Designerly Ways of Knowing in HRI

Broadening the scope of design-oriented HRI through the concept of intermediate-level knowledge

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ABSTRACT

Interest in design methods and tools has been steadily growing in HRI. Yet, design is not acknowledged as a discipline with specific epistemology and methodology. Designerly HRI work is validated through user studies which, we argue, provide a limited account of the knowledge design produces. This paper aims to broaden current understanding of designerly HRI work and its contributions by unpacking what designerly knowledge is and how to produce it. Through a critical analysis of current HRI design literature, we identify a lack of work dedicated to understanding the conceptual implications of robotic artifacts. These, in fact, are implicit carriers of crucial HRI knowledge that can challenge established assumptions about how a robot should look, act, and be like. We conclude by discussing a set of practices desirable to legitimize designerly HRI work, and calling for further research addressing the conceptual implications designerly HRI work.

CCS CONCEPTS

• Human-centered computing ~ Interaction design theory, concepts and paradigms • Computer systems organization ~ Robotic components

KEYWORDS

Designerly HRI; design research; design-oriented HRI; epistemology; intermediate-level knowledge

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1 Introduction

Recently, there has been increasing interest in design methods and tools within the field of human–robot interaction (HRI).

Both the HRI flagship conference and the IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN) have added tracks dedicated to design in the past years. These conference tracks were complemented with a growing body of workshops dedicated to bridging HRI with the design discipline, such as the *Design skills for HRI* [1], and journal special issues, such as *Design in HRI: past, present and future*, edited by Holmquist and Forlizzi [2].

In this paper, we define the body of work in HRI that has a strong orientation towards design, (i.e., work developing novel robotic artifacts and/or engaging with design methodologies) as "designerly HRI." By using the term "designerly" (which was originally coined by Cross in 1982 [3]), we aim to position this paper within the existing body of work on understanding various ways that knowledge is produced in design. Despite the growing interest in designerly HRI, we believe that the full potential of design (specifically its unique ways of producing knowledge) has not yet been fully exploited in the field of HRI. Most of the design-oriented work in HRI tends to comply with the conventional way in which the HRI community produces knowledge: (i) define a problem or question, (ii) build an artifact and/or interaction, (iii) test, (iv) analyze, and (v) repeat from step *i* until satisfied [4]. In this process, design methods help bridge the gap between the technical research interests that drive most engineering HRI approaches with the actual sociocultural reality and needs of potential users that robots may interact with.

This way of "using" design is relevant and needed in the field of HRI, in which most often users and contexts are considered only at later stages of research [4]. However, the current HRI design process most commonly produces specific *design instances* [5] that are to a large extent unique and standalone in the vast design space of other possible solutions. In other words, very specific robots are created for very specific problems. Barendregt and her colleagues argued that such design instance-focused work generally makes a smaller contribution to a field as a whole because it is hard for other designers or researchers to build further upon the kind of knowledge presented [6].

Conference edition	Design track title	Description
HRI 2015	Enabling Designs	Contributions that describe new robot designs, including new robot morphology, behaviors, or services. Submissions that fall under this theme must provide a detailed account of the process followed as well as resources and materials involved in the design of the robot, steps that the design team has taken to ensure good design choices, such as formative evaluations, design iterations, and heuristics carried out, and a clear demonstration of the promise of the new design in enabling human-robot interaction.
HRI 2016	Human-Robot Interaction Design	Research related to robot design from a broad spectrum of design practices, including form, interaction, and service design. We encourage submissions covering a variety of design methodologies, including iterative prototyping, qualitative and quantitative evaluations, user-centered design, expert interviews, interdisciplinary design, video and animation prototyping, improvisation, crowdsourcing, Wizard-of-Oz, as well as novel methodologies for HRI design. In addition to academic research, we also seek contributions of research papers related to the design of commercial and industrial HRI. Full paper submissions in this category must provide a detailed account of the process followed, as well as resources and materials involved in the design of the robot, the method and outcome of the design's evaluation, and a clear demonstration of the promise of the new design in enabling human-robot interaction.
HRI 2017/18/19/20	Human-Robot Interaction Design	Research that makes a design-centric contribution to human-robot interaction. This includes the design of new robot morphologies and appearances, behavior paradigms, interaction techniques and scenarios, and telepresence interfaces. The design research should support unique or improved interaction experiences or abilities for robots. Research on the design process itself is welcome. Submissions must fully describe their design outcomes or process to enable detailed review and replication of the work. Further, successful papers will have evaluation appropriate to the work, for example end-user evaluation or a critical reflection on the design process or methodology.

Table 1: Description of designerly contributions in the HRI flagship conference tracks

Design can, however, also provide "*opportunities for constructing knowledge that is more abstracted than particular instances, without aspiring to be the scope of generalized theories*" [7]. These contributions are entitled as *intermediate-level knowledge* [5], and can be understood as a "middle territory" between design instances (i.e., specific robot designs) and theories that can be used to define specific design features (e.g., distributed cognition theory, used to design usable interfaces [8]). Corresponding to the discussions that are currently held in the fields of human–computer interaction (HCI) [7] and child–computer interaction (CCI) [6], we argue that researchers in the HRI field should explore the concept of intermediate-level knowledge as a framework for understanding what *HRI design epistemology* (i.e., the study of knowledge creation) is and what it can be. This paper critically discusses the epistemological and methodological role of design in HRI by (1) critically analyzing how designerly work has been, and currently is, reported and validated in HRI; (2) describing what designerly knowledge is with a specific focus on the concept of intermediate-level knowledge; (3) identifying the epistemological gaps, particularly the lack of work addressing conceptual implications of designerly work; and (4) providing a set of desirable practices to legitimize designerly HRI research and account for conceptual implications while reflecting on the role of designerly work in HRI.

2 Current Views on Designerly HRI

Over the past decades, the design discipline has gone through an evolution. Researchers and practitioners have defined design research and design practice typologies and built new theories of design (see [9] for a review). What is common in these typologies is that the design knowledge is considered partly as formal knowledge (i.e., scientific and disciplinary) and partly as informal knowledge (i.e., intuitive and common sense) [10]. Provided by these epistemological characteristics, design is not only a distinctive domain of knowledge, but also a specific form of learning and knowing, which is often referred to as "designerly inquiry" [11]. Specifically, under the notion of Research through Design [12; 13; 14], there has been increasing interest in exploring and explicating what forms of specific knowledge and disciplinary contributions emerge from the type of work in which the ac t of designing is central in the research process. In Research through Design, knowledge is inherent to the activity of designing itself (gained through engaging in and reflecting on the activity) or to the designed artifacts (gained through reflecting on those artifacts). The current understanding of design knowledge draws from this reflective perspective rather than from a notion of design as solving objectively graspable problems through artifacts in a deterministic manner.

Therefore, it is believed that design knowledge resides beyond artifacts. The act of creating an artifact is in itself a potential generator of knowledge and is, thus, crucial to design practices [15]. In order to create artifacts (or prototypes), one needs to absorb knowledge from different directions and confront, integrate, and contextualize this knowledge [14]. Prototypes can open up unanticipated design spaces [16], be vehicles for theory building [17; 18], or invite people to debate about particular issues [19]. Realizing these prototypes, for whatever purpose, requires a thinking process that in itself produces insights. What is critical is that these insights should not "disappear" into the prototype but should rather be fed back into the disciplinary and cross-disciplinary platforms that can fit these insights into the growth of theory [14].

When we describe what design is and can do from this wide perspective, the way that designerly inquiry is most commonly employed in the HRI field becomes rather limited. For example, to crystallize how design practices are interpreted and shaped in HRI, we can look into the HRI conference and how it described the "design track" from 2015 (the first year a dedicated track was introduced) to 2020 (see Table 1).

Designerly HRI work was initially (2015/2016) associated with producing novel robot designs, morphologies, behaviors, interaction paradigms, scenarios, and new service designs. To be acknowledged as meaningful contributions, the following detailed descriptions were expected: the process followed, the materials and resources employed, the methods used for evaluation, and a demonstration of the promise offered by the design. These contributions focused on novel robot designs and studies on design features, for example, such as facilitating people's understanding of robot intentions, as in the work of Szafir et al. [20], or studying behaviors and expressivity for achieving sustained human–robot engagement, as in the research with the robot Mortimer [21]. It can be argued, however, that these examples are not uniquely "designerly," as they present the development and evaluation of a standalone and unique robotic solution. This does not mean that this type of work has no value from the design perspective, but rather it emphasizes that, taken as an approach, design has more to offer.

Here, design is not considered an independent discipline that can generate specific knowledge, but rather as a *means for investigation* (i.e., a toolkit or methodology for developing robot devices and/or behaviors to employ in user studies). From this perspective, design serves HRI research to examine existing theories and explore the interaction dynamics between humans and robots. A similar perspective on design was adopted in the *Design Skills for HRI* workshop [1], which introduced the participants to the design process by focusing on need finding, design sketching, and physical prototyping (not actuated prototypes). Again, designerly investigations were not addressed as potentially having their specific objectives and ways of knowing [3].

From 2017 onwards, such vision was extended by also including investigations on the design process itself. This shift represents a crucial step toward acknowledging design as a discipline with its own research objectives. For the first time, design was also considered as a form of research in the track description. Designerly HRI transitioned from being considered solely as a generative tool to enable HRI user studies to a form of research in which both *the process and the robotic artifact outcomes are the objects of investigation themselves.* Moreover, the way knowledge is produced expands from evaluation studies to also include critical reflections.

This evolutionary broadening in 2017, however, was not sudden. It was the outcome of the discussions that the HRI community has been engaging in for years. In the special issue on *Design in HRI: Past, Present and Future* [2], published by the Journal of Human-Robot Interaction in 2014, design was treated as a discipline with its specific research objectives, and it is recognized as an integral part of HRI.

As a result, the literature on HRI is now actively addressing design more comprehensively, by documenting and reflecting on the design process. Examples range from the work investigating the aesthetic properties of novel robotic platforms and their design process, such as the robot *SCIPRR* [22] or *Haru* [23], to using human-centered design methods for understanding the context and potential users of a robot, as in the work of Moharana et al. [24]. Increasingly, the findings and discussion of HRI design contributions such as the ones mentioned above, also pertain to robotic artifacts or services rather than only the interaction qualities or paradigms that these might elicit. Such broader understanding of HRI design unveiled opportunities for employing research methods from the discipline of design, which are established in design research and HCI but are rather alien to the HRI field. These include critical design methods and approaches, as the ones explored by Cheon and Su in their work on *Futuristic Autobiographies* [25] or by Lee et al. in their workshop on *Robots for Social Good: Exploring Critical Design for HRI* [26].

Despite this growing acknowledgment of design and its potential value, the majority of designerly HRI work remains bound to evaluation studies of robots that focus on either usability or acceptability aspects. Critical reflections on method, process, and design outcomes are still not common practice. Both Research through Design and its ways of knowing are still relatively unknown to the majority of HRI design researchers, as explained by the limited number of contributions that can be found on this topic [27; 28; 29; 30]. We believe that HRI design researchers need to develop an understanding of what designerly knowledge the field can produce. To this end, we encourage the HRI community to engage in a discussion on intermediate-level knowledge and how it might be contextualized in the HRI field.

2.1 Intermediate-level knowledge in HRI

In an effort to make designerly insights explicit and feed them back to the relevant disciplines, Höök and Löwgren [7] emphasized the importance of addressing the various forms of knowledge generated in between abstraction and concretization. This intermediate-level knowledge sits in the space between designed artifacts (i.e., instances) and theories, and represents constructs that are more general than particular instances but have a different scope and purpose from those of abstract theories [6]. As illustrated in Figure 1, these are discussed with the primary concern of understanding how to articulate and validate the knowledge gained through designing. The most acknowledged forms of intermediate-level knowledge include design methods and tools, design guidelines, patterns, heuristics, experiential qualities, criticisms, strong concepts and annotated portfolios [7; 31; 32]. In the next subsections, we will review how these are employed in the HRI field and identify the potential gaps to fill with further research.

2.1.1 Design methods and tools. Design methods and tools represent the most established example of intermediate-level knowledge in design and HCI [5]. They are generated through reflection on design practices and abstracted to the extent that other designers can employ them and extend their capabilities [5].
In HRI, using design methods and tools is common practice. For example, generative methods are used in conceptualizing robots' behaviors and appearances. These methods include animation studies [33; 34; 23], sketching and 3D modeling [34; 22; 23; 35; 36; 37], and brainstorming [23; 37; 38].

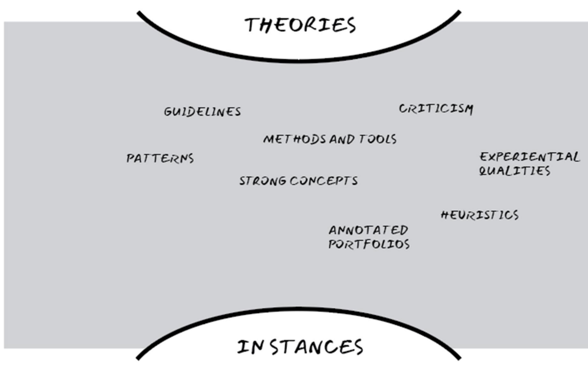

Figure 1: A drawing extending Höök and Löwgren's framework of intermediate-level knowledge, originally published in 2012 (redesigned for legibility).

Human-centered design methods that are intended for understanding users and contexts are also employed frequently in HRI. These include interviews [38; 26], questionnaires [25], personas [22; 39 focus groups [26], and observations [26]. There is also currently a shift toward including people in the design process. Another is example is participatory design methods that are adopted for codesigning robotic features and applications, e.g., [24; 36; 38; 40].
The importance of understanding the potential impact of robots on users, contexts, and society at large has also led various researchers to adopt critical design methodologies, such as *Futuristic Autobiographies* [25], a method for eliciting values and perspectives on technologies from users, designers, and researchers to inform design. There are also methods that do not stem from design research but have rather been developed specifically for HRI. This includes the use of puppeteering techniques as design inspiration [33; 34], the use of already existing devices with screens (e.g., smartphones, tablets) as fast-prototyping tools [41], and the extensive use of the Wizard of Oz [33; 38; 42; 43] not only as methods for the evaluation of new robot designs, but also as a method for investigating how humans perceive potential robotic qualities and behaviors (as in *Marionette*) [43].

2.1.2 Design guidelines. Design guidelines represent the operationalization of theories for improving their usefulness in design practice [5]. Design guidelines can take various forms, from white papers to manifestos. HCI has developed several design guidelines, such as the *Universal Principles of Design* [44] and the *IoT Design Manifesto* [45].
Conversely, HRI did not insofar produce any, at least not in a formal fashion. Even though many HRI studies include design implications and recommendations (see [33; 46; 47; 48; 49]), these hardly turn into guidelines. This may be due to the variability of robotic platforms and applications, which makes it hard to abstract and generalize design implications to a broader context. Design implications generated in HRI design studies can still represent a rich source of principles that, if subjected to a systematic reflection in relation to existing HRI knowledge, can be used to generate HRI design guidelines.

2.1.3. Patterns. A design pattern describes a problem, a rationale for a solution, how to apply it, and some of the tradeoffs that can result from applying the solution [31]. A classic example of pattern in user interface (UI) design is *action buttons*, which provide a solution to the problem of what can or cannot be clicked on interfaces like websites [31]. By adding visual cues, specific buttons can be communicated as "active."
Within HRI, only Kahn et al. [50] provided a number of design patters stemming from child–robot interaction, but potentially applicable to HRI at large. Those design patterns are meant to describe the interaction of a robot with a person and within a context. For example, an interaction pattern is an "initial introduction" in which a robot greets a child to initiate a human-like interaction. These design patterns are derived from the observation of human behavior, empirical data, and designers' experiences. To the best of our knowledge, there are no other examples of design patterns in the HRI field.

2.1.4. Heuristics. Heuristics are a set of empirical rules that are used for evaluating interactive systems [51]. In the HCI domain, the most common heuristics are related to the usability of user interfaces, such as error prevention, and user control and freedom. Although these may be valid for evaluating some aspects of robot designs (e.g., HRI) [48; 52], the uniquely complex and dynamic nature of robots [53] requires heuristics that account for more than usability factors.
Attempts to address such complexity have already been made by Weiss et al. [54], who proposed an evaluation framework that integrates usability factors with considerations of social acceptance, user experience, and societal impact. Similarly, Dautenhahn et al. [55] suggested "continuous actions" and "boundary signaling" as heuristics to improve robots' social acceptability and user experience. However, no comprehensive

account of heuristics that relate to the different dimensions of robots as socially embedded systems is yet available.

2.1.5. Experiential qualities. Experiential qualities can be regarded as conditions for a good use [56], i.e., the aesthetic, emotional, and affective components of interaction [56]. Focusing on interactions with digital designs, Löwgren [56] defined a set of 19 qualities. An example of these is *pliability*, which is the quality of a digital artifact to feel like a tightly connected loop between action and response, in which the user gets a sense of "manually" shaping the digital information even though the interaction is mediated by a series of nontactile interaction devices (e.g., mouse, monitor) [57].
Given such focus on how the properties of artifacts, which can be explored through design, are experienced in use [56], experiential qualities may be regarded as a core area of investigation in HRI. In fact, many HRI studies have investigated the effects of robot design features on human perception and on the quality of interaction (e.g., politeness [58], trustworthiness [42], and evocativeness [34]). However, the results obtained are rarely formalized as generalizable experiential qualities, but rather as specific insights.

2.1.6. Criticisms. Criticism is a core strategy for the production of knowledge in arts and humanities [59]. It has been introduced in HCI by Bardzell [60] as a way to generate intermediate knowledge in interaction design. It is important to note that criticism does not refer to user studies or qualitative evaluations. It is grounded in design research practices wherein interpretative analysis is used to assess the design process and design outcomes. Usually, experts in design and interaction design apply criticism to elaborate, unpack opportunities for design and assess the value of the design outcomes and processes. Criticism could enable deep insights into the practice of interaction design in HRI, yet explicit examples of it are still rare. In fact, even though some existing HRI studies may be viewed as a form of criticism [61; 62], these only rarely focus on the designerly aspects of HRI.

2.1.7. Strong concepts. Concepts probe or measure how people would perceive and react to some intended qualities of a design [63]. They manifest a theoretical stand, which is perceived as "*an overall organizing principle that makes up the composition of the design as a whole*" [64]. Given such a theoretical component, concepts stand in between the abstraction of theories and the concreteness of instances and can be specifically addressed as a means to generate design knowledge [63]. Höök and Löwgren [7] further affirmed such generative potential by renaming this form of intermediate-level knowledge as *strong concepts* and stressing their ability to enable designers to extend their repertoires and achieve particular operative principles. Strong concepts focus on the dynamic gestalt of an interaction: reside at the interface between technology and people, carry core design ideas, and belong to an abstraction level that makes them translatable into various forms of instances [7]. While examples of strong concepts are already being discussed in HCI, such as *seamfulness* and *social navigation* [7], and CCI, such as *head-up gaming*, *remote sensing*, and *collaborative storytelling* [6], they are so far little acknowledged in HRI.
Nevertheless, there are some examples of strong concepts that have not yet been formalized. For instance, the use of gaze represents a recurring strategy to communicate robot statuses and generate a direct engagement with people. *Gaze-based understandability* can, hence, be regarded as a strong concept containing an implicit design direction, focused on the dynamic qualities needed for generating a gaze [34; 23].

2.1.8. Annotated portfolios. An annotated portfolio consists of a collection of designs that are represented through a medium appropriate for communication (e.g., a booklet) and accompanied by brief annotations [5]. Annotated portfolios are abstracted from the concrete level of instances through combination with notes and descriptions. Pictures of artifacts and notes elaborating on features in an annotated portfolio are mutually reliant and provide connections between the specificity of the designs and issues of concern relevant to the research community. This turns annotated portfolios into theoretical statements [32]. Developing annotated portfolios is both a way to account for the design style of a particular project, studio, or institution, and a practice that enables identifying and reflecting upon features and themes that may not emerge from the discussion of single artifacts [32].
In a similar fashion, HRI scholars are starting to engage with reflections on what knowledge can be gathered by systematically analyzing artifacts [41; 62; 65], although this is usually achieved by means of literature reviews. We consider that the full potential of annotated portfolios has not been unlocked in HRI, which could represent a particularly meaningful way of reflecting upon the significant body of HRI artefacts.

3. Embracing Designerly HRI

On the basis of our previous discussion, we argue that design should be, but has not yet been, fully addressed in HRI as a distinct means of producing knowledge. In our opinion, researchers can achieve this by (1) *thoroughly documenting their design processes* and (2) *articulating their motivations* for engaging with design practices.
With the act of *documenting (1)* a work, we encourage HRI design researchers to engage with questions like "How was the work done?" and "What were the underlying assumptions and questions that have been explored?" This may enable HRI design researchers to build awareness regarding the rationale behind their specific design choices and identify which actions correspond to these. At the same time, detailed descriptions of the design process and related micro-assumptions allow for replication and provide information regarding the factors that might have affected the process and contributed to generating a specific outcome. As such, thorough documentation of the design process represents a rich source of data for systematic reviews of designerly HRI work aimed at identifying further *patterns* and *heuristics* as well as *other forms of intermediate-level knowledge.*
Similarly, the act of *describing motivations (2)* is an invitation for HRI design researchers to reflect on what the scope of their research is and articulate whether it is about validating a theory,

understanding a phenomenon, or exploring opportunities by posing "what if" and "how can we" questions. By answering these questions, these researchers are also implicitly invited to clarify the role that design plays in their research. When the scope of the research is to validate a theory or build an understanding of a phenomenon, design would most likely be approached as a *means for investigation*, such as a tool or a set of methods to borrow "as is." Conversely, when the research scope is to explore opportunities by posing "what if" and "how can we" questions (i.e., "How can we design a robot for people with visual impairments?" or "What if we used texture modifications to convey emotions?"), the design and the explorations that it enables become the central aspect of the research. In other words, the design process is approached as an *object of investigation* in itself.

In sum, thorough documentation of the process and an articulated motivation for engaging with the design are necessary for legitimizing and communicating designerly HRI work. Correspondingly, one can already see the traces of these necessary aspects in the descriptions of the design track at the HRI flagship conference. Nevertheless, these are not sufficient. As one of the open challenges in the field is to articulate what knowledge designerly HRI work produces by developing artifacts and robot behaviors and engaging with design processes more broadly, researchers should also *position* their work in relation to the existing body of HRI knowledge. They need to discuss how their work adds to it and reflect on what might be the most meaningful methods for validating and/or generating insights. In general, the concept of intermediate-level knowledge provides a means to achieve this positioning and gain awareness regarding the potential value of work. This act of positioning should be viewed not only as a retrospective action, but also as a study of the design activity that can steer research toward one approach or another or that can unveil underinvestigated areas of concern within the field.

Even within the limits of the discussion that we presented in this paper, reflecting on the current designerly HRI work through the lens of intermediate-level knowledge allows identifying several opportunities for research. First, regarding the types of design knowledge that are already being considerably addressed in HRI, such as methods and tools, guidelines, patterns, and heuristics, we can notice a fragmentation, a lack of systematic use, and formalization. To address this gap, researchers might engage with questions like *Would it be possible to formalize an HRI-specific design toolkit? If so, how would this differ from other existing toolkits? Alternatively, would it be relevant to define a set of HRI-specific guidelines? Similarly, what are the HRI patterns that might be generalizable for robot design?*

Second, some types of intermediate-level knowledge, namely, criticisms, annotated portfolios, and strong concepts, are rarely addressed or still completely missing within the field of HRI. However, our argument is that the conceptual value of these types of knowledge would make them particularly meaningful for advancing the disciplinary understanding of what a robot is, how it should behave, and what purposes it should serve. Thus, design HRI researchers should engage with questions like *What might be the strong concepts embedded in the novel robotic artifacts that are being presented? Will these have an impact on our understanding of human–robot relationships, and how? More broadly, what can we learn from existing robotic artifacts*?

In particular, these last questions related to the conceptual implications of designerly HRI work address issues that are central to the HRI disciplinary interests. As such, we believe that conceptual investigations should be a prominent part of the agenda of HRI design researchers.

3.1 A call for conceptual investigations

As we illustrated in Section 2, the HRI field already produces intermediate forms of knowledge. However, we consider that the field still finds it hard to elaborate what contributions design instances produce, beyond their concrete features and functioning. All related fields of HCI [7], CCI [6], and design research at large [63; 66; 67] have experienced similar problems in the past. In those fields, discussions on intermediate-level knowledge have specifically emerged after noticing a friction between the claimed cruciality of artifact-centered contributions and their (often) limited impact on the research community.

As Stolterman and Wiberg [63] argue, in this type of work, "researchers introduce designs of artifacts and systems that manifest new or improved form of interactivity" but "do not leave a lasting impression on the audience of the fellow researchers, as the contributions do not address, challenge, or complement the existing body of theoretical knowledge within interaction research in an intentional way."

Understanding the conceptual implications of research artifacts and how they complement existing knowledge, however, is crucial for the development of disciplines in which design is a core component, such as HRI (see the definition of the HRI field by Goodrich and Schultz [68]). Design is generative: it is concerned with creating and reflecting on *what might be*, rather than *what is* [69]. As such, research artifacts represent manifestations of preferred states [67], alternatives to existing things and interactions, which can lead to shifting paradigms of interactions, changing approaches, and rethinking values we should design for. Within HRI, in particular, exploring the conceptual implications of novel artifacts and interaction can lead to a *different understanding and shaping of what our future with robots might be.*

Implicitly, this process is already happening. As a matter of fact, some HRI artifact-centered works can be considered as landmark projects (i.e., highly influential research designs) [63] in which the main contribution and influence do not reside within the results of their user studies but rather within the way *their embodiments and behaviors challenge what we believe a robot should look, act, and be like.* To illustrate this point, we collected a series of HRI artifacts and grouped them into commercial robotic platforms (Figure 2, left) and noncommercial robotic artifacts designed and developed as part of HRI research. Even at first sight, we notice how the instances of the two groups manifest a different view of what a robot should look like and what functions it should serve. Specifically, commercial robots may be perceived as reinforcing stereotypes, controversial imaginaries of either servile machines (e.g., B and D) or friendly artificial companions (e.g., A, C, and partially E) inherited from popular culture.

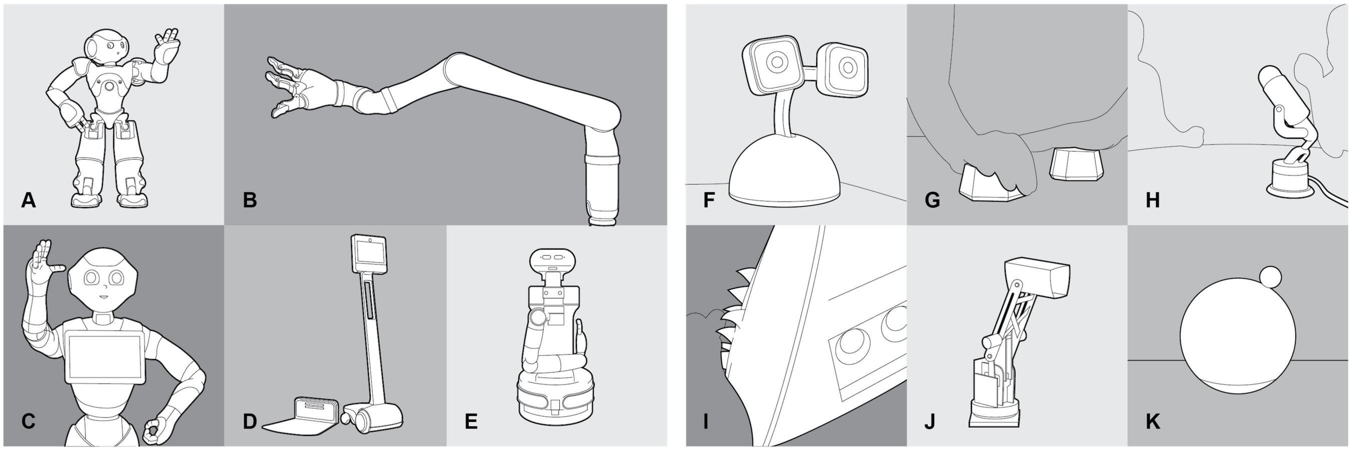

Figure 2: HRI artifacts. Left group includes commercial robotic platforms largely used in HRI research (A – Nao; B – Jaco; C – Pepper; D – Beam; E – Tiago). Right group includes non-commercial robotic artefacts designed and developed as part of HRI research (F – Haru; G – Cellulo; H – Micbot; I – Goosebumps; J – Kip1; K – The Greeting Machine)

These sometimes literally stick to the ideals of robots as tools (see D) or, most of times, replicate the complexity and features of humans and other living agents, as these are uniquely effective ways to achieve successful HRI. Conversely, robotic artifacts developed in a research content, such as *Kip1* (J) [34], *The Greeting Machine* (K) [70], or *Micbot* (H) [71], challenge assumptions of what the look and purpose of a social robot should be. For instance, *Cellulo* (G) [72] demonstrates how learning with robots does not necessarily imply replacing human teachers. *Haru* (F) [23] and *Goosebumps* (I) [73] demonstrate how effective and engaging expressivity of artificial agents can be, without the need for replicating human expressions. Altogether, these artifacts challenge the idea of robots being completely autonomous agents that humans will have to "negotiate" roles with, suggesting scenarios in which robotic technologies are much more embedded in the ecology of things that we are part of.

Addressing artifacts as implicit carriers of strong concepts would give designerly HRI work the opportunity to move from being a mere tool to a method for investigating and challenging HRI beliefs and traditions. As such, we believe that it is crucial for the discipline to engage in Research through Design investigations that aim to understand the conceptual dimension of artifact-centered work, especially through criticisms and annotated portfolios.

3.1.1 HRI criticisms. Criticism allows creating an understanding of the relationships between the material aspects of artifacts and their production process, as well as their sociocultural significance [60; 59]. In the field of HRI, both the work of Trovato et al. [62] on the representation of the divine in robots and the work of Šabanović [74] on the mutual shaping of robots and society represent good examples of how criticism can be engaged from different perspectives and yet generate meaningful knowledge for the field. While the former example focuses more on artifacts and the latter on the processes, they both discuss how design aspects, whether a morphology or an approach to develop a certain solution, are rooted within specific sociocultural practices and ideals and, as such, determine the way a robot might be perceived and approached.

As these examples demonstrate, engaging with criticism would give the HRI field the opportunity to broaden the spectrum of values to design and evaluate robots with. As in HCI, criticism opens up the discussion from sole utilitarian and functional aspects of interaction, such as task completion time, error rate, and user satisfaction, just to name few, to experiential qualities, such as esthetics, identity, meaning, and ideology [60]. However, while arguments supporting criticism can be "easily" borrowed for the HCI literature, strategies for its applicability may need to be redefined. Existing guidelines and frameworks for interaction criticism [75] often address aspects and elements that become ambiguous in the case of HRI, such as the concepts of interface and use. When asked to analyze an interface, in the case of HRI, one should first question *What should be considered an interface? Does the interface extend to the whole robotic artifact? If so, how should we address both direct and nondirect forms of interaction?* Similarly, when asked to investigate challenges and opportunities of use, one should first rethink the very notion of use. As robots are *supposedly* not mere tools executing simple tasks, human interaction with them may not be reduced to the sole notion of use. As such, researchers should first ask *What types of HRI should we address beyond use?*

Finally, the very act of criticism that is generally referred to as "an expert of a given domain's informed exercise of judgement" raises the question of how to define such expertise: *Is technical robotics knowledge relevant for HRI criticism? Can HRI criticism prescind from technical knowledge?*

3.1.2. Robot annotated portfolios. Annotated portfolios represent a uniquely designerly way of producing knowledge, as they combine visual representations (e.g., pictures) of artifacts under analysis with annotations that highlight how certain features connect to matters of concern surrounding the artifact and its design process [76].

As such, these can represent a particularly meaningful way to address robotic artifacts as implicit carriers of concepts and assumptions that relate to how we understand HRI at large. For instance, Hoggenmüller et al. [77], who to our knowledge are the only ones who have addressed annotated portfolios in HRI up till now, investigated the commonalities, differences, and principles that emerged from the design process of two robotic artifacts: *Woodie* and *BubbleBot*. By annotating these two urban robot projects, the authors generated reflections on aspects of playfulness, autonomy, and approachability that made the reader question the very way the society usually thinks about robots.

Even this single example illustrates the potential value of annotated portfolios in HRI, but it also unveils multiple methodological concerns. Starting from the choice of annotating two projects originally developed by the authors and their groups separately, one question arises: *What can be included in an HRI portfolio?* The original idea of Gaver and Bowers [32] as well as most of existing examples from Research through Design and HCI, see portfolios composed by artifacts from the same author or group of authors. However, as in HRI there are still a limited number of research groups regularly engaged with the design and development of new robotic artifacts, *should annotated portfolios be limited to the work of a few groups? Alternatively, is there a value in annotating and reflecting on robotic artifacts even if from diverse authors and "schools"? If so, what should be the criteria for inclusion?* These questions also introduce another methodological matter of concern: *Should annotated portfolios only be performed by the designers of the robotic artifacts or can they be performed by external observers?* This question is specifically addressed by the notion of curated collection, which was proposed by Luciani et al. [78], suggesting the curator instead of the author as an alternative meaningful source of annotations and reflection. Nevertheless, the question of who can contribute to the annotations can potentially be further explored: *Could the audience, the laypeople, be a source of meaningful annotations? If so, how would the emerging knowledge differ?*

Finally, the uniquely dynamic nature of robots poses the question of the effectiveness of reflecting on robotic artifacts only through annotations on pictures. *In fact, how can we fully observe and communicate the dynamic aspects of robotic artifacts (e.g., gaze)? Can we revise the concept of annotated portfolios and use it as a grounding for an HRI-specific form of intermediate-level knowledge, namely, "annotated showreels" (mesh-up videos showcasing a person's previous work used by many types of people involved in filmmaking and other media)?*

4. Conclusions

In this paper, we discussed the state of the art for designerly HRI to clarify its potential contributions to the field. By reviewing how designerly work is described at the HRI flagship conference, workshops, and special issues of the HRI journal, we highlighted the difficulty in the field to elaborate on what types of contributions the design instances produce, beyond being a standalone and unique solution to a specific problem. We believe that understanding the conceptual implications of research artifacts and how they complement existing knowledge is crucial for developing disciplines in which design is a core component. To our understanding, this difficulty is often due to the HRI researchers' lack of knowledge regarding the peculiar designerly ways of producing knowledge. In fact, the HRI field profusely borrows design methods, yet these are mostly used as mere tools for producing robotic artifacts or robot features and are not acknowledged as processes that can generate HRI knowledge. Nevertheless, we argue that the field of HRI can and should embrace designerly work, by *thoroughly documenting processes* and *articulating motivations* for engaging with design practices, with the final aim of explicating the specific contribution of such design work. To better understand and communicate such contribution, we suggest looking at the concept of intermediate-level knowledge: forms of knowledge that stand in between the abstraction of theories and the concreteness of instances.

Some of these, such as methods and guidelines, are already familiar in HRI, whereas others, such as criticisms and annotated portfolios, are still largely unknown. The latter, however, are the ones that we deem particularly meaningful for understanding the conceptual value of robotic artifacts that are regularly being developed within HRI research. Specifically, we believe that conceptual investigations of HRI artifacts, focused on embodiments and behaviors, can challenge what we believe a robot should look, act, and be like.

However, while much can be borrowed from design research and HCI literature, designerly HRI, as well as its contributions, also needs to be addressed as a niche research space with its own specificities. As pointed out in our discussion of criticisms and annotated portfolios, for instance, much should be done to make these methods of knowledge production actually meaningful for HRI research. Nevertheless, we believe that these very challenges are what constitute the HRI design research agenda that we are arguing for.

By engaging with designerly methodological questions, such as the ones suggested for criticisms and annotated portfolios, HRI design researchers have the opportunity to legitimize their work. Most of all, by fostering continuous questioning of its methods and concepts, designerly HRI work can advance our understanding of design at large and offer opportunities for extending its potential contributions in such a fast-changing world, where relationships with advanced technologies are increasingly becoming inescapable.

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