

Mapping Tangible and Embodied Interactions in More-Than-Human Design: A Review of Research Tools

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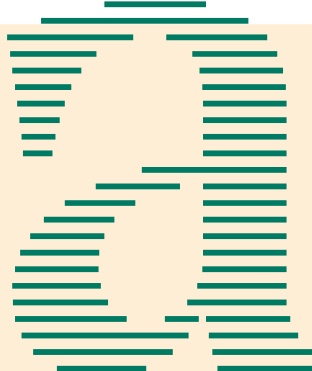
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This article reviews existing literature on human-animal entanglements to explore how justice-oriented designers utilize tangible artifacts as tools and mediators to rethink multispecies relationships. By analyzing the use of tools in the existing literature through a relationality lens, our research introduces pathways to rethink research tools and ways of doing that foreground justice-oriented multispecies interaction. Our findings illustrate how previous work that follows human-centric knowledge and interaction design modes for human-animal entanglements implicitly supports unjust interspecies power relations. By identifying emergent modes of research tools, this article offers a set of takeaways for designers to consider such tools as participants within entangled, reciprocal, and longer-term relational practices in non-human-controlled environments.

Keywords

 relationality

 justice-oriented participation

 interaction design

 human-animal interactions

 multispecies entanglements

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Mapping Tangible and Embodied Interactions in More-Than-Human Design: A Review of Research Tools

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INTRODUCTION: RELATIONALITY, ATTUNEMENT, AND RESEARCH TOOLS IN MORE-THAN-HUMAN INTERACTION DESIGN

More-than-human interaction design (MtH-IxD) is a field of study aimed at decentering human roles while researching and nurturing interactions across multispecies. As a counterargument to a human-centric pathway, studies of MtH-IxD have challenged anthropocentric practices by foregrounding cohabitation and recognizing the agency of animals, other living beings, and nonliving entities (Foth, 2017; Jönsson & Lenskjold, 2014). This body of work also explores the relational dimensions of sustainability in broader contexts, such as food systems, natural environments, and urban life (Biggs et al., 2021; Frawley & Dyson, 2014; Heitlinger et al., 2019; Li et al., 2022; S. Y. Liu et al., 2019), as well as the role of technology in improving animal welfare (Mancini, 2011).

Understanding the relational dimensions of MtH-IxD and building embodied, justice-oriented, non-anthropocentric interactions and related artifacts remain challenges for designers and design researchers in the field. Embodied and tangible artifacts include new systems, architectures, tools, toolkits, techniques, sketches, mockups, and environments that reveal new possibilities, enable new explorations, facilitate new insights, or compel us to consider new possible futures (Eriksson et al., 2024). In our research, it is important to understand the relational aspects of embodiment, understood as the lived and felt experience of the body.

In this study, we employ the relationality approach proposed by Arturo Escobar (Escobar, 2018; Escobar et al., 2024), a Colombian anthropologist and political ecologist whose decolonial approach challenges modernity and development discourses—as a framework that is both ontological and ethical—by foregrounding interdependence and mutuality over separation. We use this framework to examine existing embodied research tools and reflect on how designers' future roles in creating tangible tools might better align to foster pluriversal worlds.

“Relationality” refers to the worldview and practice grounded in the interdependence of all beings and processes toward care, responsibility, and the remaking of life, where relations come before entities, and where reality is continuously co-created through relational participation (Escobar et al., 2024). It is not a fixed definition; rather, it is an emergent, situated, context-dependent way of being, knowing, and doing. Relationality is operationalized by “attunement.” Drawing from how Escobar uses the concept, attunement is a situated practice of listening-with, adjusting-with, and co-responding to the unfolding dynamics of a place. Attunement operationalizes relationality by enabling forms of ethical noticing, responsiveness, and co-creation that are grounded in context, care, and reciprocity (Escobar, 2018; Escobar et al., 2024). In this study, we use the concept of relationality and its situated practice of attunement to look into research tools as physical mediators created and employed by designers and researchers to be used with animals across diverse contexts.

Although the field of MtH-IxD is still in its early stages, remarkable efforts are being made to examine the justice-oriented participation of animals, particularly in relation to their well-being. Tschakert et al. (2021) argue that justice-oriented participation should aspire to be relational by focusing on creating inclusive, interactive, functional, and flourishing environments. The intersectional and pluralistic nature of justice-oriented participation in MtH-IxD can be best explained through several dimensions. For example, Animal-Computer Interaction (ACI) researchers, with a specific focus on interactions, have long envisioned interdependence and interconnectedness, characterized by reciprocal interactions between animals and humans (Mancini, 2011). Reciprocal play (French et al., 2021; Noz & An, 2011), participatory engagement (Chisik & Mancini, 2019; Mancini & Lehtonen, 2018), bidirectional communication systems (Hirskyj-Douglas et al., 2021; Sadetzki & Hirsch-Matsioulas, 2021; Ur Réhman & Li, 2014), mutual understanding (Westlaken & Gualeni, 2016), and social interactions (Mankoff et al., 2005; Rault & Huber, 2017) are only a few examples of justice-oriented efforts. Building on these, we contribute to the justice-oriented, equitable participation of

animals in multispecies interactions, with a focus on research tools.

A clearer set of examples of relationality and attunement can be found in the following works: J. Liu et al. (2018) presented the concept of “collaborative survival” and explored it through the design of three wearable tools for mushroom foraging: a glove to obtain data readings, a location-aware vest to locate mushrooms, and a modified walking stick to analyze spores. French et al. (2020) explored how aesthetic principles can inform the design of interactive systems for animals, through enrichment devices such as a controller for showering elephants. Since direct and physically grounded signs are contextually established associations, understanding how embodied tools are conceptualized, materialized, and implemented in design-oriented studies supports more inclusive approaches to design by attuning to the relationality between humans, more-than-humans, and their shared environments (Mancini et al., 2012; Nicenboim et al., 2024).

Building on the possibilities of embodiment, tangibility, and multispecies interactions, our study examines how the participation procedures of animals in previous MtH-IxD studies were constructed and how the research tools were utilized. We provide an overview of tangible tools and interactions examined within MtH-IxD research, with a particular focus on human-animal entanglements. We aim to reveal how research tools are conceptualized and how they might be reimagined as participants in relational ecologies that foster more intertwined, reciprocal multispecies interactions. This study aims to support researchers and designers working toward justice-oriented animal participation by situating animals within broader multispecies relations and by understanding them as co-participants whose agency, consent, and situated needs shape the design and use of research tools rather than viewing them as isolated individual entities.

We specifically address the following questions: (1) How did designers and researchers in HCI and ACI enable justice-oriented participation of animals through research tools, and (2) What can designers learn from such emerging design approaches to deconstruct Westernized human or well-being-centric research tools? By analyzing how selected studies approach the design of tangible research tools, we identify recurring patterns and considerations relevant to justice-oriented human-animal entanglements. Our study contributes to ongoing discussions in the MtH-IxD community on cultivating more just and compassionate modes of cohabitation across species.

METHOD: STRUCTURED LITERATURE REVIEW AND REFLEXIVE THEMATIC ANALYSIS

Our approach follows the review procedures of DiSalvo et al.

(2010) and Baumer et al. (2014) by collecting a sample of papers from the ACM Digital Library (DL), the largest database for interactional, tech-mediated scientific work in the area, using a combination of keywords addressing the following themes: on the one hand, “animal” and “multispecies,” and on the other, “design” and “interact*.” The terms were combined using the Boolean operator AND to ensure that the retrieved articles addressed both themes.

We started a multi-stage screening process with an initial pool of 2,834 articles. After eliminating non-full-text, non-English articles from the dataset, 1,327 articles remained. We eliminated duplicates ($n = 505$), and 822 results remained for the screening phase. After a negotiation meeting, 710 irrelevant articles were filtered out, resulting in 112 articles. 40 articles from this pool were considered beyond the scope of this work, resulting in a final set of 72 articles.

We adopted Braun and Clarke’s (2006, 2021) reflexive thematic analysis guidelines for the detailed analysis. We initiated our analysis by formulating three questions designed to explore how justice-oriented participation was conceptualized and implemented: (a) What kinds of research tools are used when conducting studies with animals? (b) What forms of agency do research tools afford to animals during interactions? (c) How do animals engage with these research tools?

We used the questions as a framework to identify additional themes throughout the review process, resulting in a summary and a situated snapshot of the current landscape of research tools used with animals for their justice-oriented participation in Mth-IxD. Discussing results in light of Escobar’s relationality concept (Escobar, 2018; Escobar et al., 2024) enables us to capture gaps and explore possible alternatives that could help us practically implement tangibility in a more relational manner.

Positionality of the Authors

We hold an intersectional stance on justice in technology and design. We reside in a country where many see a dual relationship with animals as integral to everyday life (especially rooted in cultural practices of “not hurting a living being” and in the desire to live in collective peace within a highly polarized society). We position our vision as inspired by Suchman:

The world is a vision from somewhere—that it is inextricably based in an embodied, and therefore partial, perspective—which makes us personally responsible for it. The only possible route to objectivity on this view is through collective knowledge of the specific locations of our respective visions. (Suchman, 2002, p. 96)

FINDINGS: RESEARCH TOOLS SHAPING JUSTICE-ORIENTED MULTISPECIES PARTICIPATION

How research tools are conceptualized and constructed fundamentally shape the nature of the interactions they enable. Since active interaction is essential for fostering justice-oriented participation, we focused our analysis on the reported research tools used in the studies. In our clustering, we identified patterns in how embodied and tangible tools shape participation, roles, agency, and relational dynamics between humans and animals, revealing the affordances and constraints of current research tools in supporting justice-oriented, multispecies interactions.

The “Findings” section is organized into two parts. The first part provides a descriptive overview of the research tools used in the reviewed studies and categorizes them according to how they shape the degree of animal-technology interaction. The second part examines the *affordances and intentions* of these tools through four themes that emerged from our analysis. Together, these subsections trace how different material and technological configurations influence participation, relational dynamics, and justice-oriented, multispecies interactions.

The Planned Context of Research Tools for Animal Interactions

In this subsection, we provide a descriptive introduction to the research tools used in human-animal entanglements. In total, the first five most used tools in the studies are touchscreen devices (n = 12), control tools (n = 6), vests (n = 4), toys (n = 4), and cameras (n = 4), even though their participatory categories vary. A diverse range of technologies and tools is employed for various purposes. This analysis led to the identification of three types of research tools, categorized according to the degree of animal-technology interaction: (1) tools activated by the animal’s presence (e.g., motion sensors or joystick systems); (2) interactive tools that invite active engagement (e.g., touchscreen games or enrichment devices); and (3) observational tools that monitor behaviors without requiring input (e.g., biotelemetry systems or environmental sensors). These categories reflect varying approaches for facilitating multispecies interaction, from passive to participatory (Holder et al., 2024; Schneiders et al., 2024).

Tools activated by the presence of animals are defined as giving animals direct control and the highest autonomy over their environment or actions during the research process, and they support more justice-oriented participation. However, this group includes a smaller number of tools for animal participation. They mainly include touchscreen devices (n = 6) and

Group ● Tools activated by the presence of animals ● Interactive tools that actively involve animal engagement ● Tools designed solely for observation

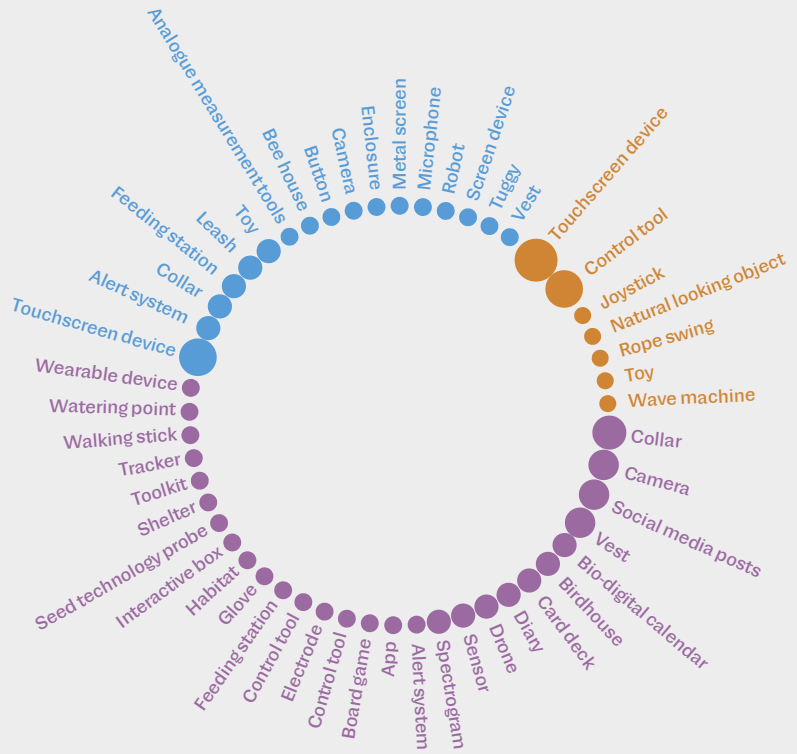


Figure 4: Radial diagram of tangible and embodied research tools, grouped into three levels of animal participation through tools.

control tools (n = 5) that give control and choice to animals (e.g., joysticks). These tools are mostly used with birds (n = 7), dogs (n = 4), and elephants (n = 3), and although they provide the most control to animals, they are used with species living in shelters and/or domesticated environments.

Interactive tools that actively involve animal engagement ranked second in terms of animal participation in design processes, comprising tools that facilitate direct interaction between the animal and technology, enabling communication or engagement. This category mostly includes various types of tools, such as touchscreen devices (n = 6), toys (n = 3), and feeding stations (n = 2) for enriching interactions.

Tools designed solely for observation consist in monitoring or tracking animals' behaviors and physiological responses without requiring active input and learning from them. Although this group offers the least control to animals among the research tools, it is the group with the largest number and most diverse tools. There are two types of research tools: human-use and animal-use. Animal-use tools are primarily composed of tracking and measuring tools, such as collars (n = 4) and vests (n = 3). Human-use tools are

based on monitoring via cameras ($n = 3$) and drones ($n = 2$); documentation via data visualization ($n = 4$) and diary ($n = 2$); and educational tools via toolboxes ($n = 5$), spectrograms ($n = 2$), bio calendars ($n = 2$), and card decks ($n = 2$).

A recurring pattern across the reviewed research tools is the tendency to center on human inquiry rather than enabling the autonomous engagement or agency of animals within interactions.

Affordances and Intentions of Research Tools

Four themes emerged from the analysis based on the degree of animal-technology interaction: (1) “Tailoring to species and individuals’ needs,” (2) “Participation, consent, and agency,” (3) “Interspecies sense-making,” and lastly (4) “Relational trust-building dynamics.” These themes summarize the affordances and intentions of research tools in Table 1, featured at the end of the article. In what follows, we give narrative examples of how papers materialize the participation of animals.

Tailoring to Species and Individuals’ Needs

Tailoring to species and individuals’ needs means recognizing and valuing all actors’ distinct characteristics, needs, and perspectives. Designers have developed interactive games (French et al., 2015; Noz & An, 2011); technological artifacts such as tracking devices, sensors, dog phones, and tablets (Bell et al., 2024; Hirskyj-Douglas et al., 2021; Jackson et al., 2013; Kleinberger et al., 2023; Ruge et al., 2018); and purpose-built habitats and enclosures (Schneiders et al., 2024) to support natural behaviors and social engagement.

While many studies prioritize species-level traits, others emphasize individual differences. Ruge and Mancini (2019) note that accounting for variation in individual traits is crucial, as it affects how behavior is expressed and interpreted during interactions. For example, interfaces for companion dogs were adjusted to individual characteristics (e.g., touch pressure, feedback modality), acknowledging personality and training history alongside species traits (Holder et al., 2021). These more personalized approaches are often applied to animals in captivity, such as dolphins, elephants, and orangutans (Andreou et al., 2023; French et al., 2017; Hirskyj-Douglas et al., 2021), as well as companion species like dogs (Holder et al., 2021; Mancini et al., 2016; Schneiders et al., 2024).

Overall, research tools in this theme act as both recognition and participatory interfaces: recognition when identifying what matters to a species or individual, and participatory in allowing those animals to actively shape how technologies are used and understood in multispecies interac-

tions. Ultimately, these acts of recognition and adaptation are considered relational practices of care by researchers.

Participation, Consent, and Agency

This theme focuses on research tools that prioritize animals' consent, agency, and forms of expression (embodied cues). While some studies are grounded in human-centered goals, such as improving caregiver efficiency or developing alarm systems for assistance animals (Robinson et al., 2015), others adopt approaches that allowed animals to act as co-participants with the ability to opt in or out through signals of interest, disengagement, or consent by means of embodied cues (Mancini et al., 2016; Schneiders et al., 2024).

Designing for animal-justice-oriented participation involves navigating complex terrain around agency, consent, and power. Key indicators of justice-oriented participation, such as animals' abilities to initiate and discontinue participation, are measured and provided through specific research tools and protocols. Tangible motivators, such as toys or food, are often used to support engagement; however, some researchers question whether these methods promote voluntary or conditioned behavior (French et al., 2020). For example, tablet-based communication panels used with parrots (such as the Goffin's Cockatoo) enable animals to communicate and initiate interactions by signaling requests for food, interaction, or learning activities using pictorial symbols (J. Cunha & Rhoads, 2020). These systems provide animals with choice and agency over their environment by directly supporting their empowerment.

Some studies employ research tools designed to capture animal agency and consent, as expressed through embodied cues, while minimizing the interpretation of the human proxy (e.g., contingent versus mediated consent). For example, animal-activated tools, such as DogPhone, allow dogs to initiate actions such as calling a distant human. These tools reinforce the theme of empowerment by giving animals control and authority over technology in the home (Hirskyj-Douglas et al., 2021). These studies show how research tools can redistribute power in multispecies interactions by enabling animals to act on their own terms and advance toward more justice-oriented design.

Interspecies Sense-Making

Understanding animal needs, intentions, and emotions is a core desire of MtH-lxD. Practices such as noticing (Rodgers et al., 2023; Sadetzki & Hirsch-Matsioulas, 2021), empathizing (Bell et al., 2024), and inter-

preting body language or behavior (Mancini et al., 2016; Paci et al., 2020) are used to derive meaning from interspecies encounters.

Researchers use wearables and biotelemetry, including GPS trackers to monitor animals (Paci et al., 2020); wearable communication interfaces for working dogs (e.g., FIDO) to capture how animals interact with technology when performing certain tasks (Jackson et al., 2013); and on-body sensors that report hidden reactions to attached devices (such as scratching or head/body shaking) as indicators of discomfort or adaptation (Paci et al., 2019a), to derive meaning by measuring the animals' physical state and their interactions with such devices.

To understand the choices, preferences, and cognitive abilities of animals, researchers use tools that they can interact with directly, such as touchscreens/tablets to study visual preferences and cognitive abilities in species like orangutans and dogs (Webber et al., 2020), and buttons/activators as canine input modalities that reveal usability and decision-making (Robinson & Torjussen, 2020). For interspecies communication, Sadetzki and Hirsch-Matsioulas (2021) use the leash as a bidirectional channel that conveys actions, intentions, and movement signals between the dog and the human.

Although designing tangible tools for understanding animals has enabled more justice-oriented participation, sense-making efforts sometimes remain human-driven, filtered by human epistemologies and technical representations, such as transforming behavior into visual data or creating symbolic languages (Erceg & Palamas, 2023; J. Liu et al., 2018). Nevertheless, these efforts do not directly speak to animals: they help facilitate awareness of interspecies relationships (Gaver et al., 2019), local ecologies (Pons et al., 2015; Soro et al., 2018), and behaviors through embodied interaction (Gupfinger & Kaltenbrunner, 2019; S. Y. Liu et al., 2019).

For example, noticing is framed as a method and a political position to surface systemic injustices, species inequalities, and multi-species entanglements (Bell et al., 2024; Rodgers et al., 2023). Visual or tactile translations of animal behavior, facilitated through spectrograms and musical feedback devices, enable new forms of attunement and interpretation (Dema et al., 2020; Erceg & Palamas, 2023). At the same time, researchers acknowledge the limits of empathy and the persistent asymmetry of human-led interpretation (Robinson et al., 2014).

Therefore, tangible tools play a central role in extracting interspecies meaning by observing, capturing, measuring, and reflecting on animals' experiences and preferences.

Relational Trust-Building Dynamics

Shared routines, consistent feedback, and comprehensibility in interaction design are crucial to the justice-oriented participation of animals, as these elements form the foundation for their cognitive, psychological, and ethical engagement in the design process (Mancini et al., 2016). Ensuring continued access of animals and their safety has also been a central concern in ACI design from a justice-oriented perspective (Mancini & Nannoni, 2022). Lastly, trust in ACI is frequently fostered through mechanisms that make system behavior comprehensible and predictable. Together, these features create a stable interactional environment in which animals can interpret the system's logic, anticipate outcomes, and engage with reduced stress.

Reliable systems are even more complex; they are the ones that behave predictably, fostering trust through comprehensibility (French et al., 2021; Mancini et al., 2016), consistency (Hirskyj-Douglas et al., 2024; Mancini et al., 2016), and habituation (Foster et al., 2019; Hirskyj-Douglas et al., 2024; Pons et al., 2015). For example, repeatedly associating a specific button press with the opening of a door enables animals to develop confidence in the system's behavior (Robinson & Torjussen, 2020). These patterns of consistency reduce ambiguity, make learning more accessible, and support mutual intelligibility between human and animal actors (Mancini et al., 2016; Wirman & Jørgensen, 2015).

Habituation, a gradual exposure to a stimulus to reduce stress, is essential when animals encounter unfamiliar artifacts (Hirskyj-Douglas et al., 2021). Researchers often scaffold these introductions by building on trust established in known environments, thereby easing transitions into new interactional contexts (Mancini et al., 2015). For example, introducing drones as a research tool requires habituation and a phased, animal-centered design and evaluation process to minimize stress, while considering the animals' welfare and sensory capacities (Foster et al., 2019; C. Kresnye et al., 2021).

However, while familiarity reduces anxiety, it also carries the risk of disengagement when stimuli become overly predictable. Particularly in enrichment scenarios, the absence of novelty can undermine the stimulating quality of interactions, leading to reduced interest (Hirskyj-Douglas et al., 2021). For example, Andreou et al. (2023) address this challenge by designing enrichment toys with multiple detachable parts that can be combined in various ways during different play sessions. While consistent embodied interactions foster trust, novelty sustains engagement.

Ultimately, when introducing new tools to animals in study designs, factors such as comprehensibility, consistency, habituation,

and novelty intersect to shape trust in relationships and influence both the selection of artifacts (Kleinberger et al., 2023; Linden et al., 2019; Pons et al., 2015) and the physical environment.

DISCUSSION: RETHINKING RELATIONAL AND INTERDEPENDENT RESEARCH TOOLS FOR “ENRICHMENT” AND “ATTUNEMENT”

MtH-IxD emphasizes the relationalities among participating actors by empowering all those affected by the design (Chisik & Mancini, 2019). Amplifying marginal voices through co-designed analog and digital technologies and interactions enables a relational design practice by shifting the gaze from dominant narratives to a plurality of voices and knowledges (Kambunga et al., 2023). Following Escobar’s concept of relationality (Escobar, 2018; Escobar et al., 2024), which challenges modernity’s separations between nature-culture, subject-object, and human-non-human, we reexamine the role of research tools in justice-oriented multispecies design as agents within entangled networks of becoming-with. Rather than solely categorizing tools by how they enrich, encourage, or embody justice-oriented participation, we further consider how they contribute to creating relational worlds.

From Domestic to Ecological: Expanding Enrichment into Unstructured Environments

Enrichment in ACI typically involves stimulating animals’ natural behaviors through interactive devices, learning tools, or monitoring systems (J. Cunha et al., 2024; Kleinberger et al., 2020; Scheel, 2018). As our findings show, these systems are often designed for human-controlled environments such as homes, shelters, or laboratories: spaces where interaction can be structured and monitored. These contexts enable the tailoring of tools to meet species-level and individual-level needs (Holder et al., 2021; Schneiders et al., 2024), ensuring safety, predictability, and habituation (French et al., 2021; Mancini et al., 2016). Yet, they also reflect and reproduce human dominance, shaping how participation and interaction occur. Kneile et al. (2025) report a similar outcome in their review, noting that the majority of nature-human interaction study designs utilize research artifacts that emerge from direct human experiences in everyday life and remain embedded within domestic settings.

Our analysis suggests the need to expand enrichment practices into non-human-controlled environments, such as forests, roadsides, and urban ecologies, where relational dynamics are more balanced, unpredictable, and shaped by multiple species. In these settings, tools operate under controlled conditions and adapt to shifting environmental and rela-

tional contexts. For example, scent-based tracking sensors (Paci et al., 2019b), modular toys for wild or semi-wild enrichment (Andreou et al., 2023), or open-ended interactive sound devices used in field contexts (Dema et al., 2020) illustrate how tools can be designed to respond to environmental change and multispecies presence, rather than manage it. Multispecies interaction research requires additional research tools to operate effectively in uncontrolled settings.

Building on Escobar's call to move design into the pluriverse—where many species and lifeworlds matter—and our findings that trust, agency, and engagement are strengthened when animals can act on their own terms, even in uncontrolled settings (Escobar, 2018), we argue for research tools that support more relational, adaptive, and justice-oriented approaches. Such tools move beyond “enriching” behavior and support relational engagements that reflect animals' own rhythms, choices, and interactions with unpredictable ecologies. When research tools are designed to adapt to, rather than control the environment, they help shift MtH-IxD research toward more relational and justice-oriented approaches.

Tools of Attunement: Designing Situated Understanding Across Multispecies Actors

From a relational perspective, understanding is a mutual becoming within entangled, co-constituted lifeworlds (Escobar, 2018). From this perspective, tools used to facilitate interspecies sense-making—whether through sensors, symbolic translations, or embodied routines—should be seen as active participants in weaving relational ecologies.

Across the reviewed studies, researchers design tools that make animal signals visible, audible, or tactile through technological mediation, such as musical feedback systems, spectrograms, or behavior-linked visualizations (Dema et al., 2020; Erceg & Palamas, 2023). These tools do not simply translate behavior into data; they also co-produce how entities interact with each other in their relational space. For example, tools such as wearable sensors, leash-based interfaces, and button-based panels enable animals to initiate, consent to, or disengage from interactions (J. Cunha & Rhoads, 2020; Hirskyj-Douglas et al., 2021; Sadetzki & Hirsch-Matsioulas, 2021). This supports the notion that sense-making is an evolving, negotiated process grounded in reciprocity and agency.

As noted, research tools are often used in human-controlled environments such as labs, indoor spaces, or domestic settings, where stimuli, feedback, and interpretation are structured mostly by human expectations. In contrast, studies conducted by researchers such as S. Y. Liu et al. (2019)

and Soro et al. (2018) demonstrate how designing for ecological attunement in outdoor settings involving a group of multispecies actors challenges these assumptions. In these environments, dialogues inherently emerge between species, meanings emerge relationally, and technologies must operate with greater sensitivity to all actors in the network. Our findings support the importance of developing attunement tools that can adapt to living and non-living entities, enabling noticing, improvisation, and embodied interpretation even in ambiguous and fluctuating contexts.

This aligns with Escobar's call to design for the pluriverse—where many worlds coexist—and supports a design stance that resists epistemological flattening (Escobar, 2018). Instead of assuming that better translation solves asymmetry, our findings confirm that decentering the human and designing for shared temporalities, mutual rhythms, and situated knowledges between actors fosters deeper relational attunement (Akama et al., 2020; Rodgers et al., 2023). This is why, to include and design-with animals in ethically grounded ways, we should reimagine technologies as companions in multispecies interaction, making them flexible, co-responsive, and capable of inhabiting wild, entangled ecologies where understanding is always partial, situated, and unfolding.

Takeaways for Designers:

1. *Reframe tools as participants:* View research tools as participants in relational ecologies. For example, instead of using a button purely to trigger food, design it so animals can explore, play, or make choices by turning the tool into a co-actor.

2. *Design for entanglement:* Embrace messy, entangled contexts beyond controlled environments to allow more fluid multispecies interactions. For instance, placing an enrichment device in a shared forest space may invite different animals over time, prompting designers to adapt tools to shifting ecologies.

3. *Prioritize reciprocity over control:* Design for reciprocity and attunement rather than directionality or control. For example, a touchpad that lights up differently based on an animal's interaction enables ongoing two-way communication rather than just human-defined outcomes.

4. *Support ongoing relationships:* Foster ongoing relational practices with attention to how tools shape and are shaped by the relational fields they enter. For example, a touch-activated wall panel in a shelter that plays familiar sounds can help animals build routines and reduce stress through repeated, trusted interactions.

| Themes | Affordances and Intentions | Articles | Number |
|--|--|---|--------|
| Tailoring to Species and Individuals' Needs. | Accessibility for animals, accepting differences, designing for species-specific requirements, minding individual differences, acts of care (comforting, setting boundaries). | Andreou et al., 2023; Aspling et al., 2015, 2018; Brown et al., 2023; Foster et al., 2019; French et al., 2015; Holder et al., 2021; Kleinberger et al., 2024; Kliman-Silver, 2020; C. Kresnye et al., 2021; K. C. Kresnye et al., 2019; Linden et al., 2019; Mancini et al., 2012, 2015; Mancini & Lehtonen, 2018; Mankoff et al., 2005; Paci et al., 2019b; Pollastri et al., 2021; Robinson et al., 2014, 2015; Ruge et al., 2018; Ruge & Mancini, 2019; Sadeztki & Hirsch-Matsioulas, 2021; Schneiders et al., 2024; Smith, 2021; Wakkary et al., 2023. | 26 |
| Participation, Consent, and Agency. | Choice and control, voluntary interaction, animals as stakeholders, being part of the community, considering animals' preferences, flattening hierarchical relations, empowerment. | Andreou et al., 2023; Aspling et al., 2015; Bell et al., 2024; J. Cunha et al., 2024; J. M. Cunha & Renguette, 2022; J. Cunha & Rhoads, 2020; Dema et al., 2019, 2020; French et al., 2015, 2017, 2020; Gupfinger & Kaltenbrunner, 2019; Hirskyj-Douglas et al., 2021, 2024; Jackson et al., 2013; Kleinberger et al., 2020, 2023; Kuznetsov et al., 2011; S. Y. Liu et al., 2019; Mancini et al., 2012, 2015; Mancini & Lehtonen, 2018; Mankoff et al., 2005; Morrison et al., 2020; Noz & An, 2011; Paci et al., 2019b; Pons et al., 2015; Robinson & Torjussen, 2020; Rodgers et al., 2023; Ruge et al., 2018; Sandbhor et al., 2021; Scheel, 2018; Schneiders et al., 2024; Sheikh et al., 2021; Smith, 2021; Wakkary et al., 2023; Wallis et al., 2017; Webber et al., 2020; Westerlaken & Gualeni, 2014, 2016; Ziegler et al., 2021. | 41 |
| Interspecies Sense-Making. | Understanding interaction, understanding emotions, searching for meaning, imitating to understand, teaching/training the animal, empathy, interpretation of actions, monitoring, awareness, somatic understanding. | Aspling et al., 2018; Bell et al., 2024; Brown et al., 2023; Byul et al., 2016; J. Cunha et al., 2024; J. M. Cunha & Renguette, 2022; J. Cunha & Rhoads, 2020; Dema et al., 2020; Erceg & Palamas, 2023; Foster et al., 2019; French et al., 2017; Gaver et al., 2019; Gupfinger & Kaltenbrunner, 2019; Hirskyj-Douglas et al., 2021, 2024; Hirskyj-Douglas & Webber, 2021; Holder et al., 2021; Jackson et al., 2013; Kasuga et al., 2017; Khot & Yi, 2020; Kleinberger et al., 2020, 2023, 2024; Kliman-Silver, 2020; C. Kresnye et al., 2021; K. C. Kresnye et al., 2019; Kuznetsov et al., 2011; Linden et al., 2019; J. Liu et al., 2018; S. Y. Liu et al., 2019; Mancini et al., 2015, 2016; Mankoff et al., 2005; Noz & An, 2011; Oliver et al., 2021; Paci et al., 2020; Pollastri et al., 2021; Robinson et al., 2014, 2015; Robinson & Torjussen, 2020; Rodgers et al., 2023; Ruge et al., 2018; Ruge & Mancini, 2019; Sadeztki & Hirsch-Matsioulas, 2021; Smith, 2021; Soro et al., 2018; Wallis et al., 2017; Webber et al., 2020; Westerlaken & Gualeni, 2016; Ziegler et al., 2021. | 51 |

Table 4: The summary of themes; associated affordances and intentions of research tools; contributing papers; and the number of studies within each theme

| Themes | Affordances and Intentions | Articles | Number |
|------------------------------------|--|---|--------|
| Relational Trust-Building Dynamics | Relationality and interdependency, familiarity, feeling responsibility, creating safe space, routine and novelty, reliability and consistency, encouragement | Andreou et al., 2023; Aspling et al., 2015; Bell et al., 2024; Brown et al., 2023; J. Cunha et al., 2024; J. M. Cunha & Renguette, 2022; Dema et al., 2019, 2020; Erceg & Palamas, 2023; Foster et al., 2019; French et al., 2020; Gaver et al., 2019; Hirskyj-Douglas et al., 2021; Hirskyj-Douglas & Webber, 2021; Holder et al., 2021; Khot & Yi, 2020; Kleinberger et al., 2020, 2024; Kuznetsov et al., 2011; Linden et al., 2019; J. Liu et al., 2018; S. Y. Liu et al., 2019; Mancini et al., 2012, 2016; Markazi & Magee, 2023; Oliver et al., 2021; Pollastri et al., 2021; Rodgers et al., 2023; Scheel, 2018; Schneiders et al., 2024; Sheikh et al., 2021; Soro et al., 2018; Wakkary et al., 2023; Wallis et al., 2017; Webber et al., 2020; Ziegler et al., 2021. | 36 |

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