Privacy Notice Design for Humanoid Social Robots in the Home: Child-Centered Co-design Study

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Abstract

This research investigates user-centered privacy notice design for humanoid social robots in domestic environments. Through a co-design study with 20 child–parent pairs, we identified distinct mental models of preferred privacy notices and control mechanisms across the two groups. Children favored social, embodied cues, whereas parents preferred persistent, explicit, and technically grounded signals. Our qualitative analysis also revealed a pronounced "surveillance anxiety," particularly around robot mobility and autonomous movement within the home. Building on these findings, we derive five design implications: (1) the dominance of LED light as the preferred visual modality; (2) dialogue as a complementary channel that affords semantic clarity; (3) anthropomorphic placement that maps notice signals onto body regions matching the underlying sensor; (4) the emerging potential of pose and gesture as embodied state signals; and (5) age-dependent modality preferences that call for adaptive designs across developmental stages. Across parent participants, participants expressed a strong desire for meaningful control and active management of their personal data. We argue that privacy notices for domestic robots should move beyond screen-based terms of service toward embodied, multimodal cues paired with interactive approval mechanisms—supporting more transparent and accountable human–robot interaction in the home.

CCS Concepts

• **Security and privacy → Human and societal aspects of security and privacy**; **Social aspects of security and privacy**;

Keywords

Human-Robot Interaction, Privacy Notice, Humanoid Robot, Domestic Social Robot

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1 Introduction

Domestic social robots available to consumers today offer a broad range of capabilities, supported by multiple communication channels. By integrating advanced sensors with AI technologies—including machine learning, natural language processing, and computer vision—these systems have substantially enhanced Human–Robot Interaction (HRI), drawing on real-time contextual data to deliver adaptive, personalized, and increasingly human-like engagement [4, 11]. However, the integration of advanced features into domestic social robots to facilitate complex interactions introduces significant privacy challenges, amplifying both risks and vulnerabilities associated with their use [8, 9, 16, 18].

1.1 Children's Privacy Vulnerability and Needs of Usable Privacy Notice for Social Robot

Deploying these robots in private spaces such as households raises specific concerns about surveillance and eavesdropping [7, 10, 13, 17, 19]. Homes are dynamic environments shared by long-term residents and temporary visitors who span a wide range of ages and levels of technological literacy, making it difficult to manage data collection and sensor control through software alone. These challenges are especially acute in households with children, who can be uniquely vulnerable [5, 15]. Children frequently exhibit a notable gap between their fluent use of digital devices and their understanding of the associated privacy risks, leaving them unaware of the long-term consequences of data sharing [12, 20, 21]. Compounding this gap, children tend to view social robots as trustworthy peers and are therefore more willing to disclose secrets and personal information during interaction [3, 14, 15, 18]. They may also uncritically accept incorrect information from robots or be overly tolerant of robot malfunctions [15]. Prior work has established a *Privacy Design Space for Privacy Choices* for IoT technologies, providing system designers and privacy engineers with essential elements for constructing comprehensive privacy notices [6]. By contrast, commercially available social robots typically lack clear on-robot privacy notices and offer only limited privacy controls, leaving users uncertain about how their data is collected and managed [1, 2]. Unlike traditional digital devices, however, the physical embodiment and social cues of robots can support a more intuitive and contextually grounded understanding of privacy. Through a co-design study with parents and children, we examine users' mental models to inform a socio-technical approach that addresses these gaps—making privacy notices an integral part of HRI that promotes transparency and agency without imposing the 'consent fatigue' typical of traditional digital interfaces.

2 Research Questions

RQ1. What privacy notice configurations regarding modality, placement, and duration do participants expect for privacy-related features during interactions with a domestic social robot?

RQ2. How do participants perceive and express privacy concerns regarding humanoid social robots in the home, and what specific mechanisms of control do they anticipate to maximize their sense of privacy protection and benefit?

3 Methodology

The study was conducted in a domestic setting to maximize ecological validity, grounding participants' perceptions of privacy in the real social and physical contexts in which such concerns naturally arise. We used the humanoid social robot NAO, and designed the interaction to encourage participants to explore and imagine its capabilities through a range of hypothetical scenarios presented during the co-design sessions. 20 parent-child dyads were recruited as participants. While the primary focus of the co-design activities was the children, parents joined toward the end of each session to provide feedback and help refine the children's designs. The study was organized as two-day co-design sessions: a card-sorting activity on the first day, and a drawing exercise paired with a semi-structured interview on the second. Each session lasted 60–90 minutes. Our goal was to understand how children preferred to interact with robots around privacy, and to identify which notice modalities were most preferred and most readily understood. For analysis, we applied *content analysis* to both the visual and verbal data, providing an objective, systematic, and quantitative description of the manifest content of communication. We complemented this with *thematic analysis*, focusing on recurring themes and elements across both activities to capture the evolution of participants' mental models.

4 Results

Dominance of "LED Light" Across the four sensor categories, Light was the most frequently selected modality, accounting for 31 of 85 selections (36.5%), followed by Dialogue (21.2%) and Sound (20.0%); Pose (12.9%), Gesture (4.7%), and Physical Cover (4.7%) trailed. Children consistently mapped each sensor's "state of awareness" to a colored or blinking LED placed on a body region close to the sensor's function: the Eye and Chest LEDs for the Camera, the Head and Chest LEDs for the Network, the Feet and Ear LEDs for Locomotion, and the Eye and Chest LEDs for the Microphone. Preferred colors included red, green, blue, and white, with several participants proposing multi-color blinking patterns. However, color choices were largely driven by personal preference rather than any communicative or social convention—e.g., "I choose the color blue because I like blue"—rather than a deliberate semantic mapping.

The emerging potential of pose and gesture. Collectively, the embodied modalities—Pose and Gesture—accounted for roughly 18% of all initial preferences (n=15/85n=15/85 n=15/85), suggesting that children perceive the robot's physical body as a primary medium for communication and expect it to convey its intentions through whole-body language. After participants selected their preferred behavioral modality, we asked them to physically model the corresponding pose to serve as a design reference. The resulting representations included kneeling (P5), a running pose (P10), and turning around (P13). Children's framing of the robot as a social entity led them to design privacy notices that functioned as social signals; for example, P19 created a "listening pose"—lifting an arm beside the ear—to indicate that the microphone was active.

Dialogue as a Modality for Semantic Clarity Dialogue was the second most preferred modality (n = 18, 21.2%), concentrated on the two most personally invasive sensors: Camera (35%) and Microphone (30%). Children valued dialogue for its semantic clarity, proposing explicit state announcements such as "Camera is on" and "The microphone is on, I am listening now." For Locomotion, children extend dialogue from announcement to consent: P15 expects the robot to ask, "I am coming into your room. Are you okay with that?" before entering private spaces.

Social presence of robots among younger children. A critical finding of this study is the developmental divergence in modality preferences between younger children (ages 7–9) and older children (ages 10–12). Younger participants showed a high sensitivity to the robot's social presence, reflected in a marked preference for embodied modalities; they accounted for 14 of the 15 Pose/Gesture selections (93%). In contrast, older children preferred light and voice dialogue, reflecting an expectation of functional signaling consistent with their prior experiences with IoT devices such as smart speakers and tablets—an orientation also echoed in parents' interview responses. The near-absence of Pose and Gesture in the older group suggests that, as children mature, they move away from treating the robot as a socially present actor and begin to treat its notifications more like standard digital interfaces.

Duration Duration preferences varied systematically by sensor. *Touch away* was the modal duration for both Camera (7/20) and Network (8/19); *Disappear after X seconds* dominated for Microphone (8/20); and *Verbal command* was the strongly preferred duration for Locomotion, chosen by half of the participants (10/20). The concentration on verbal-command duration for Locomotion suggests that children expected physical movement to be *negotiated* with the robot rather than merely *announced*. Consistent with this interpretation, two of the three children who selected Dialogue as the Locomotion modality (P9, P12) also paired it with a verbal-command duration.

5 Conclusion

Our findings show that children interpret privacy notifications as part of a social dialogue with the robot rather than as purely functional data indicators—mapping the robot's awareness onto its body and expecting it to communicate through appropriate modalities before any sensitive action. In-home co-design provided greater ecological validity than a lab setting, surfacing privacy concerns in their real social and physical context. Together, these results suggest that moving beyond screen-based terms of service toward embodied, multimodal notices with interactive approval mechanisms is not merely a design refinement but a precondition for trust—one that strengthens children's comprehension of privacy and increases a family's willingness to integrate social robots into the home.

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