Configuring Humans: What Roles Humans Play in HRI Research

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***Abstract*—Humans are an essential part of human-robot interaction (HRI), but what roles do they play in HRI research? Analysis of the role of human subjects in research can serve as an indicator of how the HRI community engages with society. In this paper, we examine humans' roles in the HRI studies published at the ACM HRI conference over the course of 16 years (between 2006-2021). We categorize the studies into three groups. The studies in the first group investigated human nature and studied humans as interchangeable subjects; the studies in the second group addressed humans as users of robots in certain contexts; the third group of studies approached humans as social actors who are closely connected to other actors and thereby generate social dynamics. The contributions of this paper are twofold: First, we reveal the patterns of how humans have been included in HRI studies. Specifically, we find that more than half of the studies limited the role of humans to interchangeable and generalizable actors. Second, we outline three opportunities for the HRI community that arise if human subjects are given more diversified roles in HRI research — opportunities for diversity, social justice, and reflexivity. On this basis, we call for a more socially-engaged research in HRI.**

***Index Terms*—epistemology, reflexivity, method/methodology, social justice, diversity, robots**

I. Introduction

Who are the humans in human-robot interaction studies? The "human" component of HRI is what distinguishes the field from other science and engineering disciplines; thus, HRI researchers investigate robots in relation to humans and to society at large, rather than focusing solely on technological advancement. Given the significance of humans in HRI, this paper examines how humans have been incorporated in HRI studies, and the extent to which they are granted *agency*—a socioculturally mediated capacity to act [1]. With agency, individuals are able to act on situations and convey meanings through their actions. The definition of agency here underlines that people's capacity to act is loosely shaped by social, cultural, and political dynamics of the contexts individuals are in, and also influences these dynamics in turn. In other words, this definition indicates that human agency and society shape each other. In this paper, we specifically ask the following research questions:

- Who are the humans who have been invited into HRI studies, and who are the humans who have not?
- How much agency have humans had in HRI studies, and how does that give humans a voice?
- What research opportunities does the HRI community miss out on, as a result of the current roles of humans?

In social constructionist work, the role of human participants in research has been an indicator of how studies incorporate the views of human participants and, more broadly, how they engage with society [2]–[9]. In particular, human participants' involvement in research has been examined to discuss what opportunities the research community has been missing out on, due to the potentially limited roles of both human (and non-human) actors [10]–[12]. For example, in the field of human-computer-interaction (HCI), this approach brought methodological and epistemological shifts that helped the researchers investigate social justice and be deeply engaged with complex social issues (e.g., ageism [13], [14], gender politics [15], activism [16], [17]). By drawing upon studies examining the roles of human participants critically [2]–[4], [18], we focus on *contextualization* (e.g., to what extent are the contextual situations of humans considered) and *collaboration* (e.g., how much voice do human participants have in research processes). To articulate how humans are configured in HRI research, we analyzed 629 papers that were published in the full paper track of the HRI conference between 2006 and 2021.

The goal of this paper is not to provide an exhaustive overview of published work in HRI, but to explore how the field has incorporated humans into research. We seek new ways of engaging with society to address issues that the HRI community has not sufficiently examined. Our contribution is twofold: first, we describe how HRI as a field has methodologically included humans in studies (See Figure 1). Although humans are by definition an integral part of HRI research, humans' position within the field has rarely been discussed from a methodological perspective. Second, we introduce a new research agenda which has not been actively discussed before, and suggest three opportunities for HRI researchers to deeply engage with society and conduct their research so as to bring about broader societal effects.

II. Methods

To analyze how humans have played a role in the studies published at the HRI conference, we focused on their roles in published papers between 2006 and 2021 (total N=629 papers). The collection of papers reviewed was gathered from the ACM digital library. We only reviewed generic HRI studies (full papers) since they presented complete studies including

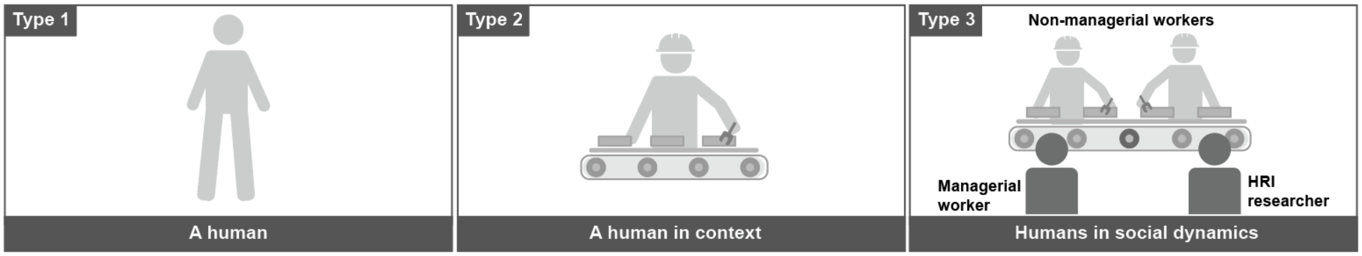

Fig. 1. Illustration of how humans have been considered in each group. Left: Type 1 - generalizable and interchangeable human participants. Middle: Type 2 - humans behave differently depending on their environment (e.g., an assembly line worker working in his workplace). Right: Type 3 - humans belong to complex societies where they develop relationships with other social actors (e.g., a worker considered to be targets of automation due to power issues pertaining to organizational hierarchy).

data collection and analysis instead of presenting preliminary studies and ideas. After the initial search, the papers were distributed to the first three authors who conducted the initial categorization based on the coding scheme presented below. The three authors examined abstracts, methods, and results sections. If needed, a whole paper was inspected. After the initial categorization, each paper was cross-checked at least twice. In developing our coding scheme, we particularly focused on two factors to identify how much agency humans had in the studies: 1) contextualization and 2) collaboration.

A. Contextualization

Contextualization has been an important component when analyzing agency of human subjects in anthropology [19], sociology [8], and HCI [4], [5]. As we defined earlier, agency is a "socioculturally mediated" capacity to act. In this definition, "socioculturally mediated" implies that the capacity of human subjects is shaped through their interaction with their surroundings (e.g., other stakeholders in the contexts, physical environments, and culture). Through this interaction, humans are considered as agents who can generate and convey meanings through their actions. Thus, analyzing how contextualization was incorporated in studies provides clues about human agency in previous studies.

From this perspective, it is crucial to understand humans' actions in relation to the social, political, and cultural contexts they are in [20]. In this paper, we analyze the HRI studies with respect to three potential approaches (hereby called "features") that reveal the extent to which context is taken into account and which are relevant to HRI studies:

- **(a)** replicating a physical study environment to reflect places that participants are familiar with [21], [22]
- **(b)** deploying studies in settings and contexts that participants are familiar with [23], [24]
- **(c)** incorporating multiple stakeholders with different roles to show how they dynamically generate meanings through their interactions [25], [26]

These three features were developed based on studies examining contextualization in anthropology, sociology, and HCI. To examine the three features, we first checked abstracts and introductions to find any information about target contexts of robotic systems. Then, for the feature **(a)**, we examined methods for information about the physical study environment, as well as the figures illustrating study settings (if any). For the feature **(b)**, we reviewed recruitment information and participants information to seek the match between the target environment (e.g., kindergarten) and participants' demographic information (e.g., age of participants). The feature **(c)** was examined by analyzing whether information about participants indicated that stakeholder diversity was taken into account. We also checked results sections to determine how stakeholders' social dynamics were described.

B. Collaboration

Collaboration between researchers and human participants has been discussed as an important factor when examining human participants' agency in anthropology [27], gender studies [28], and HCI [29]–[31]. Collaboration enables human participants to have more weight in the decision making process of the research (e.g., adjusting research directions, identifying main themes). Reconsidering collaboration between researchers and human participants has led to methodological and epistemological shifts [27]. The core contribution of collaboration is that researchers acknowledge the importance of contextual knowledge of non-researchers and become more engaged with non-researchers' situations. Considering the limited diversity of researchers in terms of their social, cultural, and economical backgrounds, this collaboration enables researchers to get more involved in social problems that have been less explored. We examine the level of collaboration by searching for one feature:

- **(d)** an opportunity for participants to discuss and shape research directions or processes [27], [30].

To examine the feature, we reviewed methods and results sections to determine if participants had a voice within the decision-making processes of studying robots (e.g., codetermine the characteristics of robots) and if participants' unique situations were considered in study design.

C. Final Coding Scheme

Based on our examination of papers in search of the four features listed above, the papers are categorized into three types: Type 1 studies, which do not have any of the four features; Type 2 studies, which have either the feature **(a)** or

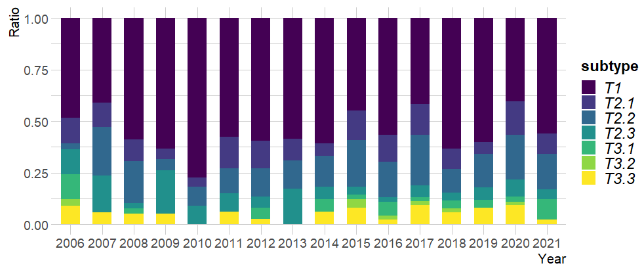

Fig. 2. The ratio of three types and subtypes throughout 16 years.

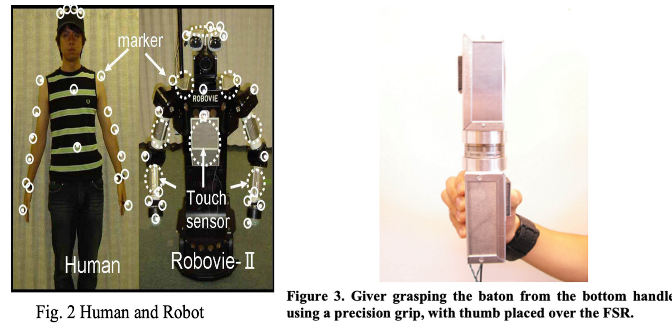

Fig. 3. Images showing how humans are understood as generalizable humans with similar biological systems (Left: [91], Right: [92]). Image courtesy of Takayuki Kanda (left) and Wesley Chan (right).

feature **(b)** of contextualization; and Type 3 studies, which have the feature **(c)** of contextualization or the feature **(d)** of collaboration.

D. Data Coding Procedure

Each paper was assigned to one of the three types (see Figure 1). Only papers reporting on empirical studies were considered; non-empirical papers (e.g., studies without human subjects or survey papers; total N=58) were coded as Not Applicable (N/A). After identifying types, the first three authors cross-checked all papers (N=571). When a paper contains more than one of the four features, categorization was made according to the highest type: Type 3 (either c or d) > Type 2 (either a or b) > Type 1 (neither a, b, c, nor d). For example, [32] was categorized as Type 2 because the robot was deployed in a mall (Type 2 - b), even though the participants tested the proposed system in a lab (Type 1 - neither a, b, c, nor d). In our categorization process, we focused on which features HRI researchers incorporated, rather than on those that they did not. After the categorization process was done, all four authors tested intercoder reliability by randomly picking 10 papers. We had 85% agreement, and the disagreements were further discussed and resolved. After categorizing papers into the three types, we read the papers in each category to discover the emerging patterns in terms of contextualization and collaboration (See this *link* to a complete list of categorization).

III. Results

A. Type 1: Humans as Representatives of Human Nature

Type 1 studies represent humans as generalizable human. As these studies investigate human nature, all humans are considered interchangeable. In total, we classified 339 papers – 59% of those published within 16 years – as being of the first type (See Figure 3). This type of paper was at its highest prevalence in 2018 (69% of total) and lowest in 2007 (36%) (See Figure 2). The number of papers of this type has been consistently high compared to other types.

To achieve generalizability of their findings, these studies include randomly chosen humans as research subjects, based on the assumption that the results would be the same regardless of who the participants are. In many studies, participants' identities (e.g., age, gender, cultural background, socioeconomic background) were hardly taken into account: 38% of Type 1 studies (130/339) do not present basic information such as total number of participants, participants' age or gender [33]–[49].

45% participants were women, and participants are on average 27 years old. There is an age gap (8 years difference) between online studies (mean age = 33) and lab studies (mean age = 25). Each study has 91 participants on average; online studies (avg 329) have about 291 more participants than lab studies (avg 38). These studies tend to contain more information about robots (e.g., robot's functionality, size, embedded program, Degree of Freedom) than about individual human subjects (e.g., specific rationales for having recruited them). Since 2010, an increasing number of papers have used crowdsourcing websites such as Amazon Mechanical Turk (mTurk) to recruit participants in large numbers for their experiments [49]–[57].

Many of these studies have hypotheses that they aim to validate, and quantitatively evaluate the participants' interaction with their robots. Often, participants were asked to provide their reaction through standardized measurement (212/339 - 63% of Type 1) using Likert scales (e.g., [58]–[65]) or standardized measures (e.g., NASA Task Load Index (TLX) [36], [40], [66]–[70], Godspeed [71]–[76], Robotic Social Attrributes Scale (RoSAS) [77], [78], Negative Attitude towards Robots Scale (NARS) [73], [79], [80], System Usability Scale (SUS) [81], Robotic Social Attribute Scale (RoSoAS) [79], Multidimensional Measure of Trust (MDMT) [82], [83]).

About 22% of Type 1 papers utilized open-ended questions (73 out of 339). The researchers in these studies asked open-ended questions after completing experiments [84]–[86], so that participants could provide their feedback [87], [88]. Although a few studies thoroughly analyze this qualitative data (e.g., [89], [90]), the majority of these studies tend to utilize quotes as a supplement to their statistical analysis.

B. Type 2: Humans as Users

Type 2 studies take into account that humans may interact with robots differently depending on their ages, occupations, and surroundings. In other words, these studies tend to incorporate at least one real-world aspect (e.g., intended users or actual environments). As depicted in Figure 1, these studies

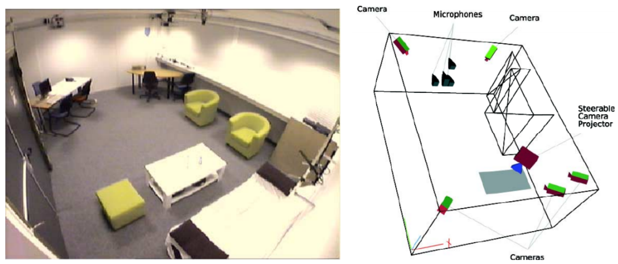

Figure 1. The INRIA Grenoble Smart Environments Facility.

Fig. 4. One example of a living lab created to replicate a real-world environment by containing everyday objects such as furniture [93]. Similar to a lab, a living-lab environment is controlled by researchers (e.g., hanging cameras that record human subjects). Image courtesy of James Crowley.

view humans as the ones situated within certain spaces (e.g., humans at the workplace). The papers of this type continuously increased except for a drop in 2018 and 2021 (See Figure 2).

After reviewing Type 2 papers, we found three emerging subcategories. Type 2.1 comprises studies that satisfy the first feature of contextualization — **(a)** replicating a physical study environment to reflect places that participants are familiar with. Type 2.2 studies contain the second feature of contextualization — **(b)** deploying studies in settings and contexts that participants are familiar with. Type 2.3 comprises studies that have both the first and second features **(a), (b)** but that do not satisfy the third feature **(c)**. These studies focus only on the targeted user group, rather than including the related stakeholders surrounding that group. Further, no social dynamics among multiple stakeholders were described.

*1) **Type 2.1: Humans in Lab 2.0- Combining Lab and Real Settings**:* Lab 2.0 is a lab setting modified to be more like an actual environment. Although these studies were still conducted in controlled settings, they incorporate a few environmental aspects. 12% of the papers (72 out of 571) belong to this category. We found two ways of utilizing Lab 2.0 in HRI papers. One way is converting a lab into a replica environment, so as to avoid logistical difficulties in using an actual environment (see Figure 4). These are often called Living labs (e.g., the AwareHome at Goergia tech [22]). For example, when Drury et al. [94] evaluated their polymorphic robots designed for natural disasters or terrorist attacks, actual disasters or attacks were not readily available; therefore, they used a replica of such a setting in their lab environment [94]. Similarly, studies were conducted in living laboratories, which mimicked real settings such as homes [95]–[100], emergency situations [101]–[105], bomb detection [106], hospital [107], [108], classroom [109], grocery store [110], and museum [111]. Recently, VR environments have emerged as a new way of simulating environment [112], [113].

The other way of conducting Lab 2.0 studies involves temporary controlled spaces within the actual settings – homes [100], [114], [115], eldercare institutions [116], [116], schools [117], [118], [118]–[134], and a music practice room [135]). We called these "a lab away from a lab", as the researchers developed controlled spaces outside of their own labs. While the first type of Lab 2.0 studies was carried out ever since the HRI conference initiated, this second approach appeared first in 2008 and was used more extensively after 2012 for child-robot interaction studies, which were conducted in school settings. These studies were performed in a separate classroom that functioned as a lab (e.g. computer lab [117]) or after school (e.g., [118]), where students followed the directions of the researchers.

*2) **Type 2.2: Humans as Representatives of Potential User Groups**:* Our analysis showed that 18% of the papers (103 out of 571) have invited potential users of their robotic systems to their research process. Potential users are human subjects with specific characteristics (e.g., age, gender, social roles) who are recruited after considering the real-world use case scenario of robotic systems.

46% of the actual users were children [96], [109], [123], [136]–[141]. 13% of these humans were domain experts including healthcare professionals [142], [143], soldiers [144], programmers [32], professional guards [86], and service workers [145]. Older adults (10%) [99], [146] and people with disabilities (7%) [147] were also part of the published studies. About 8% of the invited humans are people with specific cultural backgrounds in cross-cultural studies [148], [149].

Only two studies involved actual users of robots—one with owners of vacuum cleaner robots [150] and one with assistive arms [143]. Considering the limited numbers of robots successfully commercialized, this might not be a surprise. However, more studies with actual users who naturally brought robots into their lives could show how humans interact with robots in the real-world. By inviting potential users of their robotic systems, researchers employing a Type 2.2 approach have a chance to understand and consider their potential users' needs and contexts. For example, Stanton et al. [151] worked closely with the parents of children with Autism Spectrum Disorder (ASD), as well as with therapists, in their study investigating how those children are supported by Aibo; in creating their study environment, researchers waited until the parents confirmed that the environment was comfortable enough for the children. Incorporation of potential users broadens researchers' view on society and helps them consider situations closer to real-world settings (e.g., not just individual children but children with their parents). Similar to our findings, Briggs et al. also addressed the significance of incorporating real users in a research process, as compared to employing humans recruited randomly through mTurk [152].

*3) **Type 2.3: Humans in Public Spaces — Field Trials**:* Another subcategory of Type 2 is field trial studies in public spaces (see Figure 5), which make up around 8% in the HRI literature corpus (45 out of 571). These uncontrolled public spaces include shopping malls (36% of the total Type 2.3 studies) [153], [154], museums (10%) [155], open-house exhibitions (10%) [156], [157], universities (8%), public roads (8%), train stations (6%), classrooms (6%) and other public places (e.g., a supermarket [158]). Compared to studies employing Type 2.1, almost all Type 2.3 studies allow participants

Fig. 1. A robot attracts a crowd, which can obstruct other pedestrians

Fig. 5. Example from a field trial showing humans and Robovie within a public space [165]. Image courtesy of Takayuki Kanda.

to freely interact with their robotic systems. 80% of the field trials employed humanoid robots and more than half of the studies used Robovie (e.g. [159]). These studies lasted from about an hour [160] to 17 weeks [161]. In these studies, the robots collected real-world data (e.g., sensor data) which can be used to enhance their training sets for when they are adopted in actual settings. For example, Shiomi et al. [162] explored a group attention control (GAC) system that helps robots to properly gaze at a group of people. Also, as robots were deployed in public spaces, these studies generated realistic robot use scenarios with the general public. For example, Hayashi et al. [163] found that most people passing by a train station do not pay much attention to a robot.

Investigating humans in public settings enables HRI researchers to acquire real-world information which is not available through lab-based studies. Humans in these studies behave more naturally. Due to these natural behaviors, researchers unexpectedly find new research themes. For example, Moore et al. found vandalism as an issue relevant to autonomous vehicles [164]. Because researchers develop robot behavior models based on real-world data, these systems could be more easily adopted in the real-world. Type 2.3 studies present limited information about the participants (e.g., ages, genders, the number of participants etc). Only 35% of Type 2.3 studies provided basic information about their participants such as total number of participants, age, and gender. About half of these studies incorporated human subjects' opinion about robots by applying simple measurements (e.g., Likert scales) to briefly retrieve participants' views on specific issues.

C. Type 3: Humans as Social Actors

Type 3 studies incorporated social and power dynamics among stakeholders as an important layer, in addition to including actual users and environments. As Figure 1 illustrates, humans in these studies are not just located in the real-world, but dynamically interact with other people. These humans are often affected by power dynamics (e.g., a non-managerial worker has different views on automation than a managerial worker [166], [167]). The number of papers of this type was highest in 2006 (19%) and lowest in 2010 and 2013 (0%); since 2014, papers of this type consistently make up about 10% of the whole. In our analysis, we identified three themes: 1) humans as collaborators of researchers (satisfying feature **(d)**), 2) humans as distinctive social actors (satisfying feature **(c)** and feature **(d)**), and 3) humans within social/power dynamics (satisfying feature **(c)**).

*1) **Type 3.1: Humans as Collaborators of Researchers**:* Humans in this group of studies are collaborators: participating in the study as counselors (e.g., clinicians [168]), co-designers (e.g., [169]–[171]), and supporters (e.g., teachers [172]). In these roles, humans are partners who researchers negotiate research processes and directions with. Also, humans have a voice within the decision-making processes although the degree of their involvement varies between papers. Rather than starting with researchers' hypotheses that predetermine what to focus on in the research, Type 3.1 studies allowed negotiations between researchers and human participants to discuss what factors should be considered in studying robots [169], [171], [173]–[175].

Type 3.1 papers cover 4% of the entire publications (24 out of 571). Half of these papers (12 out of 24 papers) invited vulnerable populations into their studies as collaborators (e.g., people with disability (or health issues) [168], [171], [176]–[179], children [170], [180], older adults [171], [181], [182]), as participatory approaches are known for giving a voice to the marginalized [27], [28], [30], [183]. Collaboration in Type 3.1 studies is more than just including a human subject in a research process: it enables researchers to prioritize the issues identified from the human subject's own views.

In accordance with the focus on the unique situations of the participating humans (e.g., individual health condition), various types of robot platforms were employed, from humanoid robots (e.g., PR2 [176], [181], Robovie [184], Pepper [168]) to non-humanoid robots (e.g., Cellulo [178], Cozmo [174], YOLO [133], TACO [180], Mechanical Ottoman [185]). One fourth of the studies (5/21) did not employ specific robotic platforms and collaboratively generate appropriate platforms with more formative approaches [169], [179], [182], [186].

Through these patterns of collaboration processes, researchers actively address their participants' interests and concerns in their research processes. For example, in Scholtz et al.'s study [187] of explosive ordnance disposal (EOD) robots, the authors worked with the potential operators (e.g., civilian law enforcement teams) in developing evaluation methodologies for interactions with the robots. The researchers note that the development of the main features of their EOD systems were based on participants' suggestions. In another study, older adults took the initiative to re-frame and re-conceptualize assistive robots together with researchers [182].

To better understand issues of humans, researchers often spent extra time and efforts on relationship building with participants before the actual studies [169], [172], [184]. For example, researchers [172] first volunteered in their target environment—an early child education center—for over 3 months before conducting their study. They reported that they were able to build relationships with children, parents, and teachers in the center. This relationship building process helped the researchers grasp the potential challenges of robots

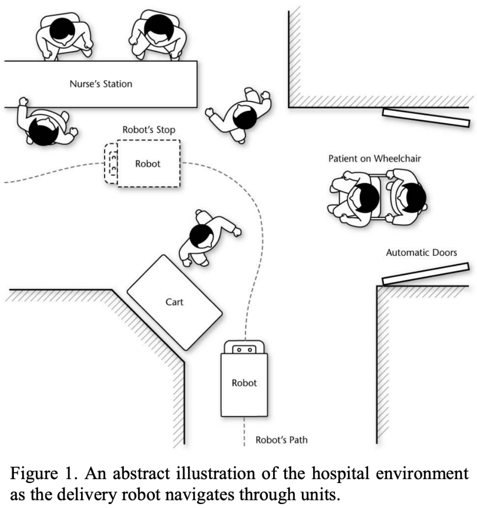

Fig. 6. One example of a study exploring humans within social dynamics [206]. In these studies, humans dynamically develop their relationships. Image courtesy of Bilge Mutlu.

in the classroom environments.

*2) **Type 3.2: Humans as Distinctive Social Actors**:* Humans in Type 3.2 studies are distinctive social actors. Type 3.2 studies highlight how a robot could support unique conditions of individual participants. These papers only cover 1% of the paper published in the HRI conference (7 out of 571). The participants in these studies (6 out of 7 studies) are mostly the vulnerable such as people with ASD [188], [189], the blind [177]), people with mobility limitations [190], and children [191]. These studies were often conducted with a small number of participants (3-12), and the condition of each participant was considered within the design process. For example, in Jacq et al.'s study, three children had a robot with different behaviors for each of them [191]. The researchers consulted with a therapist, developed hypotheses for each child, and evaluated the primary issues of robot design for them. Another example is a study that designed robotic shopping carts for the blind. Kulyukin et al. applied a principle of "ergonomics-for-one" which occupational therapists adopt to devise individualized solutions [177]. This principle does not assume that there is one standard procedure to support blind people [192], [193], which is similar to the principle of patient-centered care [194], [195]. This line of studies prioritizes heterogeneity, and this approach has been considered a legitimate method in other fields (e.g., single-subject studies in healthcare [196]–[201], autobiography in gender studies [202]–[204] or HCI [205]).

*3) **Type 3.3: Humans within Social/Power Dynamics**:* Humans in Type 3.3 studies are people in specific social roles (e.g., mothers, nurses, team members). They are taken to be situated within society where possibly a myriad of complex relationships exist (see Figure 6). These humans are considered as people who dynamically develop relationships and exist within power differentials (e.g., the limited voice of the entry-level worker compared to that of the managerial-level worker). Type 3.3 covers 6% of the papers published at the HRI conference (36 out of 571).

Type 3.3 studies investigate robots considering various types of social dynamics including family dynamics (10 out of 37 Type 3.3 papers) [174], [186], [207]–[212], social dynamics in organizations/workplaces (7/37) [206], [213]–[217], gender dynamics (7/37) [207], [218]–[222], and racism (1/37) [223]. For example, a group of Type 3.3 studies showed how robotic vacuum cleaners changed the cleaning routines and division of labor among family members, which has been developed based on family dynamics in home settings [207]–[209]. Type 3.3 studies also consider complex power issues such as gender and race. For example, Reich-Stiebert and Eyssel investigated how the perceived gender of the robots influences their interaction with humans [218]; in particular, they explored if and how human gender biases are reflected in their interactions with robots in educational settings. Racial and gender biases are power issues derived from the notion that society is a multilayered space where some people's voices are more limited than others.

IV. Discussion

Based on our analysis, we found that humans have mostly played passive roles in HRI research, rather than active roles in which they collaborate with researchers and utilize their contextual knowledge. Given that all approaches have their own strengths, it is difficult to tell what the best approach for an HRI study might be. However, considering the importance of humans in, and the interdisciplinarity of, the HRI community, the uneven distribution regarding human roles can be problematic (see Table I).

In terms of contextualization, around 60% of the studies did not consider actual contexts in which robots will be used (Type 1). 30% of studies considered people's contexts to some extent (Type 2.1 + Type 2.2), yet human subjects were rarely allowed to interact with robots in the way they would in their everyday lives (90% of all studies). In terms of collaboration, we found that only 5% (Type 3.1 + Type 3.2) of the studies published at the HRI conferences allowed their participants to play an active role such as interacting with robots within the existing social dynamics and sharing their contextual knowledge with the researchers. In this section, we discuss what opportunities there are for the HRI community, given an increased consideration of contextualization and collaboration: opportunities for 1) (epistemological) diversity, 2) social justice (attitude toward participants), and 3) reflexivity (examining unexamined bias of researchers).

A. Opportunities for Diversity

An epistemology is "a theory of knowledge [224]," which discusses what can be justified to be knowledge. A dominant epistemology in science generally strives for *generalizability* and *reproducibility* [83], [225], [226]. This may explain why a majority of HRI studies investigate human nature in response to robots' appearance or behaviors by randomly

TABLE I
SUMMARY OF ALL TYPES

Rank	%	Human role (Type)	Contxt.	Collab.	Strengths
1.	59%	Generalizable humans (Type 1)	No	No	Exploring human nature
2.	18%	Actual users (Type 2.2)	Yes	No	Getting actual users' feedback on robots
3.	12%	Users in replicated labs (Type 2.1)	Yes	No	Incorporating some aspects of actual settings
4.	8%	Users in public space (Type 2.3)	Yes	No	Understanding robots' interaction with humans in public space
5.	6%	Social actors in social/power dynamics (Type 3.3)	Yes	No	Understanding humans' complex issues within a society
6.	4%	Collaborators of researchers (Type 3.1)	Yes	Yes	Incorporating contextual knowledge of non-researchers
7.	1%	Distinctive social actor (Type 3.2)	Yes	Yes	Addressing unique and tangible issues of humans

selecting human subjects, without considering their backgrounds and without inviting them to collaborate with the researchers. When contextualization is incorporated, this is not necessarily helpful in terms of the creation of generalizable and reproducible knowledge. However, they are not the only epistemological goals that researchers can pursue.

Science and Technology Studies (STS) scholars have discussed how focusing on generalizability could make the issues of people with less voice—socially marginalized groups—invisible because generalizability does not pay attention to interindividual differences [20], [26], [227], [228]. For example, although African-American older adults develop dementia at almost twice the rate of other races [229], HRI studies exploring dementia have rarely included this population [169], [230], [231]. Another example showing the importance of diversity is facial detection algorithms with lower accuracy rate of detecting the faces of women or people of color [232]. Designers considered all humans to be interchangeable, and trained their algorithms on conveniently accessible samples of college students; eventually, this reinforces existing discrimination towards socially marginalized groups.

To challenge the invisibility of socially marginalized people's issues, *diversity* emerged as alternative epistemological goals [20], [233]. These new goals enable researchers to learn about how humans experience society in their own ways, and pay attention to their unique difficulties. Contextualization and collaboration have been considered as promising ways to address these new goals. Through contextualization, HRI researchers could understand how certain groups encounter different issues, and understand them based on their social, economical, cultural, and political position in society. Collaboration will also enable HRI researchers to take their human subjects' situations into account. Being aware of epistemological goals that HRI researchers can choose, other than generalizability and reproducibility, would help diversify the knowledge in the HRI community.

B. Opportunities for Social Justice

If the opportunities for diversity address the significance of diversifying epistemology by focusing on diversity, this section discusses how researchers *perform* their studies to directly empower people with less power. A traditional epistemology of science requires *objectivity* as an essential attitude of researchers. Through objectivity, researchers keep away from human subjects and society, and observe them from a distance rather than engage with their situations. With this approach, researchers can generate generalizable knowledge. Accordingly, in Type 1 studies, HRI researchers keep their distance from participants while they perform the main tasks with robots. In contrast to objectivity, an "action-oriented approach [28]" requires researchers' *engagement* with society and research participants, which helps researchers act on social issues. Rather than keeping a distance, these studies examine power dynamics among various stakeholders in specific contexts, and advocate for the most marginalized people in that settings. This is considered as a more active research approach that goes beyond merely describing the complexity of society or the participants' situations. This engaging approach also relates to the practice of "caring" [234], [235] and activism [16], [28].

In these alternative approaches, researchers' engagement with society and participants is considered as an ethical responsibility of researchers [236]. As the goal of research is helping participants tackle their issues, strong collaboration between researchers and participants is necessary. For example, when Euebank conducted her studies with low-income women, the first step was to understand the participants' issues before setting the goal of her study [28]. She originally wanted to teach low-income women computing skills as a way to help them get a job; however, through close collaboration, she discovered that they require more assistance in making informed decisions about a welfare system within a neoliberal society. Understanding the complex issues of participants is similar to contextualization (especially with the third feature **(c)** of contextualization in our paper); however, the action-oriented direction distinguishes this type of engagement studies from studies with contextualization features only.

Objectivity can help HRI researchers generate generalizable knowledge; however, we would like to encourage HRI researchers to also explore social justice. Considering the influence of robots in society, HRI researchers' active engagement with society and especially with socially marginalized groups, could provide them with opportunities to act on society and address social justice issues.

C. Opportunities for Reflexivity

While analyzing the studies published at the HRI conference, we found that socioeconomically underserved populations are one of the groups whose voices and knowledge are largely overlooked in our field. This might be due to the fact that we, HRI researchers, are mostly educated, middle-class, and from developed countries ourselves. Those socioeconomically marginalized populations may also be far away from the researchers' own social networks. For example, although HRI researchers have investigated robots in manufacturing settings [217], [237], the issues of the production workers—so-called low/mid-skilled workers with non-managerial positions—were not actively discussed. In particular, as entry-level workers, a number of them have limited voices at their workplaces, and yet economists are assuming that entry-level workers will be the most vulnerable concerning human replacement due to innovative technologies like robots [238]–[241].

Regardless of the potential influence on these populations, their concerns about, and experiences with, robots have not been very visible in the HRI conference. If asked to participate in a Type 1 study, they would interact with robots in the lab the same way undergraduates (or other participants) do; however, they may not have the chance to interact with robots in their workplaces, and their perspectives on robots are not likely to become visible. At the same time, managers can easily consider that type of work to be mindless, which can bias their views towards the humans who perform it. The problem is that, unless researchers deliberately choose methodologies that lead to more caution about power dynamics between management and workers, they can accidentally adopt the viewpoint of managerial workers (who are generally researchers' points of contact).

This need for caution closely relates to the social constructionist's notion of *"reflexivity."* Since researchers are humans, we (researchers) all have our own sociocultural backgrounds that could make certain types of populations invisible to us. Suchman addressed the substance of reflexivity within the research of emerging technologies, particularly in workplaces [26], [166]. For example, when she worked with a law firm to design new technology, she found that the manager-level personnel often view entry-level workers as performing mindless tasks that can easily be automated. The managers planned to replace these workers with the new technology that Suchman would design. However, after she closely observed the workers, she found that their tasks required tacit knowledge that cannot be automated. Reflexivity allowed her to realize that the managers' viewpoint was biased and to adopt different views towards the workers. Her study describes the role of researchers designing emerging technologies as an intervention to avoid human replacement issues.

Like Suchman, we as HRI researchers could intervene in these replacement issues and alleviate them by acknowledging our backgrounds and any potential biases they might cause. More engagement with socially marginalized populations, such as entry-level workers in manufacturing, would allow HRI researchers to be more aware of the societal changes their work can cause; that awareness, in turn, provides opportunities to steer those changes in more socially beneficial directions. Reflexivity will help researchers achieve genuine collaboration with socially marginalized groups as researchers become sensitive to their unexamined biases. Furthermore, the robots we develop can benefit these marginalized populations.

D. *The Tension between Research Goals and Participant Roles*

While humans are a crucial component of HRI research, so are robots. Correspondingly, a valid goal of HRI research may be to validate a novel algorithm. For that goal, a Type 1 study with undergraduate students could be fully appropriate, considering the unique strengths of the Type 1 approach. Still, even this type of study might cause social and ethical issues. For example, when facial detection algorithms—which had been validated in tests with largely white undergraduate populations—were applied to nonwhite populations who were already socially marginalized, there were unintended consequences [242]. After conducting a Type 1 study, computational systems might then be evaluated again with different approaches to alleviate unexpected issues.

Another possible mismatch between goals and participants' concerns is that HRI researchers focus on the design of robots, whereas participants may be more interested in different types of intervention. STS researchers, conversely, can explore their participants' issues through lenses of social intervention, including policies and educational programs. In HCI, which has traditionally been more technology-centric, recent studies have explored more diverse types of solutions (e.g., policies [243], [244], or technology as part of infrastructure [245], [246], as opposed to technologies in and of themselves). This change was possible because of the HCI community's increasing awareness that technologies which work well in the lab do not necessarily work well in the real world (for example, smart home studies, where lab stories and in-the-wild studies use very different methodologies [23], [247]–[255]), as well as because of researchers' efforts to prioritize human voices and issues. Although HRI researchers may still focus on robots, more collaborative and contextualized approaches may help our community envision new types of robots and investigate other types of interventions along with them.

V. CONCLUSION: *Towards More Socially-Engaged HRI*

Since the influence of robots on society can be greater than that of any other technology, HRI researchers have a responsibility to generate knowledge of robots in a way that takes that influence into account. From that perspective, it is critical to investigate how people are taken into account in HRI research. When researchers work with vulnerable populations such as children or people with disabilities, they cautiously design their studies not just for generating knowledge but for *"caring" for the populations* [234]. This implies that HRI researchers may want to incorporate specificity, heterogeneity, and engagement as research goals, in addition to generalizability, replicability, and objectivity, which are currently in focus. In this paper, we argue that the HRI community has several conscious decisions to make about where we want to head in the future, what epistemological goals are the most important to strive for, how we incorporate humans, how we engage with society, and how we take responsibility for the robots that we generate.

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