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Qualitative Research in HRI: A Review and Taxonomy

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Abstract
The field of human–robot interaction (HRI) is young and highly inter-disciplinary, and the approaches, standards and methods proper to it are still in the process of negotiation. This paper reviews the use of qualitative methods and approaches in the HRI literature in order to contribute to the development of a foundation of approaches and methodologies for these new research areas. In total, 73 papers that use qualitative methods were systematically reviewed. The review reveals that there is widespread use of qualitative methods in HRI, but very different approaches to reporting on it, and high variance in the rigour with which the approaches are applied. We also identify the key qualitative methods used. A major contribution of this paper is a taxonomy categorizing qualitative research in HRI in two dimensions: by 'study type' and based on the specific qualitative method used.

Keywords Qualitative methods · Survey · Taxonomy · Human–robot interaction · Social robotics · Interviews · Ethnography · Participatory design · Social science · Grounded theory

1 Introduction

The field of human–robot interaction (HRI), which includes the domain of social robotics, is concerned with understanding, designing, and evaluating robots for use by, or with, humans, often in uncontrolled, or 'real-world' settings. HRI originated from the field of Human-Computer Interaction (HCI), but over several decades has established itself as distinct research field [1,2]. Factors that distinguish HRI include the embodied nature of robots, the effect of anthropomorphism and the unconstrained nature of interaction between robots and people typical of HRI experiments. Collectively, these serve to uniquely define HRI as a research field in its own right.

HRI is a research area that remains young and highly interdisciplinary, and the approaches, standards and methods are still in the process of negotiation. While this brings a high level of interdisciplinary attention, innovation, and creativity to the field, it also leads to challenges in establishing agreed upon systematic approaches and methods. The field has been widely criticized for its lack of scientific quality and methodological rigour [3–6]. This has led to calls and proposals for the development of a standardized approach to allow for comparable and reproducible results [7]. Researchers have also called for larger sample sizes [5,6,8], more longitudinal studies to mitigate the novelty effect [3,5], more controlled trials [3,5,6], higher quality reporting [3,6] and an increase in the number of methods used [8].

However, caution should be used when calling for a single, standardized approach, or for an insistence on controlled, testable conditions across all studies. Such a move could preclude studies that aim to understand social contexts, human perspectives, the nature of interactions, and to generate new understandings and explanations. Theory testing is one aspect of scientific inquiry, but theory development and refinement are equally important [9]. For this, qualitative, interpretative and exploratory research provide powerful tools. While qualitative studies necessarily lack the precision of hypothesis-driven experimental studies, they can capture holistic, multi-factorial and emergent data in a way that is nonetheless formal, rigorous and systematic [9]. Instead of developing a single, standardized approach, then, a foundation of complementary approaches and methodologies are needed [4,10], as well as greater clarity in methodological reporting [6].

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This paper aims to contribute to the development of this foundation by tracing the use of qualitative methods in HRI studies in recent years. The first contribution of this paper is a systematic review of the use of qualitative methods in HRI. Arising from outcomes of the review, we present a new taxonomy which identifies three distinct HRI research approaches, or 'study types', and maps them to qualitative methods used. This taxonomy, which is the second key contribution of this paper, will help to further qualitative research in the HRI field by allowing researchers to situate their research within the interdisciplinary field and follow best practice in terms of selecting and using qualitative methods. Furthermore, it is the authors' intention that this paper will support researchers in the HRI field in gaining a greater understanding of how systematic qualitative research may be used to 1) develop greater insights and new theory related to the field, 2) contribute to more innovative and transformative robot design, 3) provide a more critical and ethical lens on participant engagement and representation, as well as the social impact of robots, and 4) complement quantitative and statistical research practises by providing explanatory data.

In this paper, we first introduce qualitative research as the focus of the study. This is followed by an outline of the methodology used to conduct the review and the articulation of a taxonomy of qualitative research practises in HRI based on three distinct study types: insights-driven, design and hypothesis-driven research approaches. We show how these categories influence the way in which the qualitative data is gathered, analysed and reported. We then discuss each of the six qualitative methods identified in the papers and how they are used across the three study types. The paper closes with a summary and discussion of the key issues, challenges and opportunities for HRI researchers using qualitative research.

2 Qualitative Research

The choice of whether to use quantitative or qualitative approaches is often more than just a methodological one. It may, in fact, be based on distinct assumptions on the nature of reality, of knowledge, and of the ultimate goal of the analysis [9]. Quantitative research is often used within an experimental frame, and based on an ontological assumption of objectivity. In the case of human studies, relevant social or human phenomena are reduced to a single, numerical data point, independent of context, which may then be scientifically measured, validated and generalized. Within this paradigm, statistically significant sample sizes are necessary. A qualitative research approach, on the other hand, assumes that the phenomena under investigation are mediated, context-dependent, emergent, and open to interpretation. These factors cannot be reduced to independent variables and are therefore not subject to the precision of controlled, scientific investigation. All qualitative analysis necessarily involves a level of interpretation by the researcher, including inductive analysis and creative synthesis [11]. The approach therefore makes no immediate claim that results are generalizable, although results from good qualitative research do uncover generalities that are widely applicable. Qualitative research is therefore often exploratory, insights-driven and may be used for theory building [9]. In good qualitative research, rigour is ensured through a detailed description of the systematic and transparent approach taken for data collection and subsequent analysis [9]. Actions to ensure greater objectivity, such as inter-coder reliability and data triangulation, may also be taken. Credibility is increased through the researcher's own reflexive stance in the analysis [11]. Despite this ontological distinction, quantitative and qualitative methods can be used effectively together to obtain several perspectives on the same phenomenon, and is an approach commonly used in triangulation.

Qualitative methods bring the researcher closer to the participants. The researcher is not considered a fully independent and objective observer, and is expected to account for their own presence in the analysis through a process of reflexivity. This perspective, along with engagement with wider social theories, inevitably draws research attention to the broader societal and ethical issues related to robotics research. This often facilitates researchers in adopting a more critical stance in relation to issues related to the field.

Despite the potential for qualitative research to contribute to the field, a number of challenges remain to using qualitative methods in HRI research. There is a tendency in HRI to aim for precision, characterized by the use of quantitative metrics and clearly defined hypotheses, which can seem more compatible with psychology and engineering disciplines in general. The technical complexity of robotics technologies also makes iterative, qualitative approaches to design more challenging [10,12]. An additional challenge is the knowledge and skills needed to adopt new approaches from other fields [7]. This may contribute to what we observed as a lack of consistency in how qualitative methods are described and reported, and a wide variation in the quality of data gathering and analysis techniques. Finally, whether it is an extensive ethnographic project, or the transcription and analysis of qualitative data, qualitative methods tend to be time intensive. Despite this, as we shall see from this paper, there have been many successful applications of qualitative research in HRI.

3 Methodology

There are a number of previous literature reviews in HRI, including those that deal with concepts in HRI [7], research

on socially assistive robots and older people [3,5,6,13,14], and robotics technologies for people with disabilities [15]. To our knowledge, only one HRI study has taken research methods explicitly as its focus [8]. Although the aforementioned study focuses on human studies methods, it does not focus explicitly on qualitative research. There are reviews of methods in related fields, such as human–computer interaction (HCI) [16] and technical communications, including papers focused specifically on qualitative methods [17]. However, the applicability of these reviews in a HRI context is typically low, as robots rarely (if ever) feature in these studies. In this paper, which we have written to address this gap, we hope both to elucidate the approaches, as well as the challenges and benefits, of using qualitative research in HRI. We hope that this will support researchers in integrating these methods in their studies. Additionally, we define a taxonomy to help researchers better understand where and how qualitative methods can be used in HRI research.

3.1 Approach

The literature search for the review was carried out in February 2019. The first step involved a review of HRI studies using either social scientific approaches and/or qualitative methods in IEEE Xplore, ACM Digital library and PubMed. Additionally, a free search was conducted in Google Scholar. The search involved multiple keyword searches using the terms 'HRI' and 'social robotics' with qualifiers including 'qualitative', 'interviews', 'focus groups', 'ethnography', 'social science', 'grounded theory', 'case study', and 'participatory design' in various combinations. No limitation was applied to publication date. The earliest study featured is from 2004. Only publications in English were considered for this research.

The review consisted of a 4-stage process. In the first stage, we undertook a broad keyword search using the keywords outlined above, which returned 291 papers. The second stage involved reading all abstracts and removing wholly non-relevant papers, for example, those that did not feature any study involving robots and/or human subjects. This stage resulted in 224 papers for full review. The third phase involved re-reading the abstracts and narrowing down the papers to those that appeared to consist of significantly-described qualitative methods. This stage resulted in 115 papers. In the fourth and final stage, these 115 papers were reviewed in full separately by both authors. Results were cross-checked for consistency and any disagreements were resolved through discussion. Of the 115, a further 42 papers were removed. This included papers that are primarily reviews, theoretical discussions or proposed frameworks, e.g. [4,18], as well as HRI studies describing qualitative methods but lacking significant detail related to data gathering or analysis, e.g. [19,20]. No formal restrictions were placed on paper type, however, it was common for shorter format papers, such as late-breaking reports (LBRs), extended abstracts or proposals to be excluded from the analysis. Also removed were papers that featured a different meaning of the word 'qualitative', e.g. [21–23]. A number of papers featuring qualitative studies but not specifically, or primarily, related to robotics were also removed, e.g. [24]. This led to a final selection of 73 papers being chosen for study in the analysis. Of these papers, 56 were from conferences, 14 were from journals and 3 were from workshops. All of the papers removed in stages two and three are listed in the Appendix along with a code detailing the reason for their exclusion.

3.2 Dimensions of Analysis

All of the papers that were reviewed use some form of qualitative methods, however, it emerged from the review that the way in which the methods are used and reported varies considerably depending on the goals of the study. We therefore categorized the HRI studies across two dimensions. The first dimension is 'study type', for which we identified three distinct categories: insights-driven, design and hypothesis-driven (Fig. 1). Insights-driven studies do not specify a hypothesis and instead aim to develop new insights and understandings from the data gathered. Design studies are oriented specifically around the design of a robot, such as needs-findings or acceptance-testing, or within a defined design process such as participatory or user-centred design. Hypothesis-driven describes experimental studies that posit a hypothesis, which is subsequently tested through the collection and analysis of quantitative data. While not all HRI papers can be easily categorized into one study type (13 out of 73 papers were given two classifications), it is useful to consider the three different paradigms within which HRI researchers are working and how this influences their choice of qualitative method, as well as how they describe and report them. These three research categories have not previously been used to demarcate a field in this way. The categories

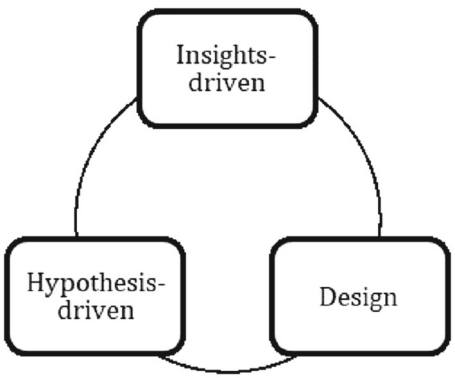

Fig. 1 The three dimensions of analysis

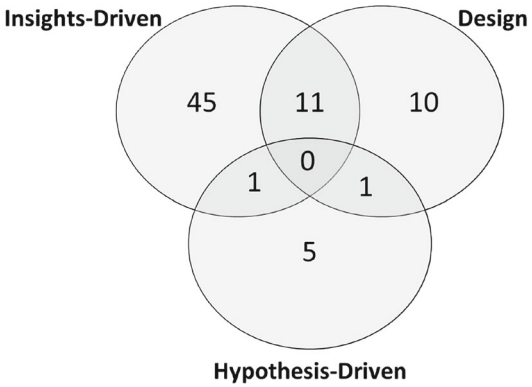

Fig. 2 Frequency of HRI study types identified across the 73 papers reviewed

reflect the inter-disciplinary nature of the HRI field rather than any predetermined disciplinary boundaries or existing categorisations borrowed from another field. Other labels that we explored using included 'exploratory', 'confirmatory', 'inductive', 'deductive', 'quantitative' 'constructionist' and 'positivist'. The final labels were chosen as descriptive terms focusing on the respective strengths and compatibility of the methods, and to avoid the assumptions and associations associated with some of the other terms. The frequency of each study type across the 73 papers considered in the review is given in Fig. 2.

The second dimension is 'qualitative method', of which six key qualitative methods emerged from an analysis of reviewed studies. These are: qualitative observation, semi-structured interviews, focus groups, generative activities, reflective and narrative accounts, and textual/content analysis. While the qualitative methods listed and described in the studies do not always conform to these precise labels, we have organized the studies informed by best practice and standardised labels as used in the social sciences. As well as traditional qualitative methods from the social sciences, a number of novel methods from design research are also highlighted, such as 'reflective and narrative accounts' which, we believe, offer promising research avenues for the field. Thus, while the methods listed are not novel (nor would we wish them to be), they do offer useful guidelines to support increased consistency and clarity for the use and description of qualitative methods in the HRI field. We believe that these six methods also represent the most significant and fruitful qualitative methods for HRI studies, integrating both research and design techniques in order to develop innovative, even transformative, insights and designs for a nascent field.

These two dimensions, study type and the qualitative method, are used to create a taxonomy for categorizing qualitative methods in HRI, which is described in the following sections. It is not intended that this taxonomy limit or regulate the use of qualitative methods, rather that it encourages and supports researchers currently using, or considering the use of, these methods. We hope that this will promote systematic analysis and reporting to develop the standard and quality of qualitative research in order that it might contribute to better design, richer insights, and a more critical and reflective stance with regard to wider societal and ethical concerns.

4 Review of Qualitative Analysis across HRI Study Types

4.1 Qualitative Methods in Insights-driven Studies

The majority of the papers reviewed (57/73) fall into the 'insights-driven' category. These do not aim to generate numerical data, nor is their primary aim to design a specific robot, rather they aim to develop a greater understanding of, and insights into, the problem context. It is perhaps not surprising that insights-driven studies tend to make liberal use of qualitative research and make up the largest group in our analysis. These studies range from long-term ethnographic or field studies spanning several weeks or months [25–29] to shorter engagement using ethnographic principles and techniques and other qualitative methods.

Broadly, insights-driven studies in HRI aim to understand novel situations, taking into account context, user perceptions and complex environments, often over an extended period of time. They can be used to gain insights into people"s experiences with, and perceptions of, robotics technologies. An example of these are HRI studies involving the Roomba robotic vacuum cleaner, which span many diverse research groups and more than seven years of study [26–28]. Other studies aim to develop nuanced and multi-dimensional understanding of the lived realities of specific user groups, for example older people [26,30] or factory workers [31] into whose lives the robot is intended to be accepted. These methods are also used to understand communities of technologists, such as the Robot Operating System (ROS) community [32], with a view to examining the best way to implement new practices. For most insights-driven research studies, qualitative data is systematically gathered using audio-recording or field notes. The data is then transcribed and thematically analysed.

One of the greatest areas of potential for qualitative methods in insights-driven research is to build new, or extend existing, theories [9]. A number of the studies in our review draw on existing social theories, such as social constructionism/constructivism [31,33,34], organizational studies [35], or systems theory [36] to frame their studies. In some cases, researchers have developed new concepts relevant to the field of social robotics, such as 'interruptability' [35]. Drawing on the anthropological concept of 'ecology', Jodi Forlizzi initially developed the concept of a 'product ecology'

[25,37,38] to facilitate a systematic approach to incorporating dynamic, social and contextual considerations into an analysis of assistive robotics. [39] build on this concept to develop the Domestic Robot Ecology (DRE), a framework to theorize about long-term acceptance of robots in domestic environments. This is also later used and validated in other studies [28,30]. Other studies use qualitative methods to develop new frameworks and conceptual tools for HRI analysis, such as ratings scales [40].

In a number of studies, participants are challenged to play an active role in evaluating the future impact of robotics research [34], with researchers working to empower them to be able to critically evaluate technologies [41], and to develop an awareness of how images and stereotypes of specific user groups may be unintentionally perpetuated [42].

Despite being insights-driven, a small subset of these studies tend to express the study and results in terms more generally associated with experimental or hypothesis-driven studies. For example, a number of studies aim for results that are statistically relevant [43,44] or analyse the qualitative data in a way that aims to avoid interpretation by using methods from verbal or linguistic analysis, enumerating verbal data or syntactic structures [45,46]. These studies tend to use qualitative methods to support statistical findings, rather than engage with broader social research or wider societal contexts.

4.2 Qualitative Methods in Design Studies

Design studies are those that aim primarily at the design of a specific robot or robot behaviour [34,36,47–49,49–54] and/or the design process [42,55–58]. Studies that are part of an overarching participatory or user-centred process are also characterized as design [41,52,53,55–58].

It is common to see overlap between insights-driven and design research (11/73 papers). For example, insights-driven research is commonly used as an input to design [59], to evaluate the impact or perception of a robot [60], or both [61]. For the purposes of this study, we have classified methods that aim at general insights and data as 'insights-driven', and those that are explicitly focused on the design of a specific robot, process or technology as 'design'. Often, a combination of qualitative techniques and generative design activities are used as a direct input to design, by providing the basis of further brainstorming, ideation and the development of prototypes [42,47,51–53,55,57,58,62]. However, shorter, light-touch, single-method engagements, such as design-oriented focus groups [49,54] are also used to get quick feedback on a specific aspect of the design.

As with qualitative methods in insights-driven research, use of qualitative methods as part of a user-centred or participatory design approach often entails a radical re-imagining and ethical re-orientation of the relationship between the researcher and the participant [41,52,55,58]. Participatory design was originally developed as a co-operative design methodology for involving users from the start of the design process. This was done to ensure that they were given a voice and had influence over the technologies they would later be expected to accept and use [63]. In these studies, we see collaborations between designers and user-representatives [55], with the rationale that such participants are 'experts in their own lives' [52], are empowered by the opportunity to shape the technology that is going to affect them [41], and should be sufficiently informed to make decisions regarding their use of new products or technologies [41].

While many design studies also capture and transcribe qualitative data for subsequent thematic analysis and coding, it is also common for these studies to analyse findings collaboratively using techniques such as affinity diagrams [64].

4.3 Qualitative Methods in Hypothesis-Driven Studies

'Hypothesis-driven' studies aim primarily to gather quantitative data in order to generate statistically-significant findings. These studies tend to take place in experimental or 'controlled' conditions. Of the 73 reviewed papers that used qualitative methods, only seven were categorized as hypothesis-driven.

The only two qualitative methods used in this sample are observations and interviews. Observations in these studies tend to take place in laboratory environments and are generally video-recorded. The qualitative methods that feature in these studies are used to provide additional explanatory data, such a supporting quotes, for the statistical data that forms the main focus of the studies [65–68]. Qualitative data is also used to support robot evaluation [46] and to generate insights for design [65,68].

There is no consistent way of analysing the qualitative data that is gathered for these studies. A number of the hypothesis-driven papers follow a systematic qualitative process of transcribing qualitative data and thematically analyzing it [65,67], and seeking intercoder reliability [68]. Others look for quantitative, rather than interpretive, ways of analyzing qualitative data, such as adapting approaches from linguistic analysis [46,66], although these inevitably still involve some level of researcher interpretation. Still others use techniques associated with design research, such as affinity diagrams [64,67].

5 Review of Qualitative Methods Used

The review revealed six predominant qualitative data gathering methods in the HRI literature: qualitative observations,

Table 1 List of qualitative methods with description

Method	Description
Qualitative observation	Observations of people in everyday contexts and uncontrolled environments. Data is primarily gathered in the form of field notes. Less commonly, qualitative observations may be video recorded
Semi-structured interview	Semi-structured interviews follow a pre-defined interview protocol but allow for flexibility to respond to the natural flow of the interaction. Data is usually captured in notes, as well as being audio recorded
Focus group/group interviews	A focus group is a group interview or discussion with a small group of participants (usually 6–10) on a specific topic. Focus groups are guided by a moderator or facilitator. Data is usually captured in notes, as well as being audio or video recorded
Generative activities	Qualitative data is gathered during a generative activity, such as brainstorming, ideation or prototyping. These activities often take place in a workshop setting
Reflective and narrative accounts	Qualitative data is produced by participants writing reflective or creative descriptions related to the study
Textual/content analysis	The use of written text or documents as a source of qualitative data. This category also includes free participant responses in questionnaires

semi-structured interviews, focus groups, generative activities, reflective and narrative accounts, and textual/content analysis. The methods are defined in Table 1 below and detailed in the following sections.

5.1 Qualitative Observation

Qualitative observation involves observing people's experiences and social interactions in their everyday contexts and describing them in detailed field notes. Observation is the foundational method of ethnographic research.[1] Observation allows researchers to study the context, as well as the tacit or embodied knowledge, that is a part of interacting with robots. It is also used as a primary method to understand unstructured or open-ended participant activities. Observation is often used very effectively when combined with interviews to generate a holistic account of an interaction.

[1] 'Observation' as a method is often used interchangeably with 'ethnography'. However, 'ethnography' refers to the descriptive output of a study of people and their social lives. This may involve a suite of methods, as well as qualitative observation.

There is a notable difference in the papers reviewed between observation as it is used in an uncontrolled or field setting, and observation as practiced under controlled conditions. While the former generally aims to limit the use of video, under controlled conditions the use of video is very common. More commonly in qualitative research, observational data is captured using field notes.

5.1.1 Use of Observation in Insights-Driven Research Studies

A number of insights-driven studies aim for a full ethnographic or descriptive account of a robot, or system, in a particular field site over an extended period of time [25–29,35,75]. However, whether as part of a larger ethnographic study, or as part of a shorter engagement, observation is used extensively in insights-driven studies, most commonly in combination with interviews [25–27,29,30,32,33,35,36,40,42–44,58,59,71–77,81,82], or focus groups [79] (Table 2).

Qualitative observations are generally captured in field notes and subsequently systematically analysed along with any other data gathered [26,30,32,33,35,52,73,77]. Those studies that capture observations on video tend to follow approaches more aligned to controlled or experimental studies [36,43,69,70,75,76,78,80–82] or design research [52]. These studies are also more likely to use observation as a sole method, without capturing data from interview or other interactions with participants [69,70,78,80]. A number of studies give specific reasons for eschewing video recordings, including ethical and data protection implications [44], as well as concerns as to how it might impact the naturalistic setting [28].

5.1.2 Use of Observation in Design Research Studies

There is widespread use of observation in design research, although often it is not reported as such, or at all. As [52] have identified, the line between research and design may be blurred, and exploratory research may be seen as an integral, but implicit, part of the design process. Observations may instead be described as 'contextual inquiry' [55] or simply as the viewing of session footage [47,52,56]. For some studies, while it is likely that observation is used, it is not reported and thus cannot be categorized as such, e.g. [83]. Nonetheless, as with observational data, data gathered in this way may be systematically coded and thematically analyzed [47,52,55]. In combination with interview data, a number of these studies aim to generate design recommendations [47,55]. In the case of participatory design studies there is also often a reflection on the design process [52,55].

Two of these studies use observational methods to generate both insights and design outcomes [42,52]. Rose and Björling [52] successfully weave together disparate methods

Table 2 Observation across the three study types

Method	Insights-driven	Design	Hypothesis-driven
Observation	[25–30,32,33,35,36,40,42–44,52,58–60,69–81]	[42,47,50–52,55,56]	[46,66,67,81]

and study types, using video and field notes to document insights-driven observations during a participatory design session. In combination with artefacts generated during study session, the team generate both insights into the experiences of the teen participants, as well as a low fidelity robot prototype. [42] uses participatory techniques and interactions with a robot called iRo to generate design insights as well an analysis of the self-perception of older users.

A number these studies use a combination of qualitative methods, such as observation, interviews and/or focus groups, generative activities [47,55,56], and reflective accounts [42,52]. Only two papers (from the same research group) use observation as a sole method; this is done in an experimental, laboratory setting to generate design and user insights [50,51].

5.1.3 Use of Observation in Hypothesis-Driven Research Studies

Just four of the hypothesis-driven studies that we reviewed used qualitative observation, although observations tend to take place in highly structured, laboratory environments [46,66,67,81]. Generally, for these studies, observational data is elicited from observing videos of user-robot interactions [46,67,81]. In these studies, qualitative observations and analysis are used in combination with other methods, including quantitative analysis of observations [66], quantitative surveys [46,67], face and body tracking [46], and interviews [67,81], to investigate various aspects of the interaction, including the impact of contingency on robot feedback [66], levels of engagement [46,67] and the viability of a robot in a clinical setting [81]. Data obtained by qualitative observation is used in a way that aims to a generate numeric, rather than qualitative, output. This is done by counting or annotating specific observed behaviours, such as qualitatively generated baseline social behaviours [81], linguistic utterances [46,66] or interaction events [67].

For [67] and [81], initial, exploratory observational data is used as an input for subsequent quantitative studies, including generating a set of baseline social behaviours [67] and for the formulation of hypotheses for subsequent testing [81].

5.2 Semi-structured Interviews

Semi-structured interviews are the most common approach to interviews in these studies. In a semi-structured interview, the researcher is guided by an interview protocol, but has the flexibility to respond to the natural flow of the interaction. Best practice across all categories for interviews is to audio-record and transcribe the session, followed by a thematic analysis.

5.2.1 Use of Interviews in Insights-Driven Research Studies

The majority of the insights-driven studies (23 out of 32 cases) that use interviews do so in combination with qualitative observation. While a combination of observation and interview is most common, a number of studies combine interviews with other methods, such as with focus groups [60,61,84–86], textual analysis [32,84], and reflective diaries [84]. Others combine them with physiological methods [86] or surveys [87].

Insights-driven interviews are used to elicit perspectives, attitudes and opinions in order to evaluate the use, or potential use of, robots with various groups in various different settings. These include older people's domestic settings [25,71,73], older-care facilities [29,44,72,74,76], and living labs [85,88], for children in educational settings [36,87,89], and for workers in industrial and clinical settings [31,35,61,77,90] and at an airport [40]. They are used to investigate the social context into which the robot is expected to fit [25,73], and the potential use of robots for older users [30,33,84] and children [89].

Most of these studies use systematic qualitative analysis techniques, including audio-recording, transcription and thematic analysis [26,29,31,33,35,40,42,44,58–61,73–75,85,86,88–90]. Less commonly, researchers used a more design-driven approach to data analysis, such as affinity diagrams [32], or a combination of the above techniques [40,75].

5.2.2 Use of Interviews in Design Research Studies

Design interviews aim to elicit people's perceptions, attitudes and opinions regarding specific robots or robot systems [47,48]. Some of these studies incorporate interviews as part of a wider participatory [55,83] or user-centred design process [57]. In these instances, interviews are used as an input to ideation activities [55], or to elicit design recommendations [47,48]. Nine of the papers with a design research classification used interviews.

As in other categories, many of these studies combine interviews and observations in order to gain a more holistic account of the interaction [27,42,47,55,75]. However, for the design studies it is most common for interviews to be cou-

pled with some type of generative activity (see Sect. 5.4.2 for further discussion). Some of the design studies combine interviews with quantitative techniques, using the qualitative data gathered from the interview informally to support quantitative and physiological data, such as flight path direction of drones [83], motion detection [48] and quantitative questionnaires [64].

Three of the papers feature interviews that are classified as both design and insights-driven, as they are aimed at generating insights into people's general perceptions about, and experiences of, specific robots [42,75,90]. In some cases, because interviews are part of a wider collaborative and intensive engagement, they tend to be with fewer participants. In our sample, three of the interviews had just one or two participants [42,47,48].

5.2.3 Use of Interviews in Hypothesis-Driven Research Studies

Five of the hypothesis-driven studies use semi-structured interviews, with one falling both into the hypothesis-driven and design categories [64]. In all cases, qualitative data elicited from the semi-structured interviews is used to provide additional explanatory data for the wider quantitative study. A number of these studies focus on aspects of a single robot's design, such as the effect of the robots' design on people's perception of them, for example the FLASH robot's anthropomorphic design [65] or eye design on simple paper prototypes [64]. Other studies focus on engagement, for example measuring the effects of personalization [67] or developing an empathic model [68].

Generally, these interviews are used as a sole qualitative method in combination with other quantitative methods, such as quantitative questionnaires [64,67,68] or physiological measures [65,81].

5.3 Focus Groups

Focus groups, or group interviews, are an effective way of gathering a large amount of data in a relatively short amount of time. In contrast with interviews, focus groups are useful for facilitating group discussions and understanding social knowledge, such as revealing varying perspectives or consensus on particular topics. In HRI studies, focus groups are commonly used for gathering preliminary data or as the basis for further workshop activity. Focus groups may be used effectively to give a voice to marginalized people [91], who may be emboldened to speak up by being in a group of peers, rather than a more formal interview setting. However, focus groups are less useful for eliciting sensitive or personal information. The key to a good focus group is a strong facilitator who can ensure that the discussion is not dominated by one or two people, ensuring that all participants share their views.

Group workshops in which the focus is on fostering collaboration to generate design outcomes are considered distinct from focus groups in this paper. Instead, they are classified as 'Generative Activities', and elaborated in Sect. 5.4.

5.3.1 Use of Focus Groups in Insights-Driven Research Studies

Once again, the majority of studies that use focus groups are insights-driven (20 out of 27 cases). Like interviews, they are used to gain insights into people's perceptions and often used as a preliminary method to understand people's reactions to and attitudes to robots in general [54,61,79,85,92], to conduct early needs-finding [30,33,84–86,93,94], and to explore potential applications or acceptance of robots by a specific community or user groups [54,62,95].

Focus groups are also used to investigate the social context of target user groups, such as older people's level of independence [93], or people's household usage patterns [28]. An interesting use of focus groups is to give engineers first-hand experience of their target users [96] and to sensitize them to alternative perspectives, outside the academic 'echo-chamber' [97], challenging implicit preconceptions [98].

Focus groups that are aimed at understanding needs within the context of the design of a specific robot are classified as 'design' and described in the following section. However, focus groups can also accommodate group exercises or demonstrations in order to facilitate group discussions. [61] uses a ranking exercise, in which therapists rank factors effecting engagement, to facilitate reflective in-group discussion amongst therapists. In [54], an initially insights-driven focus group becomes a design workshop once the robot is introduced mid-way through the session and is therefore classified as both insights-driven and design.

Six of these insights-driven studies rely solely on focus groups [54,93–95,97,98], while the others combine focus groups with other qualitative methods to gain a rounded view of people's perceptions of robot technologies. A number of studies audio-record, transcribe and coding the data [28,54,61,62,86,95,97,98]. For others, the focus groups are a preliminary or complementary method, and the data capturing and analysis techniques are not described in any great detail. As focus groups are a public forum, it is relatively common to record them using video [54,62,94,98]

5.3.2 Use of Focus Groups in Design Research Studies

Focus groups in the design mode are used to get qualitative insights to directly inform the robot design, or within the context of an overarching user-centred or participatory design process. This is distinct from understanding perceptions of

robots generally. They are also distinct from workshops that use a generative design activity to generate design outcomes, such as storyboarding or prototyping, which are discussed below. Seven of the papers in our review that use focus groups are classified as design.

Design focus groups that are part of a participatory or collaborative design process are used to capture insights into the potential integration of robotics into the relevant contexts, such as a school setting [47], older-care communities [49,56], clinical settings [53], public spaces [36] and communities for people with disabilities [54,55]. For [56], a workshop that merges a focus group, generative activities and observations is the first step of a user-centred design process to create a robot designed for a public space in an urban environment. For [49], a design-oriented focus group is used to complement technology acceptance criteria gained from structured questionnaires.

5.3.3 Use of Focus Groups in Hypothesis-Driven Research Studies

There were no focus groups or group interviews in the hypothesis-driven studies in our review. It is likely that the unstructured format was less suited to controlled, hypothesis-driven studies.

5.4 Generative Activities

Generative activities are not a traditional qualitative research method and have instead emerged from design research. Yet, they are an effective way of generating qualitative outcomes. Generative activities tend to take place in a group and workshop format. They range from the use of objects to stimulate discussion and provoke ideas, to activities such as brainstorming, story-boarding and prototyping with participants. [62] draws on Sherry Turkle's concept of 'evocative objects', to describe the use of objects to stimulate tactile impressions and evoke thoughts and design ideas. Not surprisingly, perhaps, this method is most common in studies that are classified as design.

5.4.1 Use of Generative Activities in Insights-Driven Research Studies

A generative design activity in the insights-driven mode uses a design activity or artefact to elicit qualitative insights. Seven of the insight-driven studies use this method, with four of these falling both into the insights-driven and design categories.

In insights-driven generative activities, objects are used to stimulate discussion and ideas, such as the robot 'building set method' [96] and 'open-ended objects' [62]. While not using tangible objects, [30] similarly use an activity, in this case asking participants to evaluate robots when watching a video, as a precursor to brainstorming possible applications of robot technology in the home. A combination of generative activities, including drawing, writing and rating scales, is used to help participants reflect on the activities that are difficult to express in words [27]. For [52], design sessions are video- and audio-recorded, as well as captured in field notes. After each session, the resulting design artifacts are analyzed along with field notes, photographs, and drawings yielding both further designs and qualitative insights. These then inform the following iteration of the design, as well as the thematic analysis of the data.

5.4.2 Use of Generative Activities in Design Research Studies

11 of the studies classified as 'design' use generative activities. These include co-design activities with participants, such as developing low-level specifications [55], participant drawing activities [36,52,83], as well as brainstorming, ideation, storyboarding and prototyping [41,47,52,53,57,58,62]. Generative activities in the design categories also include 'evocative objects', such as in [41], where craft materials such as feathers, pipe cleaners, and cardboard, are used to stimulate and develop new designs.

Four of these studies, [41,52,56,62] are classified as both insights-driven and design. In these studies, a complex interplay of design activities and qualitative methods are used to develop both designs and insights. Indeed, [52] recognize the line between research and design may be blurred in a participatory design session, which combine qualitative and design research methods and outcomes. As discussed above, their study yields both qualitative data and design artifacts, which inform both design outcomes and insights. [56] use a combination of reflective and narrative accounts, detailed in the following section, and generative activities to foster creativity in participants [56]. Similarly, [41] use a more radical participatory approach in a study that brings participants into a critical research engagement with the community to generate both insights and design outcomes. In this study, generative activities, such as 'playful approaches and games' are used 'to motivate participation, stimulate creative and critical thinking, and overcome hesitancy to using unfamiliar technology'. Participants are thus empowered to engage critically with the project, using reflective analysis and interpretation to question common assumptions and beliefs, both about the technology, and the urban environment into which it is expected to fit. Ultimately, the project aims to inform and empower participants to be able to make decisions in regard to the capabilities, limitations, and applications of technology.

5.4.3 Use of Generative Activities in Hypothesis-Driven Research Studies

Generative design activities were not used in any of the studies that were categorized as hypothesis-driven. As with focus groups, it is likely that the unstructured format was less suited to controlled, hypothesis-driven studies.

5.5 Reflective and Narrative Accounts

Reflective and narrative accounts are used to elicit reflective and creative descriptions from participants as an input to generating nuanced insights, design solutions, and even engaging in speculative and futures research. The approach requires, and thereby acknowledges, creativity and interpretation on behalf of the participants. Reflective and narrative accounts generally take the form of a written text, however a number of studies [36,52] also use drawings to elicit reflections and projections. Only 12 of the studies reviewed for this paper use this method, but the increasingly innovative ways that researchers are starting to incorporate these methods into their studies suggest that it offers compelling possibilities for the field.

5.5.1 Use of Reflective and Narrative Accounts in Insights-Driven Research Studies

Reflective and narrative accounts as a method is relatively unusual in these studies, but is most common in insights-driven research, with 10 studies featuring it. Reflective accounts, such as participant diaries, are often used to augment other methods, such as interviews, and may be used in the researchers' absence as a way to get participants to document and reflect on their experiences or situation over time [26,27,42,73,84]. However, [27] found that participants did not fill out the diaries provided in their absence, and instead had more success in gathering data by asking them to document their thoughts in emails [27]. [99] use the method of 'explication interviews', rather than a diary, to facilitate participants in reflecting on their experience of the usefulness of a robot's non-verbal, affective cues and to create a narrative around it. Combined with generative design activities, reflective and narrative accounts may be used to get participants to reflect on their experience of designing [41].

However, not all reflective and narrative accounts involve reflecting on a past activity. Others use the method to project in to the future. [34] propose adding 'futuristic autobiographies', a method from design fiction, to the qualitative method toolkit. This collaborative and creative method involves the co-creation of narratives by researchers and participants. As the authors point out, the aim is not to predict the future, rather to open a space for discussion, revealing insights into people's values in relation to technology, as well as allowing for a consideration of the ethical and social implications of emerging technology [34]. It allows researchers to foreground the ethical and moral concerns of the envisioned technology over simply functionality, while also compelling researchers, whom they acknowledge occupy a privileged position in technology, to reflect on their prior assumptions or biases. Another use of this method involves asking participants to project into the future by imagining how they think a robot should react to everyday situations at an airport, [100] use a 'crowd-sourcing', open-ended questionnaire to investigate cultural differences between user preferences to robots.

Not all reflective and narrative activities require a physical output. For [41], reflective inquiry is rather a stage of the process through which participants are guided by facilitators. This empowers them to consider the limitations, capabilities and potential uses of the technology in their neighbourhood in an informed way, ultimately enabling them to discover and invent new applications of the technology for locally relevant issues. Thus, reflective and narrative accounts may facilitate a more critical and ethical perspective on HRI studies.

5.5.2 Use of Reflective and Narrative Accounts in Design Research Studies

Four papers use reflective and narrative accounts in the design mode, including two that use it to generate both insights and design-outcomes. [101] ask participants to reflect on their experience of wearing a tactile wearable communication device and the sensations it creates. Rather than asking participants to write a narrative, both [36] and [52] use a drawing activity in which participants are asked to imagine what a future robot might look like. For [52], the method is a modified form of a future workshop from participatory design, designed to enable a group of people to develop new ideas or solutions to social problems. It echoes the use of 'futuristic autobiographies' to envision future robots as described above. [36] ask their participants, in this case children, to draw a picture to 'give to' their blended reality character Alphabot. The children are encouraged to reflect on their experience, freely associate, and tell a story.

5.5.3 Use of Reflective and Narrative Accounts in Hypothesis-Driven Research Studies

Reflective and narrative accounts were not used in any of the studies that are categorized as hypothesis-driven in this review.

5.6 Textual Analysis

Textual or content analysis in HRI studies is the identification and thematic analysis of documents, texts or written participant responses. It differs from reflective and narrative accounts as participants are not prompted to develop a creative description. In HRI studies, textual or content analysis features most commonly in free-form responses to structured questionnaires. Questionnaires are a popular method in HRI studies to gather quantitative data, however, qualitative data may also be obtained by including free-form or open-ended questions. They are a particularly useful method for reaching a large number of participants and thus obtaining a large amount of data. However, as the researcher does not interact with the participant, it can be more difficult to identify context, legitimacy and to elicit further data. Other approaches that fall into this category include reviewing online content such as newspaper articles, medical records and online fora.

5.6.1 Use of Textual Analysis in Insights-Driven Research Studies

Ten of the insights-driven studies reviewed use textual analysis. This includes an analysis of documents such as medical records [77] and academic publications [42]. The 'virtual ethnography' approach of [32], involves 120 hours of studying the ROS community online infrastructure, including the a textual analysis of online fora, and other virtual interactions.

In a number of studies, this forms part of an overarching, structured questionnaire with pre-defined rating scales in order to generate both qualitative and quantitative data [45,87,102,103], with the qualitative data adding explanatory detail to support the quantitative results. Similarly, in a primarily design study, [56] collect additional insights in the form of attitudes towards robots using a short questionnaire. A study by [76] focuses on older people living in a care facility and uses a combination of observation and interviews to understand how the older residents would engage with a robot. A parallel free-form questionnaire is used with staff to elicit design ideas.

An alternative approach is used by [92], in which a combination of focus groups and free-description in a questionnaire is used to generate the categories for a subsequent structured, ratings-based questionnaire.

5.6.2 Use of Textual Analysis in Design Research Studies

Four studies featuring textual analysis are classified as design; two of these are classified as both design and insights-driven and are described above [42,76]. Of the two others solely classified as design, in both cases this is done as part of a larger study featuring a number of different methods, and used in a manner particular to that study. For [53], free-form descriptions are used in conjunction with other data to help refine the number of concepts (from 57 to 14). For [62], participants first interact with the robot and are then asked to fill out an open-ended questionnaire covering a number of issues relating to the acceptability, size, appearance and behaviour of the robot.

5.6.3 Use of Textual Analysis in Hypothesis-Driven Research Studies

None of the hypothesis-driven studies that we reviewed featured qualitative textual or content analysis.

6 Taxonomy of Study Types by Methods Used

In this paper, we reviewed 73 papers from the HRI field that used some form of qualitative methods. Through the review we identified three different paradigms, or 'study types', with which HRI researchers are approaching their studies. We have labelled these: insights-driven, design and hypothesis-driven, based on whether the study is aimed at generating exploratory and insights-driven data, informing design, or whether it is intended to test hypotheses. We have also identified and described the six most common qualitative methods that are used in the study. In this section we present a novel taxonomy of all the papers reviewed by study type and qualitative method used, as can be seen in Table 3 and illustrated graphically in Fig. 3.

It is perhaps not surprising that insights-driven studies tend to make liberal use of qualitative research and make up the largest group in our analysis, with 57 out of the 73 papers falling into this category. 22 of the studies fall into the design category. Hypothesis-driven studies make up the least common study type, with just 7 papers falling into this category. This is not surprising as qualitative research tends to play a secondary role in these studies which primarily use quantitative measures. While some hypothesis-driven studies feature qualitative interviews and observations, none featured

Table 3 Taxonomy of study type by qualitative method used

Method	Insights-driven	Design	Hypothesis-driven
Observation	[25–30,32,33,35,36,40,42–44,52,58–60,69–81]	[42,47,50–52,55,56]	[46,66,67,81]
Interview	[25–27,29–33,35,36,40,42–44,58–61,71–77,84–90]	[27,42,47,48,55,57,64,75,83]	[64,65,67,68,81]
Focus group	[27,28,30,33,54,60–62,79,84–86,88,92–98]	[47,49,53–56,58]	
Generative activities	[27,30,41,52,56,62,96]	[36,41,47,52,53,55–58,62,83]	
Reflective and narrative	[26,27,34,41,42,52,73,84,99,100]	[36,42,52,101]	
Textual analysis	[32,42,45,56,76,77,87,92,102,103]	[42,53,62,76]	

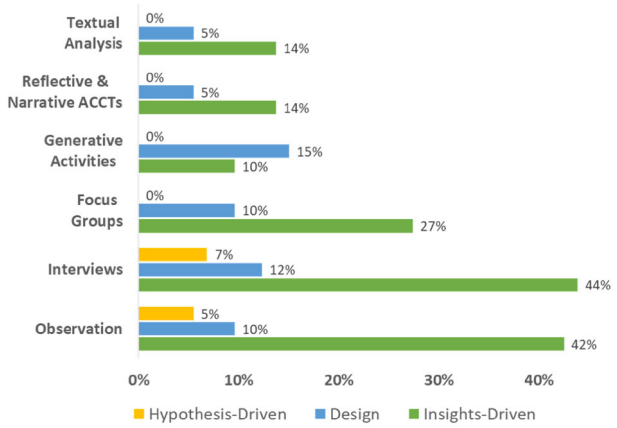

Fig. 3 Frequency of qualitative method type over the 74 papers reviewed

focus groups, generative activities, reflective and narrative accounts or textual analysis.

Of the 22 design papers, 11 of them use methods that are also insights-driven, and one which is also hypothesis-driven. 13 out of 73 papers were given two classifications, with the most common combination being both insights-driven and design.

Interviews are the most common qualitative method used in the HRI studies in our review, with the majority of studies, 42 of 73, using them. This is followed closely by observation, with 39 studies using some form of qualitative observation as a method for data gathering, whether as part of a larger ethnographic study, an experimental study, or as an independent research method. The most common combination of methods are observation and interview, with 27 of the studies reviewed using them together.

Of the papers reviewed for this paper, just over one third (26 papers) use focus groups.

Generative activities, used in 14 of the 73 papers, is the only category in our taxonomy where design studies outnumber insight-driven. From these papers, there were 11 cases where generative activities were used as a design method and seven where it was adopted for attaining insights.

The least common qualitative methods used in these studies were reflective and narrative accounts (12 out of 73 papers), and textual analysis (12 out of 73 papers).

7 Limitations

The papers reviewed in this article do not represent an exhaustive list, but rather a representative sample of the current state of the literature in HRI. The keyword search was biased towards studies that were inherently qualitative and therefore qualitative methods within hypothesis-driven studies that are not explicitly labelled as such may not be represented. We acknowledge that HRI is a rapidly changing field and the range and application of various methods, including qualitative ones, appears to be improving over time. Therefore, any systematic literature review is going to be limited in how it represents the current state.

The taxonomy represented in this paper is the result both of careful classification, as well as negotiation between the authors, and therefore represents an element of interpretation. Despite this, we believe that the overall classification and taxonomy system represents a useful way to understand and develop the standard of qualitative in the various study types. Finally, the authors do not focus in detail on the subject of ethics, which is clearly both closely aligned with qualitative research and an increasingly important focus for the field. It is our intention to address this in a follow-up paper.

8 Summary and Conclusions

To date, there has been relatively little attention paid to the potential for qualitative research to enhance the field of HRI. In this paper, we argue that HRI studies will be improved, not simply by creating a single comparable approach or standard, but by increasing the knowledge, understanding and

practice of many different types of research in the community, including qualitative research. This will provide both for more robust studies and improved robot designs by developing a greater understanding of users' lived experiences, perceptions, and interactions with robots. As we have seen, qualitative methods can be used to enhance our understanding of the relationship between humans, robots and the wider (social) environment in many ways.

We have shown how qualitative research can support exploratory and insights-driven research, which is necessary for the creation of new knowledge and the development of new theories relevant to a field whose research object is still in the process of negotiation. The potential of a qualitative approach in HRI is to reimagine the relationship with participants and potential users of technology, using their insights, experience, domain expertise and creativity to apply to the problematic of robot use and robot possibilities. This can help to push the field beyond mere acceptance, and allows for the possibility of radical and transformative design, better technology, and new theory for the HRI field. Furthermore, these techniques also facilitate researchers in taking a critical and ethical perspective on the field and the way that studies are carried out, including the representations of users and participants in the study. Users and participants can be sufficiently empowered to support them to engage with the technology from a position of authority, and to be in a position to challenge the norms, perceptions and biases that are necessarily a part of any disciplinary field. This is particularly relevant to HRI studies, which often involve working with, and designing for 'vulnerable' groups, such as people with disabilities, older people and children.

The aim of this paper, therefore, is to contribute to a greater understanding of how qualitative research may be used to 1) develop greater insights and new theory related to the social aspect of robotics, 2) contribute to more innovative and transformative robot design, 3) provide a more critical and ethical lens on participant engagement and representation, and the social impact of robots, and 4) complement quantitative and statistical studies. In order to further these aims, we have described a novel taxonomy with two dimensions: study type and qualitative method. The taxonomy will help to further qualitative research in the HRI field by allowing researchers to situate their research within the interdisciplinary field and follow best practice in terms of selecting and using qualitative methods. We believe that this will provide valuable guidance for researchers who are not trained in the social sciences, who nonetheless wish to carry out qualitative research. It is not intended that this taxonomy limits or regulate the use of qualitative methods, rather that it encourages and supports researchers currently using, or considering the use of, these methods. We hope that this will promote an increased use of systematic qualitative data gathering, analysis and reporting, to develop the standard and quality of qualitative research in order that it might contribute to better design, richer insights, and a more inclusive, critical and reflexive stance with regard to wider societal and ethical concerns. To this end, this paper discusses the potential for qualitative research to enhance HRI research, in particularly focusing on integrating research, design and critical techniques.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

A List of Papers Excluded from Review

Code:

NS - No study, or study not substantially described
NQ - No qualitative or a different meaning of 'qualitative'
OQ - Other qualitative (not specifically, or primarily, related to robotics)
D - Exact duplicate or related to another study already included.

Author	Title	Stage	Code
Al-Badry	Possibilities in Robot Stop-Motion	2	NS
Alac	Social robots: Things or agents?	2	NS
Morana et al.	When a robot is social: Spatial arrangements and multimodal semiotic engagement in the practice of social robotics	2	NS
Anastassakis et al.	Design and Its Movements in Times of a Widespread Participation	2	OQ
Anzalone et al.	Evaluating the Engagement with Social Robots	2	NQ
Baba	Science, Technology and Society Revisited: What is Happening to Anthropology and Ethnography?	2	NS
Barnett et al.	Investigating User Perceptions of HRI: A Marketing Approach,	3	NQ
Beer et al.	The domesticated robot: design guidelines for assisting older adults to age in place	2	NQ
Beer et al.	Toward a framework for levels of robot autonomy in human–robot interaction	3	NQ
Beer et al.	Robot assisted music therapy a case study with children diagnosed with autism	2	NQ
Beir and Vanderborght	Evolutionary method for robot morphology: Case study of social robot Probo	2	NQ
Bellotto et al.	Qualitative design and implementation of human–robot spatial interactions	3	NQ
Bemelmans et al.	Socially Assistive Robots in Elderly Care: A Systematic Review into Effects and Effectiveness	2	NS
Beran and Ramirez-Serrano	Do children perceive robots as alive? Children's attributions of human characteristics	3	NS
Bethel and Murphy,	Review of human studies methods in HRI and recommendations,"	2	NS
Bjorling et al.	Teen–Robot Interaction: A Pilot Study of Engagement with a Low-fidelity Prototype	2	NS
Blond	Encountering robots in the field: How ethnographic studies of robots in practice benefit HRI	2	NS
Bradshaw et al.	Human-agent-robot Teamwork	2	NQ
Broekens et al.	Assistive social robots in elderly care: a review	2	NS
Buchner et al.	User Experience of Industrial Robots over Time	2	NQ
Carlmeyer et al.	The Hesitating Robot - Implementation and First Impressions	2	NS
Casper and Murphy	Human–robot interactions during the robot-assisted urban search and rescue response at the World Trade Center	3	NS
Chang and Šabanović	Exploring Taiwanese nursing homes as product ecologies for assistive robots	3	D
Chen et al.	Pedestrian–Robot Interaction Experiments in an Exit Corridor	2	NQ
Cheon and Su	Integrating Roboticist Values into a Value Sensitive Design Framework for Humanoid Robots	2	NS
Choi et al.	Are You Embarrassed?: The Impact of Robot Types on Emotional Engagement with a Robot	3	NQ
Chrysostomou et al.	Towards Reproducible HRI Experiments: Scientific Endeavors, Benchmarking and Standardization	2	NS
Conti et al.	Kindergarten Children Attitude Towards Humanoid Robots: What is the Effect of the First Experience?	2	NS
Coradeschi et al.,	Towards a methodology for longitudinal evaluation of social robotic telepresence for elderly,	3	NS
Cousins et al.	Development of a mixed reality based interface for human robot interaction	2	NQ
Dautenhahn	Socially intelligent robots: dimensions of human–robot interaction	3	NS
DiFranzo et al.	Linked Ethnographic Data: From Theory to Practice	2	OQ
Dourish	Implications for Design	2	OQ
Dragan et al.	Effects of Robot Motion on Human–Robot Collaboration	3	NQ
Enz et al.	The social role of robots in the future–explorative measurement of hopes and fears	2	NQ
Eyssel and Pfundmair	Predictors of psychological anthropomorphization, mind perception, and the fulfillment of social needs: A case study with a zoomorphic robot	2	NQ
Fabbri and Sattar	SmartTalk: A Learning-Based Framework for Natural Human–Robot Interaction	3	NQ
Farulla and Lamprecht	Model checking of security properties: A case study on Human–Robot Interaction processes	2	NQ

Author	Title	Stage	Code
Figueroa et al.	Learning Complex Sequential Tasks from Demonstration: A Pizza Dough Rolling Case Study	2	NQ
Fink and Bauwens	People's Perception of a Domestic Service Robot	2	D
Fink et al.	People's Perception of Domestic Service Robots: Same Household, Same Opinion?	3	NQ
Fink et al.	HRI in the home: A Longitudinal Ethnographic Study with Roomba	2	D
Fitter and Kuchenbecker	Qualitative User Reactions to a Hand-Clapping Humanoid Robot	3	NS
Forlizzi	How robotic products become social products: An ethnographic study of cleaning in the home	3	D
Frauenberger et al.	Blending Methods: Developing Participatory Design Sessions for Autistic Children	3	OQ
Frennert and Ostlund	Seven matters of concern of social robots and older people	2	NS
Fussell et al.	How people anthropomorphize robots	3	NQ
Hakken and MatZ,	The Culture Question in Participatory Design	2	NS
Hancock et al.	A meta-analysis of factors affecting trust in human–robot interaction	2	NQ
Hannibal	Bringing the Notion of Everyday Life Back to the Center of Social Robotics and HRI	2	NS
Hansen et al.	Identifying Stakeholder Perspectives in a Large Collaborative Project: An ICT4D Case Study	2	OQ
Harvey et al.	HCI As a Means to Prosociality in the Economy	2	OQ
Hasse	The Use of Ethnography to Identify and Address Ethical, Legal, and Societal (ELS) Issues	2	NS
Henkel and Bethel	A Robot Forensic Interviewer: The BAD, the GOOD, and the Undiscovered	2	NS
Hoa and Cabibihan	Cute and Soft: Baby Steps in Designing Robots for Children with Autism	3	NS
Huber and Weiss	Developing Human–Robot Interaction for an Industry 4.0 Robot: How Industry Workers Helped to Improve Remote-HRI to Physical-HRI	2	NQ
Hyrjak et al.	Utilising Online Qualitative Methods for Web Science	2	OQ
Jack et al.	Four not six: Revealing culturally common facial expressions of emotion	2	NQ
Jeong	Fribo: A Social Networking Robot for Increasing Social Connectedness through Sharing Daily Home Activities from Living Noise Data	3	NQ
Jipson and Gelman	Robots and rodents: children's inferences about living and nonliving kinds	3	NS
Jorgenson	Appeal and Perceived Naturalness of a Soft Robotic Tentacle	2	NQ
Jou et al.	Learning robotics in interactive Web-based environments by PBL	2	OQ
Kashi et al.	Playing the Mirror Game with a Robot: Who Takes the Lead, and What Movements Are Most	2	NQ
Kim	A Contextual Inquiry of AVEC: Power Assist Wheelchair Enhancing Communication	2	NS
Kim et al.,	Social robots as embedded reinforcers of social behavior in children with autism	2	NQ
Kim et al.	Development and assessment of a hand assist device: GRIPIT	2	OQ
Kim et al.	User-centered HRI: HRI research methodology for designers	3	NS
Kim et al.	Exploring the User Experience for Autonomous Vehicle and the Role of Windshield Display: Based on Framework Approach	2	OQ
Koay et al.	Living with Robots: Investigating the Habituation Effect in Participants' Preferences During a Longitudinal Human–Robot Interaction Study	3	NS
Kraft	Robots Against Infectious Diseases	3	NS
Krigistein et al.	Experiences and Challenges with Evaluation Methods in Practice: A Case Study	2	NS
Kriz et al.	Robot-directed Speech As a Means of Exploring Conceptualizations of Robots,	3	NQ
Lee et al.	Robots for Social Good: Exploring Critical Design for HRI	2	NS
Lenz et al.	The BERT2 infrastructure: An integrated system for the study of human–robot interaction	2	NQ

Author	Title	Stage	Code
Li et al.	Robot in Charge: A Relational Study Investigating Human–Robot Dyads with Differences in Interpersonal Dominance	2	NQ
Lindblom et al.	Current challenges for UX evaluation of human–robot interaction.	3	NS
Llungblad	Critical robotics: exploring a new paradigm	2	NS
Louie et al.	Playing a memory game with a socially assistive robot: A case study at a long-term care facility	3	NQ
Lucking	Geographically Distributed Deployment of Reproducible HRI Experiments in an Interdisciplinary Research Context	2	NS
Malmir et al.	Home Alone: Social Robots for Digital Ethnography of Toddler Behavior	3	NQ
Manohar et al.	Expressing emotions through robots: A case study using off-the-shelf programming interfaces	3	NQ
Martelaro et al.	Tell me more: Designing hri to encourage more trust, disclosure, and companionship	2	NQ
Martini et al.	Seeing Minds in Others - Can Agents with Robotic Appearance Have Human-Like Preferences?	2	NQ
McGinn et al.	Meeting Stevie: Perceptions of a Socially Assistive Robot by Residents and Staff in a Long-Term Care Facility	2	NS
Mordoch et al.	Use of social commitment robots in the care of elderly people with dementia: A literature review	2	NS
Morewedge et al.	Timescale bias in the attribution of mind	2	NQ
Morrison et al.	Mixing Quantitative with Qualitative Methods: Current Practices in Designing Experiments, Gathering Data and Analysis with Mixed Methods Reporting,	2	OQ
Mushiaki	Ethica ex machina: issues in roboethics	2	NS
Nature editorial	Let's talk about sex robots	2	NS
Niculescu et al.	How Humans Behave and Evaluate a Social Robot in Real-environment Settings	2	NQ
Nomura and Takagi	Exploring effects of educational backgrounds and gender in human–robot interaction	2	NQ
Nomura et al.	Why Do Children Abuse Robots?	2	NS
Nourbakhsh	On the study of human–robot collaboration	3	NS
Oyedele et al.	Contextual factors in the appearance of consumer robots: exploratory assessment of perceived anxiety toward humanlike consumer robots	3	NQ
Pennisi et al.	Autism and social robotics: A systematic review,	2	NS
Polak	Differences between Young and Old Users when Interacting with a Humanoid Robot: A Qualitative Usability Study	2	NQ
Pugliese et al.	Emergence of Leadership in a Group of Autonomous Robots	3	NQ
Ragot	ADAPT: A EU transdisciplinary research project for assistive robotics rehabilitation	2	NS
Rehm	Experimental designs for cross-cultural interactions: A case study on affective body movements for HRI	3	NQ
Reig et al.	Leveraging Robot Embodiment to Facilitate Trust and Smoothness	2	NS
Rijo	Diffusion of Culture Through Design	2	
Robins and Dautenhahn	The Role of the Experimenter in HRI Research - A Case Study Evaluation of Children with Autism Interacting with a Robotic Toy	3	NS
Robinson and Reinhard	Looking ahead in long-term care: the next 50 years,	2	NQ
Rogers et al.	Discovering patterns of touch: A case study for visualization-driven analysis in Human–Robot Interaction	3	NS
Rooksby	Can Plans and Situated Actions Be Replicated?	2	NS
Ros et al.	Solving ambiguities with perspective taking	2	NQ
Rosa et al.	Vocal Interaction with a 7-DOF Robotic Arm for Object Detection, Learning and Grasping	2	NQ
Ruckert	Unity in multiplicity: Searching for complexity of persona in HRI	3	NS
Saad	Welcoming Robot Behaviors for Drawing Attention	2	NS
Sabanovic	Robots in Society, Society in Robots Mutual Shaping of Society and Technology as a Framework for Social Robot Design	2	NS

Author	Title	Stage	Code
Sabanovic	Inventing Japan's 'robotics culture': the repeated assembly of science, technology, and culture in social robotics	2	NS
Sabelli et al.	A conversational robot in an elderly care center: an ethnographic study	2	D
Sakuma et al.	Positive and Negative Opinions About Living with Robots in Japanese University Students	2	NS
Sato	Learning Ecosystem in Elementary School Using Modifiable Humanoid Robot	2	NS
Scassellati et al.	Social development [robots]	3	NS
Scassellati et al.	Robots for use in autism research	2	NS
Schermerhorn et al.	Robot social presence and gender: Do females view robots differently than males?	2	NQ
Schmidt-Rohr et al.	Òeasoning for a Multi-modal Service Robot Considering Uncertainty in Human–robot Interaction	2	NQ
Sellner et al.	Attaining Situational Awareness for Sliding Autonomy	2	NQ
Siegel et al.	Persuasive Robotics: The influence of robot gender on human behavior	2	NQ
Slovak	Supporting Teaching and Learning of Situational Empathy by Technology	2	OQ
Smith	Technologies of stage magic: Simulation and dissimulation	2	OQ
Steinfeld et al.	Common Metrics for HRI	3	NS
Stubbs et al.	Challenges to Grounding in Human–robot Interaction	2	NS
Tapia et al.	Good Bones: Anthropological Scientific Collaboration Around Computed Tomography Data	2	OQ
Thill and Ziemke,	The Role of Intentions in Human–Robot Interaction	2	NQ
Torrey et al.	How a Robot Should Give Advice	3	NS
Van Oost and Reed	Towards a sociological understanding of robots as companions	2	NS
Van Turnhout et al.	Design Patterns for Mixed-method Research in HCI	2	OQ
Veling	Becoming Real: An Anthropological Approach to Evaluating Robots in the Real World	2	NS
Vertesi	Seeing Like a Rover: Team Work and Human–Robot Relations	2	NS
Vicente and Bernardino	Wedding robotics: A case study	3	NS
Virnes	Robotics in Special Needs Education	3	NS
von der Putte	A Social Robot for Autonomous Health Data Acquisition Among Hospitalized Patients: An Exploratory Field Study	2	NS
von der Putten et al.	An android in the field	3	NS
Weiss	HRI research: the interdisciplinary challenge or the dawning of the discipline?	2	NS
Weiss et al.	The USUS evaluation framework for human–robot interaction	3	NS
Weiss et al.	A methodological adaptation for heuristic evaluation of HRI	3	NS
Weiss et al.	The USUS evaluation framework for user-centered HRI	2	D
Wilkinson et al.	Oh Yes, Robots! People Like Robots; the Robot People Should do Something': Perspectives and Prospects in Public Engagement With Robotics	2	NS
Williams	AIDA: A Social Co-Robot to Uplift Workers with Intellectual and Developmental Disabilities	2	NS
Wilson and Haslam	Humanness beliefs about behavior: an index and comparative human-nonhuman behavior judgments	2	NQ
Wolbring and Lashewicz	Home care technology through an ability expectation lens	2	NS
Xu et al.	The role of social context in human–robot interaction	2	NQ
Yang et al.	Robotic interaction via path planning - A viewpoint from functionalist sociology	2	NQ
Yim and Shaw	CALLY: The cell-phone robot with affective expressions	2	NQ
Young et al.	Evaluating Human–Robot Interaction, Focusing on the Holistic Interaction Experience	3	NS
Yumakulov et al.	Imagery of disabled people within social robotics research	2	NS
Zaga et al.	2Nd Workshop on Evaluating Child Robot Interaction	2	NS
Zhong et al.	A hierarchical emotion regulated sensorimotor model: Case studies	2	NQ
Zubrycki and Granosik	A Robotized Environment for Improving Therapist Everyday Work with Children with Severe Mental Disabilities	3	NS

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