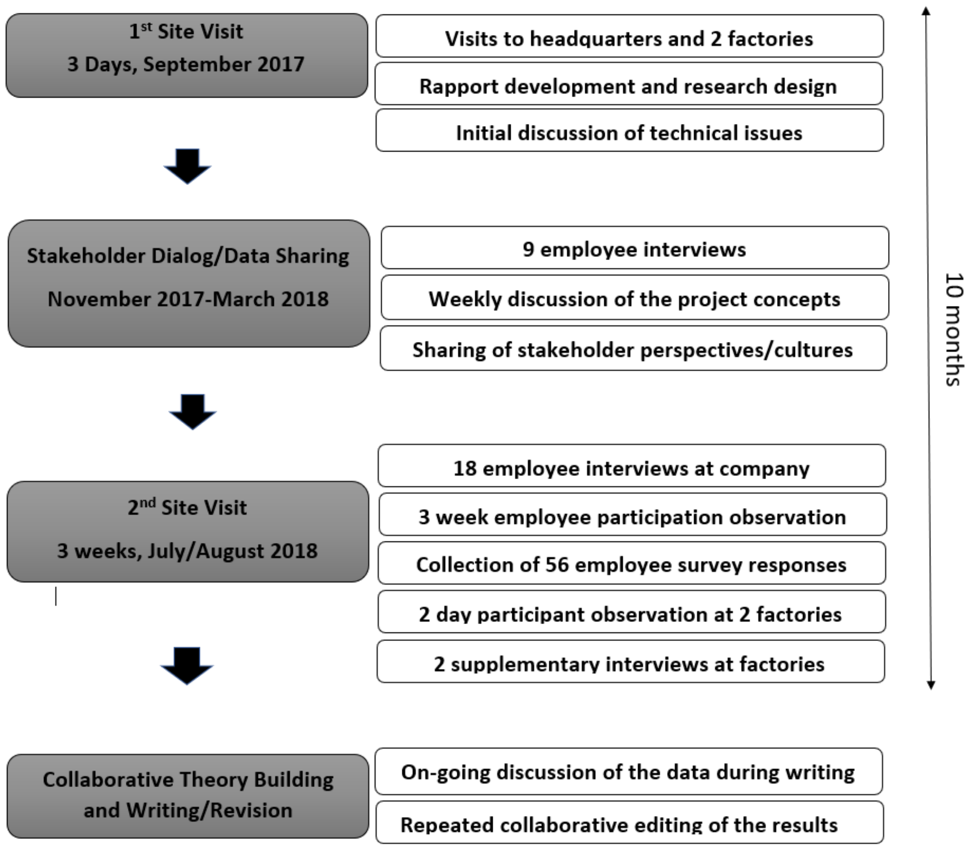


Fig. 3. Research schedule overview and activities

3.2.3 2nd Site Visit: The aim of the second site-visit was to make the use of the anthropologist's expertise, by integrating her in the employees' daily workplace routines, and engaging in two factory visits where the company's robots were deployed. During her three-week site-visit at the company and the company's customer sites, the ethnographer served as a social mediator among all the project. She delivered situations and opinions of the research lab and the company by locating herself in-between those two parties, which also allowed herself to achieve a holistic interpretation of the social construction of the robot involved in multiple stakeholder groups. In addition, she made face-to face interactions with the company employees by sharing her daily routine with them at their building for weeks–not only at work but also at break time having lunch and coffee time together with them–, which generated valuable conversations about the employees' everyday experience with the robots and opportunities for learning those robot makers' daily discussion of their own robots at work. Furthermore, she also had a chance to adjust our survey and interview questions even more customized to the individual company team members' daily experiences of their own robots.

3.2.4 The meta-aspects of working in the 'field'. Fieldwork creates mutual influences among ethnographic researchers and their participants during the period of data collection, distinct from traditional qualitative and quantitative analysis methods alone. It implies data exploration through the formation of the ethnographic "field," which indicates immaterial boundaries within which both parties of a study affect to one another surrounding certain issues under study as well as physical study sites. Hence, our 10 month fieldwork conducted between November 2017 and August 2018 includes on-site and remote research discussions and sharing of perspectives found to be relevant to data collection. In addition, activities influencing the results of this paper occurred during the period of data analysis as well (e.g., ongoing conversations with the company and interdisciplinary discussion between the roboticist and the anthropologist during the writing of this paper) due to the unique attribute of participatory ethnography.

3.3 Summary of Data Collected

Ethnographers frequently make use of both qualitative and quantitative analysis in developing their holistic cultural models of a new environment. While our data-analysis techniques are in the subsection that follows, the following data sources allowed for comparison between data channels and the integration of multiple stakeholder perspectives. Data sources included the observational field notes, images and videos collected in the field; in-depth interviews and a company-wide survey; as well as ongoing conversations between stakeholders over the research process.

3.3.1 Fieldnotes and Media. Participant observations form one of the keystones of ethnographic field work, often consisting of notes in a notebook, photos, or written reflections at the end of the day. Several figures in this paper show examples of photos taken to document on-site observations, such as Fig. 4 or Figs. 9 and 10, which reinforce understandings of both the physical and social environment in which the research was conducted. Notes collected during the onsite visits included things like "[they] want a better emotive system and way to give their robot more personality" during the 1st site visit or concepts for future collaboration like varying robot behaviors to local factory cultures. Later-in-the-research observations often detailed more specific worker habits, such as observations about how the hardware team interfaced with almost all the other technical teams, or reflections on salient points of an interview, like a test team member checking in on the robot video monitors remotely with his family. This paper itself summarizes many of the ongoing reflections developed collectively across all stakeholders.

3.3.2 In-depth Interviews. Leaning on the concepts collected in the initial site visit, 27 semi-structured interviews were conducted with company employees. One of the most important aspects of the interview was collecting stories as the answers were not analyzed one-at-a-time, but rather used as a data set to understand local culture and robot anthropomorphization. Participant answers were also used as fodder for ongoing discussions among the stakeholders, and seeded the final explorations during the second site visit. Exemplar interview questions are listed below:

- Please tell me your name and role at Clearpath. How long have you worked here?
- Have you worked in related fields before, whether robotics or other types of technology?
- If relevant, describe your interactions with customers.
- How does your job impact the design or behaviors of the robots themselves if at all?
- I want you to go back in time and tell me about the first time you met OTTO or the other robots. Can you tell me about it?
- Did your impressions of the robot(s) change as you spent more time with it(them)?
- Have you ever noticed interesting interactions of the robots with its environment or equipment? Positive, negative, funny?
- Can you tell me about the time when a robot surprised you?
- Have you ever felt embarrassed on behalf of the robot?

Fig. 4. Robot test floor at the robotics company. Through the left door one can find access to additional parts areas as well as the traditional office spaces.

- How do you think about the robot? How would you describe it?
- Do you ever project a personality?
- Is it ever useful to project humanlike characteristics onto the robots? Do you find that people at Clearpath do that at times?
- Do you think the robots have a gender? Does your team ever use he or she?
- Have you ever found yourself following along behind a robot to see where it goes? Who was the leader and who was the follower?
- Do the different robots behave differently from each other?
- Give us some examples of people at factories that work with the robots closely.
- Have you every heard customers tell you stories about the robot? If so, can you share some?
- What would be some hopes you would have for this collaboration?

The employees represented a wide distribution of teams and lasted around 45 minutes each. The number of interviewees were distributed evenly by team (i.e., four to five interviewees from each of the six teams identified in the next section). Interviews were started with the interviewer's verbal obtaining of informed consent and captured as written field notes by the interviewer. All the online and face-to-face interviews were watched and recorded by a company employee, a member of the UX design team since the project was a collaboration between the research lab and the company.

3.3.3 Online Survey. Upon completion of the interviews and co-timed with the ethnographers site visit to the company, an online survey was also sent to the all company employees, receiving fifty-six responses. Rather than reporting individual summaries for the answers to each of these questions in our results, we instead include these qualitative and quantitative answers in our overall grounded coding.

In this case, questions included many Likert questions that pulled out words and concepts from the original interviews such that we could better understand overall and team trends. For example different classes of questions included:

- *Descriptives:* The robot is [dedicated, reliable,friendly, fancy, flexible, extroverted, playful, serious, intentional, mature, immature, stupid, clumsy, naive, headstrong, precarious, introverted, bumbling, troublesome, fun, intelligent, easy to understand, annoying, stupid, has a lot to learn, confusing]
- *Nouns:* The robot is a [coworker, machine, subordinate, teenager, child, adult, male, female, crature, dog, farm animal, device, robot and nothing else]
- *Statements:* The movement of the robot meets my expectations, I believe that the robot would stop if I jump in front of it, I feel confident and safe to be close to the robot when it is moving around me, I feel like following behind the robot to see its movement, I feel disappointed with the robot when it can't achieve tasks that human can easily do, It boosts up my moods when I see the robot dressed up, I think of the robots as characters, The robots surprise me, The robots scare me, The robots frustrate me, The robots impress me, The robots have minds of their own.

And, perhaps most importantly, the survey concluded with open-ended questions similar to the interview questions, in particular, soliciting stories, reactions to robots, how their trust has changed over time, or addressing bonding with particular robots or robots in general. Seeded by the descriptives, nouns, and statements earlier in the survey, employees often detailed interesting perspectives relative to our overall analysis and research questions, as well as opportunities for future technical innovation.

3.3.4 On-going Conversations. It is also important to reinforce the centrality of ongoing conversations between all stakeholders throughout the research process. Interestingly, the anthropologist' lack of technological know-hows about the collaborative industrial robots combined with her expertise in field research methods generated great study opportunities in this project, because such position as an ethnographic researcher motivated the team members at the company and the operators at the factory sites to thoroughly explain their own knowledge and concerns about the robots from A to Z. Inversely, she and the research lab were able to share interim findings with the company teams and received the research participants' own comments about the results during her site visit. Such collaboration in the field site and during the ongoing research process was mutually evolving in a reciprocal manner.

3.4 Data Analysis Techniques: Grounded Coding & Triangulation

The theory-building aspect of ethnographic research involves building up conceptual models from the data, rather than approaching the research with explicit hypotheses. To do this is a repeatable manner, all ethnographic analyses were underpinned by three sources of data collected during the ethnographic field research: interview transcripts, field notes, and online survey responses. This qualitatively multi-variate approach is called *triangulation*, a research technique of comparing and cross-verifying the data collected by multiple methods against each other to increase the level of validity of results [65, 66]. Triangulation is an inherently holistic approach, because considering a social concept from many data and analysis angles synthesizes layered insights about robot social design criteria and potentials. This reflexive analysis contrasts explicit approaches from controlled behavioral studies in which participant and researcher perspectives are excised from the data-analysis process.

A second method we used to pull out theoretical concepts from the data was *grounded theory*, an axial coding process in which concepts are annotated in individual data sets such as interview scripts or field notes. In our case, we analyzed data using three stages of the qualitative data coding process: an open coding, an axial coding and selective coding [67–69]. First, we conducted an open coding through which codes (i.e., labels) were assigned to all relevant concepts such as events and references. For example, a quote from an interview, 'The 100 is like a Chihuahua and the 1500 is like a Great Dane' labeled as 'Comparison between the 100 and the 1500,' 'self-reports of one's anthropomorphism' and 'robots are like dogs.' Then, we conducted an axial coding through which core categories of patterns such as repeated events and similar social interactions are identified among codes from the

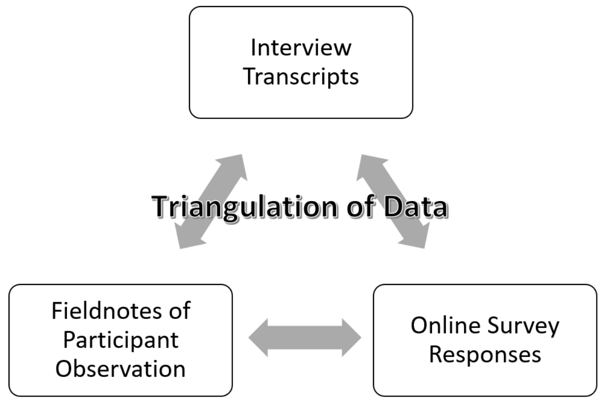


Fig. 5. Data triangulation in ethnography. This study utilized three data sources including in-depth interview, participant observation and online survey to let them triangulate one another.

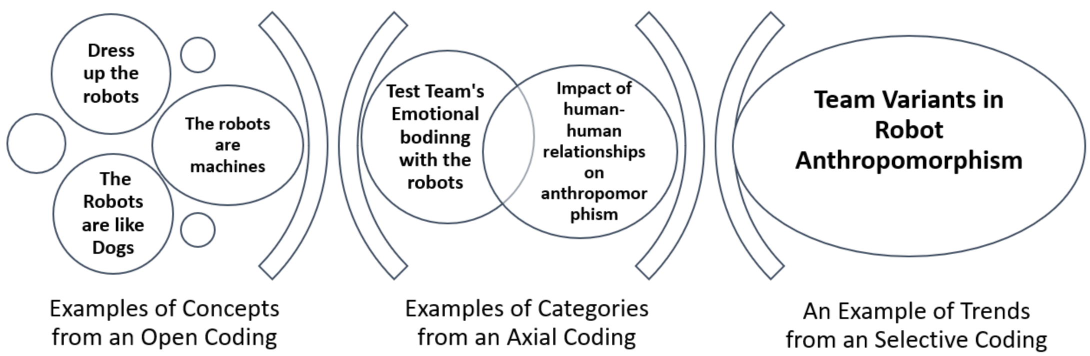


Fig. 6. Three phases of grounded theory coding. The figure presents examples of concepts from open coding, categories from axial coding and trends from selective coding in this study.

open coding; an example of codes (i.e., categories) created by the axial coding is 'emotional bonding with the robot,' 'think of the robots as Kids and pets,' and 'impacts of human-human relationships on anthropomorphism.' In the axial coding process, we associated labels into categories until there is no emerging dimensions found. Then, we conducted a selective coding referring to the process of selecting one category to be the core category, and relating all other categories to that category to develop a single story line of anthropomorphic trends and variations of the company teams' mental models, which imply important technical implications for the future innovation. Such holistic approaches can reveal cultural and social insights at a broad level, which is a great baseline for future design explorations of how sociability might be usefully integrated into and/or taken into consideration for these factory-transport robots.

4 RESEARCH SETTING

The following subsections describe the robotics company, its self-driving factory transport robots, the company's client sites and the teams developing and selling those robots.

4.1 The Company

This study was conducted at Clearpath Robotics for 10 months between November 2017 and August 2018. Clearpath Robotics Inc. is a robotics company which develops and sells self-driving industrial vehicles under the "OTTO Motors" and "OTTO" brands, as well as robots for industrial and academic researchers under the original "Clearpath Robotics" brand. During the period of this study, there were between 150 and 200 full-time staff employed by the company.

During the study, the company was manufacturing and selling two variants of their own mobile factory transport vehicles, namely, the OTTO 100 and the OTTO 1500, marketed as self-driving vehicles for industrial environments. The company also has a research division, which manufactures a variety of robots for universities and companies. This paper is about the OTTO self-driving vehicles, which are currently used by factories and warehouses across Canada and the United States. Most of the employees share a building with one of the OTTO robot test floors, often holding team-wide meetings adjacent to the testing area.

4.2 The Robots

The factory transport vehicles come in two sizes (Fig. 7), both of which were designed to work well with small obstacles in industrial settings, using their laser-based scanning to localize, avoid obstacles and plan paths to their goals. The **OTTO 100**, is a smaller-sized vehicle (29.1 x 22 x 12 in) released in 2016, designed for light-load material transport. It can transport up to 220-pound loads, at speeds up to 4.5 miles per hour. When it comes to the perception and safety related capability, the OTTO 100 has a safety-rated front LIDAR sensor, 3D vision system, one emergency stop button, and perceptive 360°LED lighting. Meanwhile, the **OTTO 1500** is a larger-sized vehicle (71.2 x 46.8 x 15.7 in) released in 2015, designed for heavy-load material transport. It can haul pallets of goods weighing up to 3300 pounds, at speeds up to 4.5 miles per hour, equivalent to the OTTO 100. The OTTO 1500 has front and rear safety-rated LIDAR sensors, 360°LED lighting, and four emergency-stop buttons.

The OTTOs are integrated directly with factory and warehouse managers' existing enterprise resource planning software and factory control systems via their central managing app, the "OTTO Fleet Manager," which commands, monitors, and dispatches fleets of vehicles. The OTTO Fleet Manager controls the vehicles via Wi-Fi, and it uses the factory map to decide on the robots' paths. The OTTO Fleet Manager manages the vehicles' battery charge levels, and automatically sends the vehicle to its charger without human intervention.

According to those we interviewed, one of the reasons the Robotics Company refers to their robots as "self-driving vehicles" is because the word "robot" tends to imply "robot arm" in the context of factory automation. Thus, using the word "robot" would have implied to potential customers that they were developing manipulation-centric machines with little intelligence. This is a naming trend in manufacturing that contrasts common academic uses of the word "robot" as connotating embodied machines with intelligent, perception-based behaviors. According to them, this association of "robot" as implying robot arms originated with the first industrial robot - a Unimate brand robot arm [70].

Self-driving vehicle, in this case, was therefore used by the Robotics Company to aid the situation of their technology as a "robot co-worker," and to avoid the machinery connotation. Recognizing the industry sociological and historical connotations, this paper identifies the robotics company's self-driving factory transport vehicles as "robots," as that usage maps better to the academic use of the word robot, particularly in the field in which we are publishing.

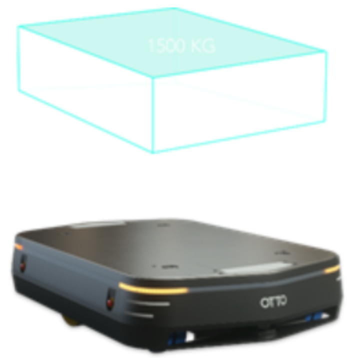
OTTO 100	Exterior	OTTO 1500
		
29.1 x 22 x 12 in (750 x 550 x 304 mm)	**Dimensions**	71.2 x 46.8 x 15.7 in (1190 x 1810 x 400 mm)
280lbs (127 kg)	**Mass**	1157 lbs. (525 kg)
220lb (100kg)	**Maximum Payload**	3300 lbs. (1500kg)
4.47 mph (2.0 m/s)	**Maximum Speed**	4.47 mph (2.0 m/s)
Front safety-rated LIDAR sensor, 3D vision system, emergency stop button, perceptive 360° LED lighting	**Perception and Safety Features**	Front and rear safety-rated LIDAR sensors, perceptive 360° LED lighting, 4 emergency-stop buttons

Fig. 7. The Overall Specifications of the OTTO 100 and the OTTO 1500

4.3 The Clients: Factories & Warehouses

Humans are still needed for a large portion of manufacturing needs. For example, in car manufacturing, an average of 50% of car assembly occurs by human hand, from the sewing of the leather around a steering wheel to the wiring, that is applied to connect the different car subsystems [71]. Thus, for many, it seems economically advantageous to investigate ways in which humans and the robots can leverage their complementary skills for at least some proportion of these processes.

The two most common locations in which these robots are used are factories and warehouses. In both, the robots most often do point-to-point transport of boxes, carts and shelves (Fig. 8), in which a human or automated lift loads them up at one location (Fig. 1), and then it travels to another location, where a human or automated lift unloads it. Other uses of these robot in factories have included flexible factory lines in which a product is manufactured on the bed of the robot as it travels from station to station, with potentially flexible ordering or fan-out.

Fig. 8. The OTTOs load and deliver boxes (left), carts (middle) and shelves (right) from one point to the other at factories and warehouses.

The size of the client site, and their products or storage items, often predict which of the OTTOs they will use. For example, the OTTO 1500s are often used in car manufacturing factories, where they transport large pieces. The OTTO 100s can help supply factory workers with smaller individual parts, or, in one case, stacks of printed fliers. There are also locations where both 100s and 1500s are used.

The robotic company's development of autonomous vehicles as intelligent co-workers also tracks with a rising trend in industrial robotics: the transition from idealizing fully-autonomous factories toward innovations that enable people and machines to effectively accomplish tasks together [72–74]. The ideal of the "lights out factory," in which there were no humans, only robots, so the building theoretically didn't need lights, originates in the 1980's, for many industries, this ideal did not turn out to be good business [75].

The first sign of this paradigm shift is evidenced by companies like Volkswagen establishing Mensch-Roboter Kollaboration groups in which the conventional ideal of full automation has been augmented with the metaphor of "co-worker robots." Although there are exception firms like Tesla in the United States, and Foxconn in China (which recently replaced 60,000 workers with robots [76]), a growing number of companies are investing in systems that make use of both human and robot capabilities.

4.4 Teams at the Robotics Company

This subsection introduces the structure and job roles of some of the teams at Clearpath. A minority of the team works adjacent to the robot test floor (Fig. 9, left), while most employees work in traditional office spaces at a distance from the robots (Fig. 9, right). Members on Sales and Services teams also have frequent visits to factories where current and potential clients use their expertise to program, fix, or experience the OTTO vehicles in situ (Fig. 10).

Distinct perspectives were evident in how these different teams conceptualized the OTTO vehicles during the study period. Thus, we focused on team deviations in their mental models, expectations, and interactions with the OTTO vehicles regarding six teams at the company: Test team, Software team, Hardware team, Product Design team, Sales team and Services team. Throughout this paper, quotes, site observations, and survey data will be indicated with labels "Test" for test team, "Software" for software team and so forth. Fig. 11 describes structures, locations and job roles of the six teams.

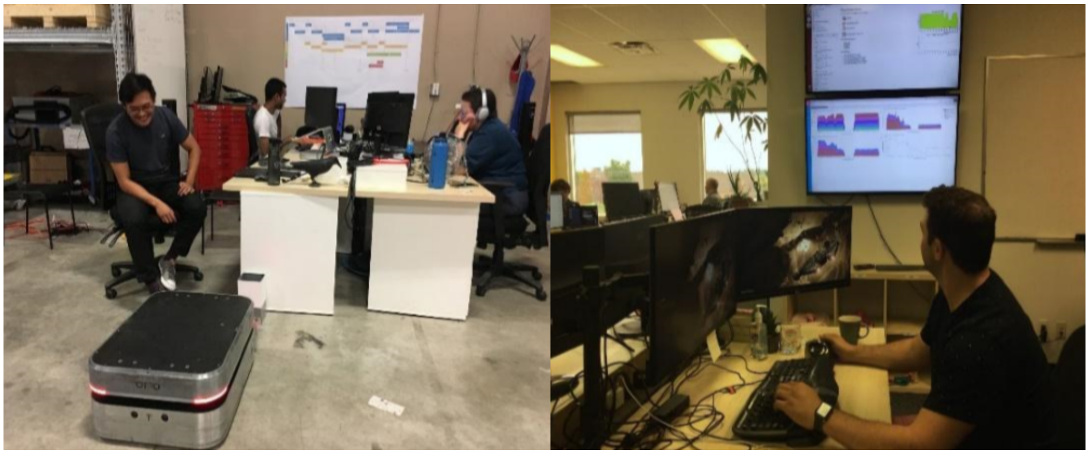


Fig. 9. The Test team has desks on the test floor near the robots (left) while most other teams work at offices, e.g. a Software team member's desk with monitors in a traditional office setting (right).

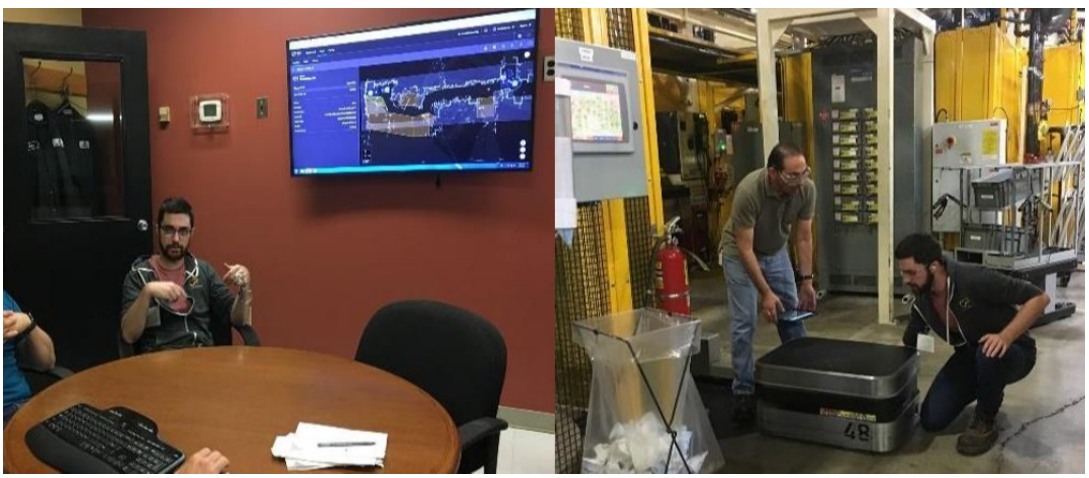


Fig. 10. Members on Sales and Services often visit their client sites and provide technical services for the customized integration of the fleet manager system (left) as well as the robot (right).

5 TEAM TRENDS

Prior work has found that people's attitudes toward robots in the workplace vary greatly by job role [1], which was reinforced during our early interviews at Clearpath in which our collaborators frequently discussed people's attitudes towards robots relative to their team membership. Building on these early impressions during our first site visit, the remote and onsite interviews explicitly invited a diversity of teams to participate to further explore this phenomena. During the final site visit, the anthropologist on the team also sought out observations and discussions with these varied teams, who were often separated by walls and had different day-to-day working environments. From an anthropological perspective, culture can be described as the norms, values, and customs

Team	Company Sub-Teams Included	Location (Order List)	Job roles
Test	Test	Test floor	To find out and to debug errors of the robot software before new versions of robots or software is released.
Software	Operating System (OS), Fleet Manager, Autonomy	Office	To develop and to improve the robot software and capabilities.
Hardware	Electrical and mechanical design	Office, Test Floor	To design and to improve the physical hardware of the robot.
Product Design	Product Applications, User Experience (UX) Design	Office	To design the control interfaces and communications between robot and people.
Sales	Sales, Marketing	Client Sites Office	To interact with potential customers, to conduct demo activities at potential customer sites
Services	Client Success, Field Services	Client Sites Office	To interact with current customers, to provide technical services or support in the case of errors.

Fig. 11. Teams at Clearpath

of a particular group, thus considering individual team as local cultures at the robotics companies is an approach that is well-suited for ethnographic analysis.

In the following subsections, we present team variations in the trends of anthropomorphism with the first set of three themes. We begin with the high-anthropomorphism Testing Team who have desks on the robot testing floor, versus the low-anthropomorphism Software Team, who tend to work with aggregate robot data sets in a different part of the building (section 5.1). This theme suggests that people that spend time in close physical proximity with robots, particularly robots that make mistakes, are likely to have high anthropomorphism levels. Next, we consider connective groups at the robot companies that work with many other teams, namely, Hardware an Product Design (section 5.2). These connective groups use flexible metaphors, suggesting that anthropomorphism may rub off, i.e., it may have been efficient to communicate with high anthropomorphism teams using anthropomorphic metaphors, which can then impact your own thinking about robots. Finally, we consider teams that interface between the company of and clients: the Sales and Services Team, finding that they use de-anthropomorphism strategically, to reduce customer disappointment in the face of what are anthropomorphic but not technical failures (section 5.3).

5.1 Test vs Software: People That Spend More Time With Robots Bond with Them

Test and Software were two extreme counterparts in the trends of anthropomorphism. Test showed a remarkably strong anthropomorphic tendency than the rest of the company teams while Software showed the lowest level of anthropomorphism among the all company teams, e.g. the robot is like a dog (Test 1) vs a food processor (Software 1). Consider two illustrative and contrasting quotes:

> **Test 1:** On the Test team we talk about them like **dogs**. Like **the 100s are chihuahuas**, they are little fierce things that go straight for your ankle. And **the 1500s are more like great danes**, they just kind of go around and somebody stops them and they're like, "Yeah, okay whatever."

> **Software 1:** The robot is not "alive." Using emotional language toward the robot is like using similar language about **a laptop or a food processor. Robots are machines** and they need to stay that way for us to trust and understand them.

Particularly, there were three prominent deviations between Test and Software members regarding self-acknowledgement of one's own anthropomorphism(section 5.1.1), anthropomorphic understanding of robot personas and personalities(section 5.1.2), and social play through the robot(section 5.1.3).

5.1.1 Self-Acknowledgement of One's Own Anthropomorphism. Test members were more likely than any other teams to assign the robots' anthropomorphic descriptions like "annoying", "serious", "precarious", "headstrong", and "introverted", as well as to agree with the statement, "It boosts up my moods when I see the robot dressed up." They exceptionally admitted their own anthropomorphism in their self-report of their mental models as the following two employees stating they "view them as sort of dogs or creature (Test 2)" and "always think that the robots are kinds of farm animals (Test Survey Respondent 1)".

> **Test 2:** I have been working around and with these robots for nearly 3 years on a daily basis and have never felt unsafe and am **completely comfortable with the robots and view them as sort of dogs or creatures**.

> **Test Survey Respondent 1: I always think that I am a sort of "owner" of them and they are kinds of farm animals.** When I am responsible for managing an entire test fleet they require maintenance like a vehicle or any other device but function nearly autonomously which makes them feel a little more like animals or creatures than just a device.

Meanwhile, none of employees on Software team admitted their anthropomorphizing of the robot behavior, instead describing them as "devices (Software 2)" or "cars (Software 3)":

> **Software 2:** I would describe them as **devices**. **For me, robots are robots.** They do as they're programmed, sometimes they look very good doing that, and sometimes they look kind of silly doing that.

> **Software 3: I think of it as a car.** I'm trying to think, because we're so custom to robots, we all have different perceptions of what robots should be. So, I don't consciously think of it as anything else but within the robot connotation there are kind of inherent assumptions of how you think they should watch, or act, or behave.

5.1.2 Anthropomorphic Understanding of Robot Personas and Personalities. Test and Software members also had prominent deviations from theme 2, the likelihood of employees to anthropomorphize robot actions but not the robot itself. Test members anthropomorphized both robot actions and the robot itself. While most Software members self-reported that they think of the robot as a car, a Test member mentioned that one day he has wondered who the robot drivers might be (Test 3).

Test 3: I remember even talking about stories like, **"What is the personality of the tiny little robot drivers?** Are they a Ferrari driver? Are they a taxi driver? Are they a **grandma?** Are they a Ford truck driver? What is that personality?" I think a lot of that has faded away at this point... Maybe it's just because I've gotten to know them better, so I know what that personality is.

Importantly, in their narratives, those two anthropomorphisms were always interconnected to one another; their anthropomorphic conceptualization of the robot personas revealed ways in which they understand and differentiate individual robot's (mis)behaviors; reversely, their everyday job role, working closely on individual robot's behavioral errors, also influenced their understanding of the robot personas (Test 4). Test 4 differentiated individual robots' behaviors by naming the robots that misbehave. Meanwhile, Test 5 believes that costuming to the robots not only boost up their moods at work but also make it easier to distinguish individual robots in testing.

Test 4: The developer versions are having a nervous breakdown on a regular basis. Because it's people's coding stuff. [They] are **little kids who've been given way too much sugar** And **the pre-released version is the teenagers.** They're kind of cool, they don't care, but every once a while they still get into trouble. I think we [Test members] almost think of them as kids we are taking care of because **our job is to spend a lot of time to completely understand how they behave** and all the little caveats particularly related to behaviors.

Test 5: You know those **Santa leg things** you're supposed to put into your trunk to make it look like you've crushed Santa in your trunk? I put that between the two levels of the bricks. There was also one with **elf ears and an elf hat**. People react to the costuming of the robots fantastically. They fall over laughing. It's very amusingâĂęand you know we have **Batman and the googly eye one**. People on other teams say costuming is also useful in distinguishing individual robots when they work on them.

Members on Test team tended to anthropomorphize the robot itself, whereas the Software team tried to avoid all anthropomorphism, particularly regarding the robot personality (Software 4).

Software 4: When you think of robotics is the more human-like robots, but when you see OTTO, **it's just the RC car**. Then, once you understand a little better what it's actually doing underneath, figuring out the path on its own, then you see the more **AI-ish point of view**. The self-driving part of it is interesting, but otherwise **it didn't have much of a personality really**.

Survey respondents also found metaphors in other expressive machines, saying, "I tend to think of the robots less as embodied creatures and more as incredibly sophisticated clockwork automatons. When they work well, it's like seeing an amazing Rube Goldberg machine successfully executed." Yet, again, one respondent declared, "I do not associate human characteristics with robots."

5.1.3 Social Play through the Robot. Test team members frequently included the robots in social play, whether inferred, "the party that the robots must've had (Test 6)" or initiated, "I like to run the robot with the Santa smashed in the middle of the pile of bricks when important clients are coming by." In addition, Test team members were more likely to introduce the robots to their families and friends and to talk about them outside of work (Test 7).

Test 6: This morning we were having discussion about the party that the robots must've had, because everything was stopped and in weird places and some of the environmental stuff had been pushed out of the way ... We were like, oh yeah, **they had a good party**. The other fleet had shut down, too, so they were tired out as well.

Test 7: My whole family knows the robots. So, our families are like, "so, how was the robot today?" I'm usually here with them on the weekend, getting them going again after they've died.

Fig. 12. The OTTO 1500 with Googly Eyes on the test floor.

> My two-year-old, she sees the robots as just like a cat or a dog. She thinks it's a person. **It's become a part of our life, I guess. We just live down the street, so we walk down here all the time**. It's cool.

Software members, however, indicate that they are significantly less likely than the Test team to talk about the robots outside of work (Software 5).

> **Software 5:** Well, I do talk about their technical issues all the time with colleagues at work, but **I don't really talk about the robots outside of work**. (Why?) Because I don't think people are interested in them. They are just factory vehicles you know people are interested in the stuff like the humanoid robots, but they usually have no idea about factory vehicles unless they work for factories. When I should introduce myself to people I simply say I am programming factory vehicles.

5.2 Hardware & Product Design: Anthropomorphism is contagious

In terms of their job roles and workplace situations, Hardware and Product Design had several things in common. Both interacted with particular robots and worked with many other teams, as in a Hardware team member's statement, "obviously the team itself is multidisciplinary because we have a daily interaction with people on production, test, purchasing, or procurement." What was different, however, is that Hardware members spent more time working with "misbehaving" robots, while product more time observing the robot's communications and user interfaces, in particular, the OTTO Fleet Manager which is their control software for multiple robots operating in the same location.

Because of those overlapped but distinguishable job roles and workplace situations, there were three comparable anthropomorphic tendencies in two teams' mental models of the robots including moderate levels of anthropomorphism(section 5.2.1), i.e. Hardware and Product Design teams anthropomorphize the robots less than Test team but more than Software team, deviations in the use of the coworker mental model(section 5.2.2), i.e. Hardware and Product Design teams employ the coworker mental model as Sales team does but in different ways and for different reasons, and overlapped expectations for more understandable and normative robot behaviors(section 5.2.3).

5.2.1 Moderate Levels of Anthropomorphism. The ethnographic data of both Hardware and Product Design teams evidenced relatively moderate levels of robot anthropomorphism in comparison with the two extremal groups at the company, Test and Software, presented in section 5.1. By inference, the portions of time each week spent by them observing or fixing particular robots seemed to serve as a prominent factor in shaping their moderately high level of anthropomorphism; most of members on Hardware and Product Design teams spent much less time with particular robots than Test team members but much more time than software members. For example, the following quotes support their moderate levels of anthropomorphism, mostly related to their experience of physical interaction with or observation of the robot. Hardware 1 describes testing the limits of the robots' ability to carry a load as "trying to trick the robots into thinking nothing is there." Watching robot react with unforeseen events may be part of why they begin to attribute the robots more anthropomorphic descriptions, tracking with previous Test team findings. Meanwhile, Product Design 1 explains when anthropomorphism is particularly useful in developing better technical communications as well as better robot functioning with the example of "patience."

> **Hardware 1:** I do a lot of **trying to trick the robots into thinking that nothing is there**. Usually by disabling bits of their safety systems or protocols... Particularly when we're adding new features to the robots, we're seeing what the impact is going to be of running with an extra 500 kilograms on the robot, extended out over the front of the robot, sometimes a few inches. See what happens when the robot, all of a sudden, stops because an object has risen in its field of view.

> **Product Design 1:** There was a particular development at the company called "patience." **I think patience is a great example of anthropomorphic communications**. Because **when the vehicle is impatient it will replan very quickly** to choose another path. It'll move very quickly to go around you. If the vehicle is very patient, then it will take more time before it begins to replan around you. You can see how people react to its impatience. They might ask **what it's doing or why it's bullying** its way through a particular space.

Meanwhile, employees on both Hardware and Product Design teams self-report that they neither strongly anthropomorphize the robot "as much as Test team does (Product Design 2)," although they are aware of the existence of a certain degree of anthropomorphism in their teams (Hardware 2). The interview data revealed that employees on both teams had a fair amount of the background knowledge on other teams' mental models and often used it as a reference in their self-reports (Product Design 2). In addition, members on those two teams neither strongly denied nor completely asserted the existence of anthropomorphism in their mental models of the robot (Product Design1, Hardware 2) mentioning that "it is sometimes useful to humanify [the robots] (Product Design 2)."

> **Product Design 2:** I know some people on Test team enjoy naming particular robots or attaching some human-like decorations or stickers to the robots... But I don't think I think of them as new

> species or a kind of creature. To my mind, personally, it is non-personified, but **I totally agree that it is sometimes useful to humanify [the robots]. But still I don't think I anthropomorphize them as much as the Test people do.**
>
> **Hardware 2:** I know we **sometimes use human-like metaphors** when we work on the robots especially on the test floor, but most often, I mean **more generally, we just refer to it as 1500 and 100**. We definitely don't say he or she. It's generally like, "Oh 1500 is like this, 1500 did that," or, "this doesn't ... there's a problem with 1500." It is the most common way of describing them when we need to correct their problems from a mechanical design perspective.

Like this, the moderate level of their anthropomorphism and their self-acknowledgement of it shows an obvious contrast with both the strong anti-anthropomorphic trend in Software team as well as the high level of anthropomorphism among the Test team presented in section 5.2.1.

5.2.2 Deviations in the Use of the Coworker Mental Model. Employees on both Hardware and Product Design agreed with the idea of "the robot coworker" in different ways and for different reasons in relations to their job roles, that could also inform the way Sales might present the robots to customers. In particular, these teams tended to anthropomorphize both of the robot and the Fleet Manager in relation to their jobs rather than any outside entities.

The Hardware team's concept of the robot coworker was strongly associated with designing the physical infrastructure of the robot. For example, a Hardware member said, "their value comes from their ability to perform the task that people hire those vehicles to perform (Hardware 3)." Similarly, Product Design team members aligned with the idea of the robot coworker in a philosophical manner. For example, Product Design 3 explicitly calls the robot "a member of your team," or "coworker," suggesting it helps to use "jobs for hire" when explaining the robots to clients.

> **Hardware 3:** As hardware people, we have to understand the language of the area where the robots are deployed, or the language of the industrial workplace to understand how things are typically communicated within that space. Then, we can design the robots' physical infrastructure, for examples, their lights or visual appearance. This is important, because in those industrial workplaces, **our robots are supposed to accomplish their tasks assisting their human coworkers**. They should meet their [human] coworkers' requirements and accomplish their tasks in the timeline. **Their value comes from their ability to perform the task that people hire those vehicles to perform.**
>
> **Product Design 3:** For me, the mental model we use when designing, talking to clients, is as **a member of your team**. They go do jobs assigned to them, they'll take breaks to charge. They behave just like a regular worker would and it's a more human label on them, rather than just another machine. I do think of it more as **a coworker** that's being hired. Again, that probably stems from my design background because I'm a big believer in the "jobs to be done" methodology of "you hire a product to do something" or you hire a service to go and do something for you. Even our personas are defined as the jobs to be done stuff, so **somebody hires OTTOs to do work for them**.

In the case of Product Design members who work on designing the interface of the fleet manager system, one Product Design member described the Fleet Manager in anthropomorphic terms, saying that "the Fleet Manager is literally like a manager you would have in real life (Product Design 4)."

> **Product Design 4:** The Fleet Manager is **literally like a manager that you would have in real life**, saying, "Dave, Tom, Jill, I need you to go do this and you to go do this and you to go do this. When you're done, come back to me and I'll give you your next piece of work to do."

Robots that Makes Mistakes are more Anthropomorphic. Hardware, like the Test team members, revealed high levels of anthropomorphization during robot misbehavior. For example, in referencing that the robots are supposed to know each other's locations; "it's the one thing that they're supposed to keep in mind: where all their friends are."

Additionally, Hardware 4 also describes their reaction to the robots "doing things deliberately because they know that it upsets us," also reframing the intersection of two robot's safety fields as "when they decide they're going to hang out, it's purely to ruin our day." The emotional reactions to robot 'misbehavior' ("starting at the sky, cursing God!") also supports the trend of attributing greater personality or intent to robots that make mistakes.

> **Hardware 4:** Sometimes, I'll come in, and someone is sort of staring at the sky, cursing God from the Test team because all the robots have stopped... and often times it'll be because a pair of OTTOs with different safety fields have turned into each other, and are completely incapable from separating... that's, I think, the one time I feel like the robots are **doing things deliberately because they know that it upsets us... it's the one thing that they're supposed to keep in mind: where all of their friends are. When they decide they're going to hang out, it's purely to ruin our day**, it's loads of fun.

5.2.3 Expectations for Understandable and Normative Robot Behaviors. Hardware and Product Design team members expressed their expectations for more understandable and normative future robots in anthropomorphic languages. For example, Hardware 5 stated, "the biggest pain point is the challenge of just fitting everything in the situation into the robot itself" and wished both people and the robots would be less unsure and hesitating. Product Design members also expressed similar expectations particularly for the improvement of the robots' communication capability because the robots seemed still "too introverted to express its intentions (Product Design 5)" to them.

> **Hardware 5:** Sometimes their interactions are more **"unsure and stay back"**... In my perspective, the biggest pain point is space or social-related. **It's not the actual driving of the vehicle itself, it's the challenge of just fitting everything in the situation into the robot itself.**

> **Product Design 5: They are often too introverted** to communicate like "It is going to be really tight going through that doorway, but I am going to go through that doorway anyway. Right, left, right, left. Anybody? Okay nobody. I am just going to do it okay?" They are not good at that kind of stuff, you know. Even when they are just turning to go somewhere, they are not like "Woop." They are more like "Ngngngng" like that kind of thing. **They don't take any risks, and they are too cautious to express its intentions.**

Finally, members on Product Design team also shared ideas for more normative robot motion behavior, as illustrated in Fig 7, comparing the robot's current motions with more legible motions that corresponded to humanlike navigation behaviors. Such sketches and hopes for the future reinforce the overall trend of employees desiring more robot social intelligence, which is the subject of the next subsection.

5.3 Sales & Services: (De)Anthropomorphism can be strategic with customers

Both Sales and Services seek to please the customers; Sales via engaging potential and new clients, and Services by helping current clients accomplish their goals with the robots. Thus, the prominent anthropomorphic trends found in Sales and Services employees' mental models were associated with their overlapped job roles as customer pleasers.

While both of their job roles are involved in the customer satisfaction, a contrasting trend was found in their mental models. It was notable that Sales members have found "coworker" to be an effective metaphor in communicating with clients about the unique features of their robots relative to the factory or warehouse equipment the client might be familiar with (section 5.3.1). In addition, the coworker mental model was also useful for the Sales team in dealing with common job-replacement fears among operators on the factory floor(section

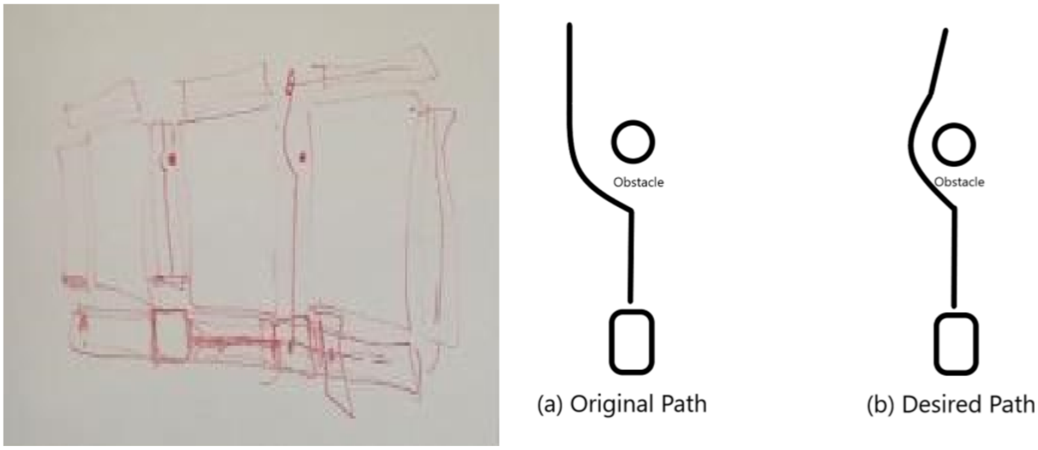


Fig. 13. Product Design members often discussed the robot behavior occurring in client sites with whiteboard illustrations at the office (left). A recreation of this whiteboard image is depicted on the right; showing the current path of the robot around an obstacle (a), versus a more natural desired path (b).

5.3.2). In contrast, employees on Services often strategically de-anthropomorphized the robots in effort to clarify to clients what the robots are incapable of doing (section 5.3.3).

5.3.1 Emphasizing the collaborative robot. For Sales members, it is crucial to help clients understand the "collaborative" aspect of their robots (i.e. the sociability of the robot), which distinguishes themselves from the traditional industrial machinery, mainly, AGVs and robot arms. On the one hand, the co-worker persona is useful for them when they describe the deployment of the robot is not associated with the elimination of AGVs. This is an important part of the Sales communication because "customers don't want to spend money on the elimination of their current facilities to have the OTTOs in their factories (Sales 1)" Thus, Sales members take the co-worker mental model, because the OTTOs "do not replace AGVs but the manual means of transporting labors that people were traditionally in charge of (Sales 1)."

> **Sales 1:** At factories, one common misconception about the OTTO is it is supposed to replace their AGVs. People wonder if they should get rid of their AGVs or other major facilities to get the OTTOs. That would be a huge risk for them. **Customers don't want to spend money on the elimination of their current facilities to have the OTTOs in their factories**. So, I say, **they do not replace the AGVs, but the manual means of transporting labors that people were traditionally in charge of. The OTTOs are co-workers**. Think about the typical factory situation that all material movement within a manufacturing facility is done by manual means. It's inefficient, it's dangerous and it is expensive.

5.3.2 Anthropomorphism to Reduce Job-replacement Fears. The co-worker mental model is also useful in the communication with operators who work on the factory floor. Operators in client sites often express their "fear of the robots stealing their jobs, and it is often associated with the image of fully automated factories with the robot arm (Sales 2)" The co-worker mental model helps reduce this fear because "when you say the OTTO is a colleague, it's like you and the robot doing the same job."

> **Sales 2:** (Do you project any human-like persona onto the robots?) Colleagues. I think using words like "colleague" helps reduce the fear of them stealing your job. **Operators in client sites often**

express their fear of the robots stealing their jobs, and it is often associated with the image of fully automated factories with the robot arm. But **when you say the OTTO is a colleague**, it's like it's not you versus the robot, it's **you and the robot doing the same job**. So, you stay in your station, because you were hired to work a job, you weren't hired to push a cart around a facility. That's just something that comes with the job. You do the job that you were hired for, and the OTTO will bring the materials to you, versus you wasting time walking around the facilities.

Meanwhile, employees on Services have a related but different challenge of keeping clients happy even when robots might not do what they have been told to do. In other word, employees on Services are not only physically dealing with the robots' technical issues on the factory floor but also interacting with clients in person and via phone.

5.3.3 Clarifying Robot Incapability via "De-Anthropomorphization". In making the balance of those dual interactions with the robot and the client, employees on Services maintain dichotomic concepts of the robots in their mental models. As field technicians, they sometimes feel "embarrassed on behalf of the robot, when customers look at it and ask them like "why is this thing so slow? (Services1)" because they spend a fair amount of time with the robots on the factory floor to learn and fix their technical issues. At the same time, they sometimes de-anthropomorphize the robots in effort to clarify to clients what the robots are incapable of doing. Their de-anthropomorphism helps factory clients be more tolerant towards the robots and their mis-functioning drawing on the manufacturing people's common understanding of the nature of machines, which always can be broken and fixed out (Services 2).

Services 1: As a field technician, I sometimes should go to client sites and fix them out right away even though there also are many things we can figure out by logging in the program. I sometimes feel **embarrassed on behalf of the robot, when customers look at it and ask like "why is this thing so slow?"** [Clients will] look at me like, "What are you doing? Why is this thing so slow?" Then there's some interactions where people will just come talk to you and want to ask all the questions in the world about what it's doing and how it's doing it.

Services 2: There's a lot of just, "We need this done in this amount of days." in customers' phone calls. Sometimes we should deal with their aggressiveness. Usually I say "Okay. I'll go fix it." but I also should tell them... I don't know. I mean I think the overall goal of client success management is to make sure customers are happy and want more robots, and I guess humans' tolerance also helps the robots' improving efficiency. So, I am like, **they are not human but machines, machines are not as good as human and machines can always be broken and fixed up easily**.

6 COMPANY-WIDE TRENDS

While the previous section considers cultural deviations between different teams at the robotics company, we are also interested in overall trends at the company. These overall trends highlight ways in which the individual teams discussed before are either the norm or highly different. These trends also clarify opportunities for socio-technological collaboration, identifying common employee values. Ethnographic methods can be used at various "zooms" in analyzing cultures, that of the large group (this section), the small group (last section), or that of the individual (see factors discussion in section 7). This section considers aggregate trends of robot anthropomorphism common across all robotics company employees, presenting social considerations that could influence the success of future social robots. We found that despite the fact that many employees deny their anthropomorphization (section 6.1), there were high instances of robot anthropomorphism for robot actions (section 6.2). Many desire increased robot behavioral intelligence (section 6.3), which could be addressed via improvements of robot perception, decision making, and communication capabilities.

6.1 The Robot Makers Anthropomorphize the Robots, But Don't Like to Admit It

Do employees anthropomorphize their robots at the company? Yes, they do. But, they do not like to admit this directly. Anthropomorphism is widely evident in their interview dialogues, describing their experiences of the robots, but frequently disavowed.

For example, in the overall company survey of 70 questions regarding employees' mental models of the robot, the strongest disagreement was expressed for the following phrases: "The robot is a farm animal" (mean=-1.60, var=0.52), "The robot is an adult" (mean -1.48, var=0.64), "The robot is a dog" (mean=-1.41, var=0.98), and "The robot is a creature" (mean=-1.29, var=1.05). In contrast, the statement most agreed with across the entire survey was: "The robot is a machine" (mean=1.22, var=1.12).

In the open-ended question section of the same survey, however, many of them shared anthropomorphic stories matching robots to humans or social companions: "At one point to have a little fun, I matched serial numbers on the robots to famous basketball players," or, "I like to hang out with my fleet when no one is around."

Similarly, in the quotes extracted from the qualitative interview analysis, Employee 1 first self-reported that he does "not project any kinds of human-like personalities onto [the robot]" and that he "simply thinks of it just as a robot or a self-driving vehicle." However, soon after that, he made an analogy between "the robot in a dynamic environment" and "nine-year-old kids solving a tough math question." Employee 2 also reported that his mental model was not anthropomorphic. A moment later, however, he recounted his experience of a robot "saying hello" to him.

> **Employee 1: I do not project any kinds of human-like personalities onto [the robot].** I would simply think of it just as a robot or a self-driving vehicle. In a non-human environment, it seemed pretty competent, but in a dynamic environment it almost seemed like you know, **let's say there is someone nine years old**, you give them a tough math question that they might know the answer to, that they should know the answer to, and they're trying to think through it and then they finally get it.
>
> **Employee 2: I usually don't see life-like characters in them**, and I am more likely to ignore the robots when I am passing by them, you know, but one day I was surprised by a robot because **it had just come up behind me, and it said hello**. And I was like, "wait, we don't have anything that has a hello sound pack," but I still felt like that it came up to me saying hello, which was very weird because I normally never think of them as a human.

Meanwhile, our interview data also showed that anthropomorphism was particularly pervasive in procedural descriptions of the robot behavior such as explanation of robot perception (e.g. "He can see obstacles"), description of frustrations (e.g. "Sometimes it is hard to understand what they want to do") and differentiation of individual deviations or errors (e.g. "Did you see the Batman one on the test floor?"). The following two themes break down this phenomenon further identifying two common categories where acceptable anthropomorphism seems to occur.

6.2 Robot Actions are More Anthropomorphic Than Robot Hardware.

The second theme presents that employees describe what robots do using creature-like metaphors, but not who they are. Employees commonly used anthropomorphic language in their reflection on sequences of the robot behavior and motion characteristics. In contrast, fewer anthropomorphic metaphors were found in their statements of the nature of the robot or the robot persona.

For instance, employees anthropomorphized the robots to describe individual robots' behavioral deviations. They often contrast behaviors and motion characteristics of their two variants of robots (i.e. OTTO 100 and

OTTO 1500) using anthropomorphism. The OTTO 100s' motions are described as "a little bit more aggressive than the OTTO 1500s (Employee 3)" while "the 1500s are more graceful (Employee 3)." Meanwhile, sequences of the physical interaction between those two variants are often presented with direct quotations (Employee 3) or as descriptive narratives like "a 100 is bullying a 1500 (Employee 4)"

> **Employee 3: The 100s are probably a little bit more aggressive** than [the OTTO 1500] because they're smaller, so they're quicker to respond to something. **The 1500s are more graceful**. If you watch the two of them interacting together when they're playing together in the same space, the 1500 will stop and be like, "Oh, something's in my way," and the 100 is like, "It's okay, I'll just go around you," and then the 1500 is like, "Okay, I'll move over here."

> **Employee 4:** We say **a 100 is bullying a 1500**, because the 100 will get right up there to the 1500 and go first.

Our quantitative survey data also supports employees' selective use of anthropomorphism only for the robot actions. Aggregate survey respondents were neutral about many adjectives assigned to the robot: annoying, stupid, friendly, serious, clumsy, dedicated, all having means <|0.25|, but these responses had variances between 1.25-2 (meaning some people had very different opinions from each other). The statement "I think of the robots as characters" was also neutral but contentious (mean=0.21, var=2.03). Section 5.2 explores rationales for these variances but could be the dichotomy between assigning robot actions character-like traits, versus identifying the robot itself as a character.

Like this, our results showed that employees use anthropomorphic metaphors in explaining and making sense of the robot actions, while they rarely do it regarding the nature of the robot itself.

Drawing on the anthropomorphism results shown through the previous themes, this subsection summarizes employee desires for the future improvement of their robots with the last theme of this paper:

6.3 Employees Desire Increased Robot Behavioral intelligence

This subsection presents examples of desired robot social intelligence: the desire to understand robots at a glance (legibility), socially-intelligent algorithms (e.g., by having more normative sensing), and improved communications (e.g., via lights, sound, and audio. Both the qualitative and quantitative data support and articulate those desires for more socially intelligent robots. Robots are regarded the most stupid when their decisions and actions don't make sense for the social situation, not for the robot itself, even for one who knows how its inside system works (Employee 12, 13).

> **Employee 12:** If its original path gets blocked, sometimes the robot decides to drive into another [strange] position to get out of that original stuck position. And **it looks silly to a human** because if you look at the scene, you would be like "it's clear the robot needs to go that way". To the left, for example. And it may decide to go to the right. **It makes sense for the robot itself, but it's not the right solution to the situation.**

> **Employee 13:** Because I know how the inside technology works, **I can understand what they do is a reasonable decision for their system, but it still looks silly to me.** I mean, the robot is not silly, but sometimes they can do real stupid things, and it is so funny. Then I am like, "why are you going that way?" or "why did you spin around in a circle to get to this destination?"

Simply put, the employees wanted to better understand the robot at glace. Employee 5 emphasizes that the robot cannot be regarded intelligent if its behavior doesn't fit the social situation. Employee 6 also mentions the importance of meeting human expectations, e.g. in path-planning, robots should not choose the shortest distance based on its own theory, but rather the fastest path depending on the situation.

Employee 5: When [the robot] gets into a tight spot, it doesn't do the right thing, quite often... I mean, I know that for the robot's knowledge and data it has, it's a reasonable decision. For a human, it looks still stupid. And that's like a naive approach to solving the problem.

Employee 6: You know sometimes your GPS takes you on the weirdest route because you accidentally picked theoretically the shortest distance as opposed to fastest time, and it drags you through a random neighborhood subdivision. I think the planning must go like that somehow, where it's just like, "Oh, this is the quickest path, we're going to go here. Yeah sure, there's a 1500 there but whatever. We're just going to keep going this way!"

If legibility refers to the ability to see what a robot is trying to do at a glance, communication is the robot's explicit declaration of those intentions or goals. Many individuals expressed desires to clarify current robot expressive communications. For example, employee 7 references possible bugs in the robot light and audio communications, saying they "aren't necessarily intuitive," while Employee 8 thinks current communication channels could be augmented by speech:

Employee 7: It's sometimes hard to tell what they're trying to do. Sometimes I find the lights aren't necessarily intuitive. Sometimes the sounds aren't necessarily intuitive, you are kind of wondering why is it playing the "don't dock" sound when it's obviously about to dock. But I don't know if that's just because the level of software in it, that maybe there's bugs in there that sometimes cross that up a bit.

Employee 8: I think about maybe adding more audio or speech to the robot so that it can actually tell us or communicate with us so that we can understand what is going on. Like sometimes, the lighting isn't enough.

Many employee desires for future robot improvements match well with common social robotics' challenges such as legibility and better communication skills of the robot. For example, employees also underscore the significance of human-centric perception and expressive communications to the needs of their clients (Employee 9, 10). Several interviews reveal echoes of these employee desires in clients' self-reports about their own needs, such as "The lidar button should be more visible," "How can we communicate with them in an error?," "When an error happens, I don't understand exactly what happened to him," "Because its lights are staying green it is hard to know the remained distance to the target endpoint," "I just need it to honk, I mean, I just want it to warn us instead of stopping itself," and "Why does it honk at me for twenty seconds?"

The experiential reaction to clients experiencing these confusions due to lack of robot social intelligence, are also reflected in employees' storytelling about visits to client sites. For example, employee 9 says they "sometimes feel embarrassed on behalf of [the robots]," or even that sometimes they will be impressed by the robot doing something they did not expect, but also need to keep it from doing that in the future (employee 9).

Employee 9: I sometimes feel embarrassed on behalf of them when I manually drive a robot in customer sites. When I am manually controlling it, it sometimes doesn't hesitate at all when instructed to recognize something "wrong," because it can't see an obstacle that I can see.

Employee 10: When its path was blocked, it decided to just weave its way through the manufacturing area and it wasn't supposed to go there, but it did it with no problems and just went through. Afterwards we were like, "Wow, that's what we built it for. It's supposed to do that. It did exactly what it was supposed to do." Then we had to go, "How do we stop it from doing that," because we can't actually have it go through that area.

Drawing on their experiential understanding of the legibility, employees have already begun to work on these themes; this may be one of the many reasons why employees have gained trust in the system. For example, the lowest variance survey statement was, "My trust in the robots has grown over time (4.09, 0.54). One example of this is perception system improvements. Employee 11 describes how they have selected sensors that reduce robot blind-spots, so that the robot can handle obstacles in ways that make more sense to humans:

> **Employee 11:** We added cameras so that we could enable 3D perception so that we could see above and below the Lidar plane. That enable the robot to be safer, so prior to this, it would probably collide with a pallet, or something that was overhanging.

There also remain several opportunities for improvements in the robots' sensing of people. Like many industrial mobile robots, the OTTO's do not currently distinguish humans from other kinds of obstacles in the environment, which would be helpful in designing interactive and communicatory behaviors between the robots and the people in the environment around it. Current robot communications do not consider whom the robot is trying to communicate to, thus future options could include targeting communication strategies to the current position of the people around it, also adjusting volume to the ambient sound.

In sum, this theme suggests several benefits that could be taken advantage in future work: integrating socially-inspired robot behaviors and decision sequences into future robot capabilities and operations. These improvements are not just relevant to the robotics company, but also crucial for the warehouses and factories in which the robots are deployed.

7 DISCUSSION

The described analyses revealed new information about the frequency of anthropomorphic interactions between technical workers and robots, the way employees use anthropomorphic language when discussing robots with each other and with third parties, and how anthropomorphization can be a social phenomenon.

Utilities of Anthropomorphization with Clients: Anthropomorphism helped people assess robot behaviors rapidly, helped employees communicate with each other about the robots, and helped the robotics companies communicate with the clients who used this robots. Interestingly, client-oriented teams used both anthropomorphism and de-anthropomorphization of the robots strategically, as supported their current communication goals. As found within company employees, anthropomorphism is efficient for communication, but the company further used the co-worker metaphor to reduce client-site fears about robots taking their jobs. On the other hand, de-anthropomorphism was also used to scope client expectations of the robot, it's just a machine, it can't actually do that. We look forward to future work that can more extensively assess the client experience and interpretation of these social framings.

Robot Anthropomorphism to Support Team Bonding: Robots contributed to social bonding within the team, but also relative to other teams. The Test Team commonly pranked each other and the rest of the company using the robots. They were also known across the company for their attitudes toward the robots. One Hardware team member said he was bilingual, i.e., able to use the Test Team's anthropomorphic style of discussing the robots when working with them, but also able to discuss the robots with internal teams (e.g., Software) in more abstract terms. This highlights the role of social robots can play in team identity, implying that the liaisons had adopted the cultural values of the Test Team to better fit into that team, adopting their language for communication and social-bonding purposes.

Socially Intelligent Decision-Making: The human-relative construction of the robot intelligence further argues for the integration of socially-inspired decision making in future versions of these and other industrial robots. One survey respondent said, "The most common reaction we hear in the customer site is "why is it doing that?". Driving or turning too slow and not navigating smoothly around other people or mobile equipment would be the most common scenarios to raise customers' eyebrows." This client desire echos employee desires for more legible robot behaviors, 'intelligent' decision making, and ability to perceive and interact naturally with the people and objects around it. Robot actions and decision-making were frequently described in human or creature like terms, reflecting employee desires for what the social robotics community would call "social intelligence."

Misbehaving Robots are More Anthropomorphic: Employees working directly with robots seem to anthropomorphize the robots the most. Examples of this include Test, the only group of employees in the company who work directly with the robots sharing their physical work space with them. In particular, robot 'misbehavior' seems to offer a short-cut to anthropomorphism. Employees working closely to the robots describe the "problem child" robot who always ran into the wall, a group of robots that "threw a party" in the night, or event two robots with intersecting safety fields, who decided to "hang out" to "ruin their [the employees'] day." These highly-anthropomorphic descriptives are great examples of character elicited from people seeking to construct rationales behind a robot's unexpected behavior, much like a teenager might invent too many reasons why a friend is not responding to a text message yet.

Ethnography to Elicit Locally-Differentiating Desires for Robots: If culture can change within the teams of a 150-person company, perhaps anthropologists can serve an active role on suggesting how to customize robot behaviors and social-situation across many future robot stakeholders. From one factory to the next, or morning to evening, or one team to the next, a trained anthropologist' active engagement in such research processes has particularly facilitated our collaborative and experiential understandings of employee conceptualizations of the robots they are developing. The process inherently incorporates the values and knowledge of all collaborators in this project, i.e., the anthropologist, the research lab and the company its reflexive, inclusive and iterative research process. It allowed for collaborative on-site examination and theory building. To the company teams, this process also provided an opportunity to voice their experiences and desires for the robots, providing opportunities for sustainable connections and collegiality among all those three parties of research collaborators.

In terms of future work, we identify meta-factors may have influenced our work, which we expect to play an even greater role in the factories and warehouses where these robots are deployed:

- **Job Identity & Socialization:** It should also be acknowledged that the socialization of different job specifications likely impacted employee reactions to the robots. For example, on Software employee described their team with the following quote from Software: "We're like people who mostly focus on getting from A to B."
- **Technical Knowhow:** Related to the above, technical training (or lack thereof) would also be likely to influence people's mental models of machines. In this particular company, the technical knowhow was quite high across the board, with more than 80% of survey respondents agreeing they could fix the robot when it broke. However, we expect this factor to play a larger role in factory worker - robot interactions.
- **Team Camaraderie:** The final factor we identified as influencing the robot anthropomorphism results is the character of the teams themselves. For example, in the culture of Test team, there were some exceptionally playful behaviors from costuming to practical jokes that may also have increased the likelihood of playful personification of the OTTOs themselves.

It is important to remember that robots operate in human environments, but also that human environments can vary culturally from one factory to the next, but also from one room to another. Another clear opportunity for future collaboration would be to explore how worker culture impacts peoples attitudes toward and behaviors around these robots in actual factory and manufacturing settings.

8 CONCLUSION

This paper has presented thematic results from a 10-month ethnographic investigation of a robotics company employees' experiences and understandings of their mobile-transport factory robots. Our data-collection consisted of site-visits, stakeholder dialog and data sharing, employee interviews and surveys, and collaborative theory building and review. All of these data sources were integrated via triangulation, grounded coding, and reflexive review of theoretical insights with all stakeholders. Our guiding anthropomorphic concepts centered on *behavioral anthropomorphism*, the ways in which robot actions and decision making are integrated in an agentic manner. Over the course of this work, larger research themes emerged around team cultures within the robotics company, such as the Test Team, the Software Team, the Hardware Team, the User Experience Team, the Services Team, and the Sales team, each of which offer varied uses and metaphors that may be relevant to future robot software designs.

Contributions of this work include: (1) a methodology for surfacing worker attitudes toward robots that integrates technology experts' knowledge of what would be feasible to build or program; (2) explicit socio-cultural findings about how robot company teams vary in their anthropomorphic attributions to the technology they are developing, that may be related to proximity to robot, customer, and/or misbehaving robots; (3) explicit identification of the ways in which robot software and perception capabilities are benchmarked by human social behavior, i.e., they cannot be addressed at the end of a robot design process, but must rather be included into the robot's low-level technological capabilities for the robots to be rated highly people. Robots may not need to smile at us, but their decisions do need to make sense, and we do want to trust that they can see us.

This concept exploration, based on fieldwork, interdisciplinary collaboration and ethnographic analysis methods, was facilitated by on-going conversations between the anthropologist, the social robotics research lab and the robotics company. Our experience was that this non-deterministic approach to social theory-building took advantage of the unique knowledge of each stakeholder. As referenced in the methods, at every stage of our analysis, all parties discussed drafts, and reinforced reflexive understandings of the data, resulting in the paper you see here.

Overall, while employees sometimes disavowed the attribution of creature-like characteristics to robots, in practice they used many socially-situated descriptives for the robots – sometimes because these descriptions are useful or efficient or fun, but other times because that's just how people (even technology designers) make sense of the world. For example, Test members' storytelling was particularly interesting, as they had the highest and the most direct exposure to the robots and would likely be the best proxy for the experiences of workers on the factory or warehouse floors. Thus, efforts to improve robot legibility, perception, and communications would support employees and clients in anticipating and collaborating with these machines.

After this work, our recommendation would be that the scope in which anthropomorphism used should be in support of clients and employee understanding of the system. We suggest that future collaboration emphasize sociability for robots acting at close range with people; people working closely with the robots appreciate individuation and would be likely to enjoy further robot expressivity and social bonding. In contrast, it may be strategic to de-emphasize sociability for robots working at a distance from people; people working far away from the robots or with aggregate robots are less likely to appreciate additional robot social behaviors. Moreover, sociability may sometimes be the wrong metaphor if robot algorithms were not designed in ways that are similar to what people would/can do.

The robotics company employees' mental models of the robot and the trends of their anthropomorphism presented in this paper certainly demonstrate the emergence of the human-machine sociability in industrial robots. In particular, the Test Team stood out as the highest anthropomorphism group, with desks on the robot test floor and high exposure to both individual and misbehaving robots. Capturing these kinds of ethnographic stories from those working with early industrial-collaborative robots sets a new baseline for how people's mental models of robots vary, and what technical innovations will be most impactful.

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