Making a Metaphor Sandwich: Analyzing Children's use of Metaphor During Tabletop Telepresence Robot Supported Participatory Design

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ABSTRACT
Strengthening telepresence for children can improve their educational and socio-emotional outcomes. Meanwhile, understanding how children conceptualize new technologies supports designers to create engaging and intuitive interactions for them. In this pictorial, we explore children's relationship to a promising and emerging approach to telepresence–tabletop robots. We analyze metaphors children used to describe a tabletop telepresence robot platform during 2-years (~100 hours) of online participatory design with this technology. We use illustrations to convey and contextualize how children imagined the tabletop telepresence robots. We find that children used three categories of metaphor in their imaginings: (1) robot capabilities (magic/fragile), (2) robot roles (competitive/play-acting/creative), (3) robot agency (remote controlled/autonomous). We discuss these metaphors in the context of existing child-robot interaction, tangible interaction, and telepresence literature. Finally, we contribute the theoretical framework of a "metaphor sandwich" to describe children's use of mixed metaphors during high engagement with the tabletop telepresence robots.

Authors Keywords
Physical telepresence; Online Collaboration; Participatory design; Children; Child-Robot Interaction; Metaphor analysis

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CSS Concepts
• Human-centered computing
~ Human computer interaction (HCI) ~ Interaction devices
~ Haptic devices

INTRODUCTION
Telepresence refers to technology supported remote communication and collaboration [11]. In schools, telepresence empowers children facing disability or geographic constraints by providing inclusive, peer-centered education to homebound learners [18, 75]. Telepresence also supports children's socio-emotional well-being [20, 31, 61], connecting them with faraway family and friends [77, 78]. However, mainstream approaches to telepresence (i.e. video calls and co-working software) limit participation in valuable off-screen activities such as craft [6] and play [2, 7, 58].

Past research has explored how task-space video projection [77, 78] and roving telepresence robots [1, 72] can improve telepresence for children. Task-space video projection gives children a view of faraway tabletops to support shared play and making [77, 78]; and roving telepresence robots enable playful touch and spatial interaction [18, 71]. However, each of these approaches also face limitations. Task-space video systems tether children to a stationary device and lack tactile interaction [78]. Whereas roving telepresence robots face navigational challenges because of their size and leave child users out of tabletop activities [23, 27, 72].

Tabletop telepresence robots are an emerging approach to telepresence which enable tactile engagement with faraway tabletop activities [42]. They are portable, small, lightweight, and represent a promising avenue for remote creative collaboration [41, 42]. Early research has also explored the use of tabletop telepresence robots to support play and making for children [73, 35]. However, little is known about how children interpret or relate to these systems.

As a result, despite the promising capabilities of tabletop telepresence robots, there is a gap in understanding about how to produce engaging and intuitive experiences for child-users of these platforms. To learn more about how children conceptualize tabletop telepresence robots, this pictorial analyzes a longitudinal online design effort with KidsTeam UW–an intergenerational participatory design group–to create a tabletop telepresence robot system for children. Specifically, this work considers the metaphors used by our 17 child design partners (aged 8 - 12 years) during the 2-year (17 session) participatory design effort.

Metaphors reveal people's thinking process by illuminating how they connect unfamiliar concepts to existing frames of reference [16, 40, 49]. Through an analysis of video collected during our intergenerational participatory design (PD) effort, we identify three thematic categories composed of seven total sub-themes addressing children's use of metaphors to describe their interactions with and via the robots. This analysis provides insights into how designers might create tabletop telepresence robot activities that children can personally connect to and find familiar [4, 5].

Our approach is inspired by previous research in human robot interaction (HRI), which evaluated participants' use of metaphors to understand how they employed existing cognitive models to make sense of robots [3, 81]. For instance, Fanny et al. analyzed the metaphors children used during educational robotics activities to gain a deeper understanding of factors shaping their robot literacy and inform future educational robotics materials for them [26].

From our analysis, we find that children used metaphors to describe: robot capabilities (magical and futuristic, or helpless and needing care), robot roles (competitors, characters, or creative partners), and robot agency (representation of collaborator or autonomous agent). In this pictorial, we present illustrated examples of each category of metaphor, adapted from our video data. These illustrations allow us to convey a cohesive picture of how children imagined the robots in the context of our platform, instead of relying on written description to attempt to capture this dynamic.

In addition to these three thematic categories, we also find that children frequently mixed metaphors from several themes while they used the platform to its full capacity (supporting crafting or play via remote control and direct manipulation). We consider how mixing metaphors during tabletop telepresence robot activities enables children to interpret tabletop telepresence robots by: addressing their preconceived ideas about robots [7, 50, 62, 63], overlaying familiar activities onto the robots [32, 33], and considering their tendency to interpret tele-operated robots as autonomous [28, 74].

Building on this, we introduce the theoretical framework of a "metaphor sandwich," to describe the complementary mix of metaphors children used while deeply engaged with our platform. With this metaphor sandwich model, we propose a "recipe" for designing tabletop telepresence robot activities which consider the expectations and prior experiences shaping children's interactions with these platforms.

RELATED WORK

Children's Conceptual Models of Robots

Understanding how children conceptualize robots is crucial for developing child-robot interactions that align with their intuition and assumptions, to make platforms that are easy to learn and use. For example, Rubegni et al. delved into children's interpretations of scenes involving a social robot, shedding light on their fears and hopes regarding the future of robotics to inform the design of social robots for children [62]. Similarly, Fortunati et al. investigated children's imaginings of robots, offering insights into the foundation of their cognitive models (largely shaped by popular media) and the characteristics they attribute to robots, such as anthropomorphism [28].

While previous studies have explored various aspects of children's perspectives of robots [10, 28, 63] such as analyzing their drawings of robots [29, 50, 53, 56, 68], or their interpretations of images or stories about robots [14, 47, 62, 76]; it is less common to explore children's conceptual models of functioning systems [8-10, 24, 26, 74], especially during long-term use [36]. Instead, research about functioning robot systems more commonly focuses on how children *use* robots [34, 39, 61], instead of how they *conceptualize* their use.

Nevertheless, studies about children's perceptions of robots in use provide an invaluable perspective about how they make sense of these platforms in context. For instance, Fanny et al. found that children used metaphors to understand robots' abstract capabilities (e.g. comparing RAM to a post-man carrying packages), and increase their immersion in robot-based activities (e.g. calling the robots "little rascals") [26]. And Bartlett et al. found that when children interacted with a robot resembling a dog, they considered it "closer to living dogs" compared to the abstract and mechanical-looking robots also provided during the study [7].

Children's perceptions of robots are closely related to robots' shape [47, 67, 76]. For example, when Woods et al. asked children about their perceptions of robots with a diverse set of appearances, they found that participants agreed that robots with a human-like form had feelings and could understand them, while those that resembled machines could not [76]. We see an opportunity to examine children's conceptualizations of tabletop telepresence robots, because these platforms are visually distinct from both the common ways that children imagine robots [28] (being human-like in neither form nor function), and the robot platforms that have been at the center of past child-perception research [7-9, 26, 36].

By analyzing the metaphors that our child design partners used to describe their interactions with and via our tabletop telepresence robot platform, we contribute new insights about children's conceptual models of tabletop telepresence robots.

Physical Telepresence for Children

Physical telepresence refers to the integration of tangible interaction into remote communication [11, 44, 69]. Similar to real-time coworking software, physical telepresence supports

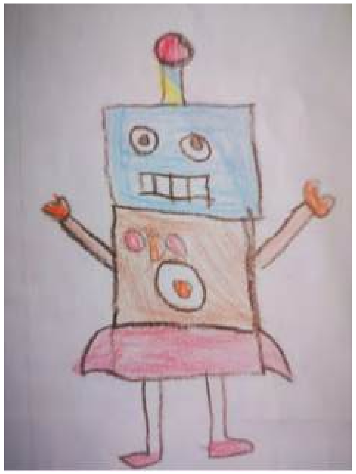


Fig. 1. A child's drawing of an anthropomorphic robot from research by Secim et al. which explored children's robot illustrations.[68]

shared task-spaces to improve remote collaboration by increasing social presence and shared context between teammates [59]. Contrasting to graphical user interface (GUI)-based telepresence–physical telepresence incorporates the physical world–supporting applications like artifact design [42, 69] and educational demonstration [44, 45].

Past research has explored how to extend the benefits of physical telepresence systems (such as tangible interaction, social presence, and shared context) to children. For instance, the ShareTable project found that top-down projection and tabletop video feeds encouraged children and their physically distant parents to engage in joint interactions around familiar artifacts, such as books and toys [78]. Meanwhile, many projects have investigated how commercial telepresence robots might support remote teaching and learning in education [2, 18, 55, 75]. For example, Newhart et al. explored how telepresence robots include homebound children in classroom activities [55], and Ahumada-Newhart et al. examined how these robots help remote children express their identity and form friendships at school [2].

Because tabletop robot systems are versatile, low-cost, and can leverage consumer-available components, they have emerged

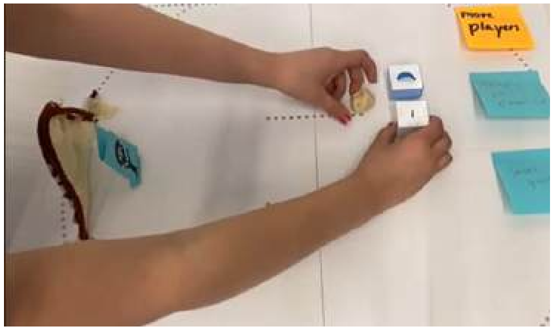


Fig. 2 A child arranges toio robots in a game she designed. Two other children are controlling these robots via our telepresence platform, competing to score a goal.

as a particularly robust approach to physical telepresence [41, 42, 45, 70]. However, while limited research has explored the adaptation of tabletop robots to telepresence applications for children [35, 73], this pictorial is the first work exploring children's perceptions of these systems. In particular, we analyze children's use of metaphors across video data collected during a participatory design effort *with children* to design tabletop telepresence robots *for children* [22].

Cooperative Inquiry Online

Cooperative Inquiry is a sub-discipline of participatory design. Where PD is a broad approach, encompassing inquiry that involves stakeholders in the design process [37, 63], Cooperative Inquiry focuses on techniques and practices that support intergenerational collaboration between children and adults [22, 80]. In particular, Cooperative Inquiry seeks to mediate power dynamics between adults and children and empower children to share design ideas [22]. Consequently, Cooperative Inquiry is a method for producing technology that integrates children's preferences and needs [21, 22, 30].

While the Cooperative Inquiry method originally focused on in-person collaborations, it has subsequently been adapted to online contexts [25, 35, 43]. During our study, we employed these adapted techniques for online participatory design with children, supported by the tabletop telepresence robots. Based on feedback shared by our child co-designers throughout the 2-year Cooperative Inquiry process, we iteratively adapted our tabletop telepresence robot system to their preferences. In this pictorial, we focus on *how children used metaphors to describe their interactions with and via these robots*.

Analyzing User Perception of Robots through Metaphor

Metaphors are foundational to developing intuitive technology [5, 38, 49, 54], because associative reasoning enables users to construct cognitive models about unfamiliar experiences through comparison with familiar concepts [16, 19]. Correspondingly, analyzing metaphors employed by users to describe interactions with unfamiliar technology results in a deeper understanding of how these users make sense of their experiences [26, 40]. Previously, researchers exploring the PD of human-robot interactions have analyzed the metaphors used by participants during the design process, observing how they use these comparisons to interpret robots.

For instance, Alves-Oliveira et al. evaluated metaphors used during a design workshop about the future of robots to learn how artists and academics conceptualize what a "robot" is [3]. Meanwhile, Zhou et al. focused on metaphors used by interaction designers while producing affective haptic experiences, in order to understand how designers make sense of emotional robotic touch [81]. Inspired by these studies which examined the metaphors participants used to describe robots during PD, we conduct a similar analysis of the metaphors used by our child design partners during the PD of a tabletop telepresence robot platform.

SYSTEM DESCRIPTION

During this study, we utilized online Cooperative Inquiry techniques to develop a tabletop telepresence robot system according to children's suggestions. Children were provided with materials and equipment to get started with the platform (next page), which used a web-hosted GUI to connect to and drive remote and local robots, supplemented by Zoom video.

Throughout the 2-year study, features were iteratively added and improved based on children's feedback. For instance, three pre-programmed movement buttons were added: dance, shuffle, and party, based on children's ideas to add "robot emotes" to the platform. Additionally, we added support for USB game controllers in response to children's requests.

Shared crafting is essential to in-person Cooperative Inquiry [22], but limited by online settings. The tabletop telepresence robots were introduced to strengthen online Cooperative Inquiry processes, by enabling children to share ownership of the physical artifacts they created.

METHODS

In this pictorial, we present a qualitative case study [52, 79] analyzing video data from online participatory design sessions. During these sessions, children provided design ideas and feedback about our tabletop telepresence robot platform, while using it to collaborate with one another to complete design activities. In this section, we describe our participatory design process, data collection, and qualitative analysis.

Online Cooperative Inquiry

During this project, we engaged in 2-years of online PD with children at KidsTeam UW, an intergenerational co-design group of children aged 8 to 12, to produce a child-centered tabletop telepresence robot platform [35]. During PD sessions, we employed techniques for online Cooperative Inquiry [25, 35, 43]. From March 2020 to February 2022, we conducted 17 sessions with KidsTeam UW, using these co-making sessions as the basis for iterative changes to the tabletop telepresence robot platform. All online PD sessions and breakout groups were recorded using Zoom video.

During these sessions, we asked KidsTeam UW to either use the platform to design or make design suggestions for the platform (Fig. 3). These prompts provided the opportunity for children to use the robots and reflect on their experiences with them over time, informing their design suggestions for the platform.

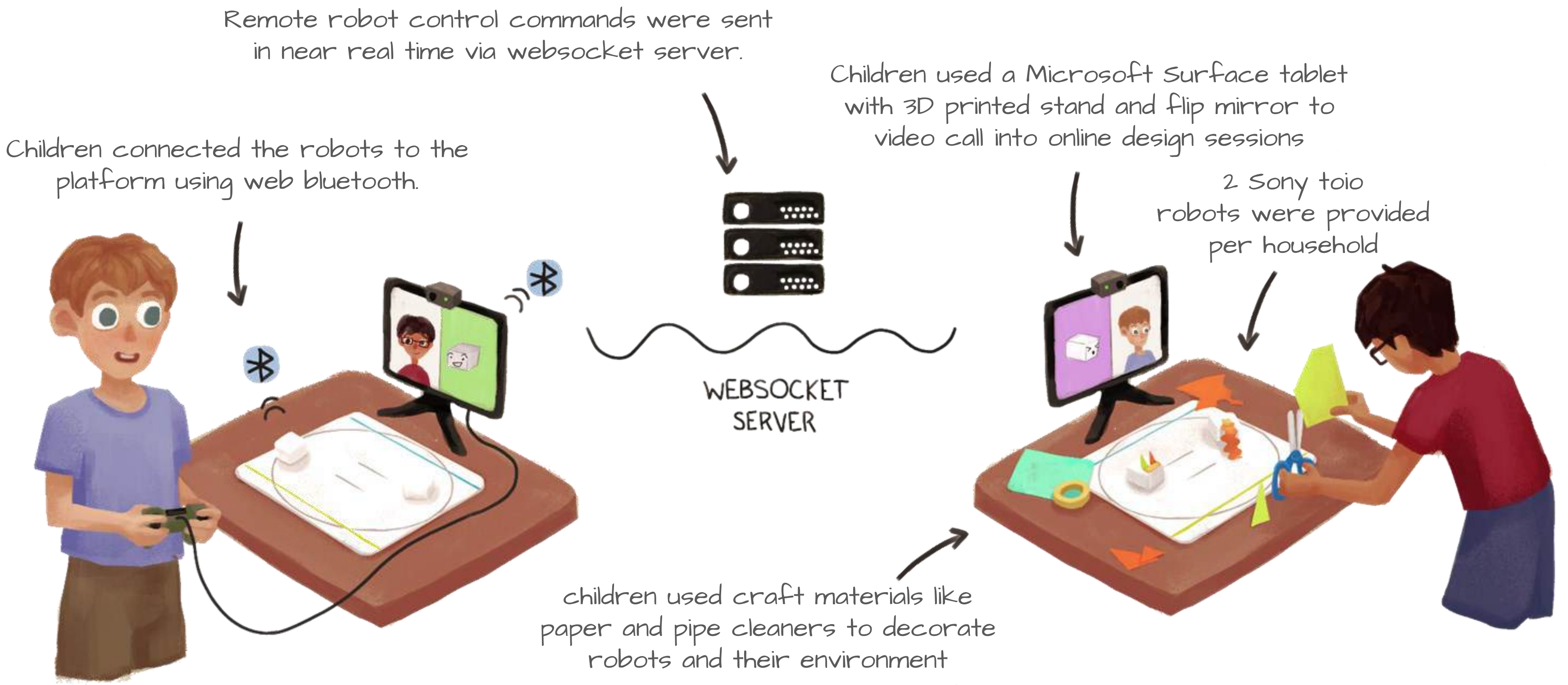
Context and Participants

The 17 child participants, that we collaborated with at KidsTeam UW are developmentally ready for design while remaining experts in children's perspectives [20]. KidsTeam UW considers ethnicity, socioeconomic status, gender, and age during recruitment to ensure that selected children represent diverse perspectives. During each online PD session throughout our study, child participants collaborated closely with researchers (graduate or undergraduate students and faculty) from computer science, industrial design, and child-computer interaction. In this pictorial, we analyze video data collected during the 17 online PD sessions using Zoom.

System Setup

Using our web-based GUI, children could select and control any robot connected to the platform (remote or local) with on-screen controls or a USB game controller. Zoom video was used during the synchronous online design sessions, enabling a view of remote children's robots and designs.

Initially, children were introduced to a proof-of-concept robot control GUI which enabled simple remote and local robot movement (forward, back, left, right) via the website. During design sessions, children used the platform to drive robots with collaborators, decorated robots, and moved robots around by hand.



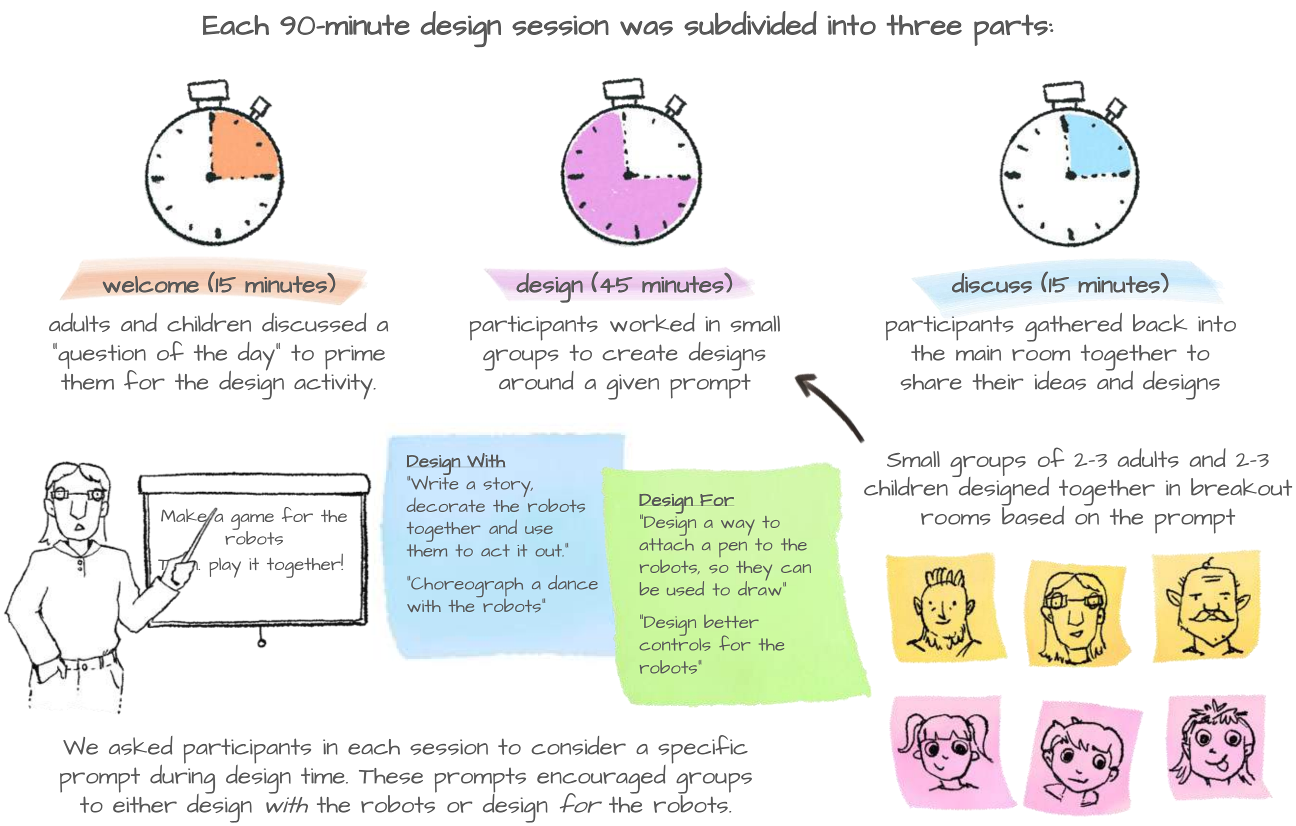


Fig. 3 The routinized structure we followed during each design session with KidsTeam UW

Data Analysis

To evaluate the metaphors used by children while interacting with the tabletop telepresence robots during our study, we analyzed video data recorded during online PD sessions. To process the over 100 hours of videos, first, seven coders (graduate students and faculty) generated analytic memos describing 10-minute segments of the design session recordings using an open inductive process [17, 60]. During this memoing effort, a codebook was developed and applied to the data through iterative discussions. Additionally, the research team (coders plus advising faculty) engaged in paired coding reviews, then met weekly to resolve any coding disagreements [4, 51].

From these memos, two student coders performed a deductive selection, using the following criteria to identify a sample of metaphors used by children throughout the recordings: (1) children use comparisons/references to describe or refer to the tabletop telepresence robot platform, (2) children use/discuss familiar cultural objects/concepts (i.e. jump rope, video games) during design sessions. Within this deductive selection of analytic memos, we conducted thematic coding based on an open analytical approach using grounded methods [17]. From these codes, the research team used reflexive thematic analysis to interpret and condense the patterns observed in children's use of metaphors while interacting with or via the robots into three thematic categories and seven sub-themes [12, 13].

FINDINGS

In this section, we present the three thematic categories (robot capabilities, robot roles, robot agency) of metaphor that children used to describe their interactions with and via the tabletop telepresence robots during our PD inquiry. Each of the following three pages correlate with each theme, and pages are subdivided into the corresponding sub-themes that emerged during our analysis.

Co-Occurrence of Themes

Although we categorize each type of metaphor separately, children often blended metaphors across multiple categories and sub-themes when describing their interactions with the robots. For instance, when a group of children played "monster robot soccer together," they considered a combination of the competition and character roles, with representative agency. In addition, they discussed how the robots would enact the monsters' magical powers, delving into their capabilities.

At times, children applied only one category of metaphor to the robots. For example, one child decorated his robots to "joust" but could not drive due to a low battery–in this case, he considered the robot role only. Likewise, in some PD sessions, children discussed the robots without actively crafting for or moving them. In these scenarios, children tended to rapidly generate ideas using a single metaphor category. During one such brainstorm, children suggested "a button to make your robot stronger", a robot parachute, and a robot that can shop for groceries. Here, the focus was solely on the robots' capabilities, not their roles or agency.

In both of these examples, the use of a single metaphor coincided with interactions where children only used the robots as passive props. In contrast, we find that children's use of mixed metaphors accompanied scenarios where they engaged substantively with the platform. For instance, while playing "monster robot soccer together," the children decorated the robots as monsters, built a soccer field for them, and drove them to enact the scenario as a group.

We note that across these scenarios, the robot platform remained the same, but children's level of engagement with it varied significantly. And, in instances of heightened engagement, children were more likely to mix metaphors across thematic categories and sub-themes.

Theme 1: What capabilities do the robots have?

While children designed and played, they used metaphors to describe the robots' capabilities. These metaphors fell into two sub-themes: helpless and needing care or magic and futuristic.

When the robots encountered difficulties, children felt responsible to help them, like catching them when they fell from a high height or tipping them back onto their wheels when they toppled over

Children used verbs like "save", "help", "rescue", and "give" to describe their caring actions toward their "helpless" robots.

Contrasting with the robots' simple appearance and small size, children described them as having magic and futuristic capabilities. Even when the robots faced limitations, children still interpreted them as having fantastical abilities (e.g. when one robot was stopped by an "indestructible post-it note").

Children suggested that the robots might shape-shift and hover in order to help around their houses by doing chores, painting the walls, and checking their homework. In these cases, the children described the robots' fantastical abilities.

Theme 2: What <u>roles</u> do the robots play?

During design sessions, the children imagined and crafted scenarios for the robots. They used metaphors to describe three types of roles (sub-themes) for the robots during these activities: competitors, characters, and creative partners.

Children adapted familiar games for the robots such as sports and video games.. During these scenarios, the robots most often took on the role of competitors.

In one common scene, the robots "wrestled", battling to push their opponents off of the table first

When children were asked to write and act out stories, they chose to use the robots to play the role of characters in their scenarios.

One group of children used their robots to tell their story about a lawbreaking Roomba. Another decorated the robots to play Mario and Luigi in their production.

Children used robots as part of their creative processes. For example, attaching a pen to them for drawing. In these moments, children referred to robots as creative partners.

Sometimes, children danced with the robots. In these instances, the robots darted about in unpredictable ways, inspiring the children to giggle and wiggle their bodies (and robots) too.

Theme 3: Who has the agency to make decisions for the robot?

Although children understood that all robot movements required a robot pilot, their interpretations of who made decisions for the robot were more complex than "object moved by faraway child". Instead, they considered the robots as one of two sub-themes: representations of collaborators or autonomous agents.

At times, children described the robots as extensions of the child piloting them (e.g. Sarah's robot). Or, the robot might even be considered a tiny stand-in for the remote collaborator controlling it (e.g. "that's Alex").

Mara drives the robot alongside Aiden. The two children write their names together. In this instance, Aiden imagines the robot as a representation of Mara, embodying her goals and motivations.

In contrast, children sometimes considered the robots to have a "mind of [their] own", acting as independent and autonomous entities with their own plans and ideas.

This description of robots as autonomous agents was especially common when many children controlled the robot at once, causing their individual commands to blend together into the "robot's" decisions.

Olivia draws pictures with a robot. Although the robot is being moved remotely by a group of her colleagues, she refers to the robot's actions not as a combination of their ideas but as if it were its own, autonomous entity.

DISCUSSION

In our findings, we identified three categories and seven sub-themes of metaphor used by children when describing tabletop telepresence robots. In addition, we highlighted that–during instances of deeper engagement, children were more likely to mix metaphors across categories and sub-themes

In this section, we consider each category of robot metaphor in the context of existing literature. Then, we present a theoretical framework–the metaphor sandwich–that addresses how children's use of mixed metaphors corresponded to richer engagement with our tabletop telepresence platform. Finally, we sum up why and how "making a metaphor sandwich" might strengthen children's interactions with tabletop telepresence robot systems

Robot Capabilities: Futuristic or flawed? Actual and imagined limitations of robots

Research finds that children hold complex perspectives around robot capabilities: simultaneously acknowledging and embracing their fallibility [63], while also attributing seemingly limitless potential to them (such as being extremely strong [62] or emotionally intelligent and empathetic [28]). However, little is known about how children's existing cognitive models about robots' capabilities translate to small, abstract, tabletop robots. Malinverni et al. emphasized the need to explore children's perceptions of different forms of robots [50]. And Bartlett et al. found that children considered robots' similarity in appearance and movements to familiar objects and animals when forming their understanding of robot capabilities (such as assigning human-like empathy to humanoid robots) [7].

Despite the small, abstract, and fragile form of the toio robots used in our study, we found that children still attributed fantastical capabilities to them such as super strength and exceptional knowledge. Also, this remained the case even when children were confronted by the actual limitations of the technology. At the same time, we find that children considered the robots' weakness or flaws as an opportunity to provide them care and protection.

From this finding about children's cognitive models of tabletop telepresence robots, we infer that *future tabletop telepresence robot designs for children can support more engaging experiences by employing scenarios about robots' potential or fictional magic and futuristic capabilities, as well as robots' actual and imaginary fragility to encourage children to care for and protect them.*

Robot Roles: Cultural forms for child-robot interaction

Cultural forms are recurring patterns of interaction which are familiar enough to act as cognitive shortcuts [15, 65]. For instance, shaping elements of a tangible interaction system like jigsaw pieces to imply they should be slotted together [32]. Horn et al. concluded that cultural forms provide context for children using tangible interaction systems, which can otherwise be unfamiliar and unintuitive [32, 46]. By referencing familiar interactions, tangible interaction systems structured around cultural forms hint at how artifacts should be moved and manipulated [33].

Similarly, we found that children relied on references to cultural forms during use of the tabletop telepresence robots–reshaping and adapting familiar roles for the robots to play. We highlight that children's metaphors about robot roles were based on three cultural forms: competitive play, play acting, and creative collaboration. This finding suggests that, like designers of tangible interfaces for children, robot designers can also leverage familiar cultural concepts to make interactions with robots feel familiar and intuitive to child users [4]. In particular, we find that *designers should leverage familiar roles like competitive play, play acting, and creative collaboration to scaffold otherwise unfamiliar telepresence robot experiences for children*.

Robot Agency: How tabletop telepresence robots impact children's perceptions of remote collaborators

Despite our tabletop telepresence robots' actual functionality, which required control actions by remote drivers, we found that children at times considered the robots to be autonomous agents. This is consistent with past research by Straten et al., which concluded that informing children that robots were remotely controlled by study facilitators resulted in them being less likely to report that the robot was autonomous. However, that this act of disclosure did not completely eliminate children's tendency to assume robots were acting on their own [74].

Meanwhile, in their study of telepresence robots in college classrooms, Schouten et al. employed the term 'robomorphism' to describe a phenomenon where remote participation via robot resulted in students attributing robot-like characteristics to remote classmates [66]. Similarly, we interpret children's metaphors about the autonomous actions of tabletop telepresence robots to be the result of robomorphism. In other words, we found that at times the robots in our study caused such severe robomorphism that children attributed their remote colleagues' actions to the robot itself. We highlight this finding because–although children reportedly understand that robots are subject to outside control [62]–in practice, they sometimes conceptualize remotely operated robots as fully autonomous anyway [74].

As a result, children do not always associate remote colleagues with the robots they operate. Therefore, remote robot operation does not guarantee improved social presence for children. Instead, we conclude that *there is an opportunity to further explore interventions which might mitigate robomorphism related disruptions to social presence in child-centered telepresence robot systems*. For instance, designers might create "avatars" of remote operators, like Ma et. al, who found that customizing tabletop telepresence robot appearance strengthens social presence of remote co-workers' in hybrid meetings [48].

Theoretical Framework: Making a Metaphor Sandwich

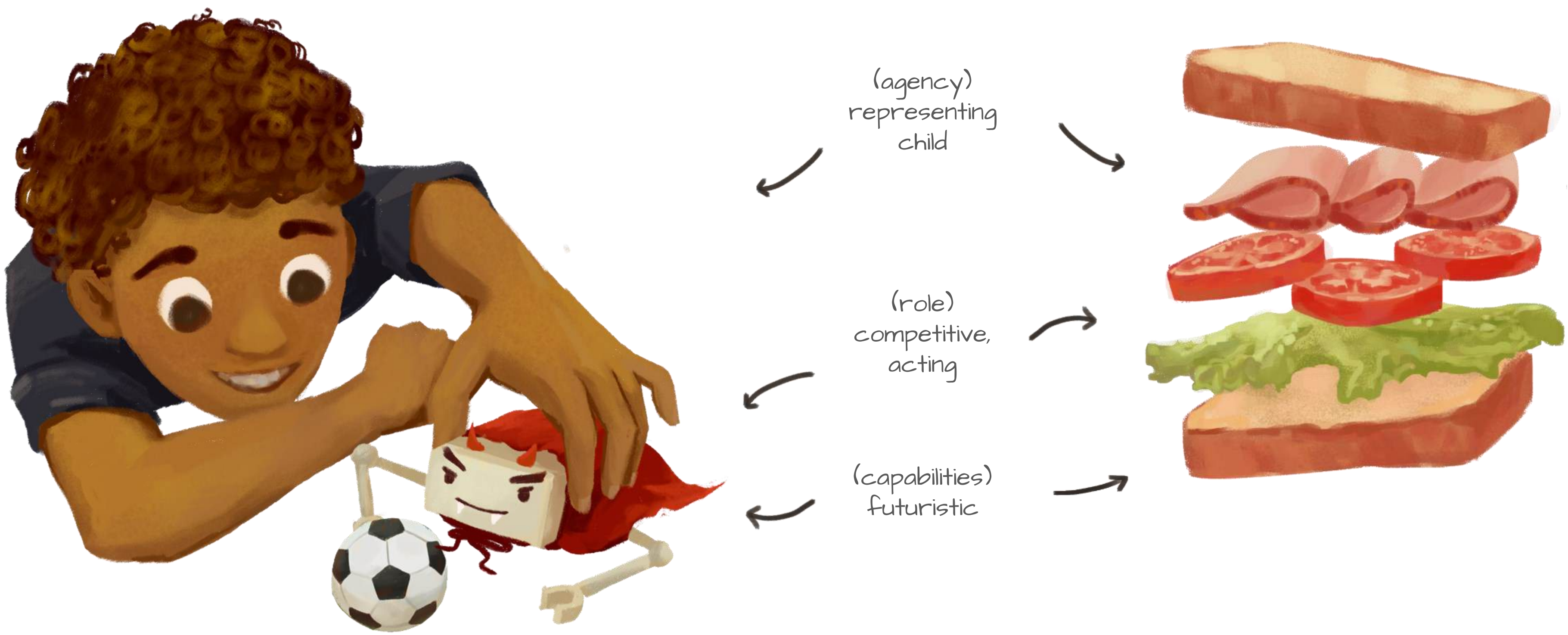
In this study, we found that children were more likely to employ mixed metaphors to describe robots during periods of high engagement with our telepresence platform. Considering how our metaphor themes cut across theories from child-robot interaction [7, 50, 62, 63], tangible interaction [32, 33], and telepresence robot literature [66, 74]–we conclude that mixed metaphors might make these unfamiliar systems more legible and engaging to children by touching on a combination of their relevant pre-conceptions about tabletop telepresence robots.

To highlight how mixing metaphors can produce richer experiences for child-users of these systems, we present a theoretical framework of "making a metaphor sandwich." The metaphor sandwich model captures the cross-domain complexity at play in tabletop telepresence robot interactions for children that emerged during our study as a "recipe", seeking to scaffold designers of these systems.

We found that when children were most engaged, they tended to use mixed metaphors to describe their robots.. To capture this characteristic of children's use of mixed metaphors, we propose the metaphor sandwich model.

Similar to a sandwich, which is more delicious because of its many components, children's experiences were strengthened while using mixed metaphors compared to when they used each "ingredient" (metaphor theme) alone. Metaphor sandwiches are powerful, because they address overlapping theories from child-robot interaction, tangible interaction, and telepresence robotics which contribute to children's cognitive models about tabletop telepresence robots.

While imagining his robot playing robot soccer, Kieran is making a metaphor sandwich. He considers how his robot represents him, as it acts like a vampire while using its collapsible legs to dribble a soccer ball.



By incorporating multiple categories of metaphor (robot capabilities, roles, and agency) into their framing of tabletop telepresence robot interactions, designers can account for the many theories that influence children's experiences of these platforms at once.

Each ingredient of a sandwich can be taken alone–bread, vegetables, or meat–but they are more delicious and satisfying when combined together. Similarly, we found that children combined several metaphors across categories and sub-themes to enrich their shared experiences with the robots, such as "playing monster soccer together." In this scenario, children combined metaphors about robot roles (competitive play, play acting), agency (representative), and capabilities (magic). Whereas, when children used one "ingredient" alone, such as brainstorming robot capabilities that might help around the house, they were less likely to use the robots to their full capacity, instead often playing with them as merely props.

This model also highlights how, just as bread is foundational to a sandwich, robot capabilities are foundational to mixed metaphors about tabletop telepresence robot platforms. First, because children's imaginings about robot capabilities are governed by the robots' appearance–forming a first impression of these systems, and shaping subsequent interactions with them [7, 50]. But also, because imagining how robots might compete, act, or create (roles) and represent colleagues or move autonomously (agency), requires an understanding of the attributes they use to accomplish these goals (capabilities).

The metaphor sandwich model emphasizes how complex and imaginative combinations of metaphors can deepen child-robot interaction in telepresent scenarios. This conclusion may be counter-intuitive, as designers might assume that *simplifying* interactive experiences for children, especially in novel contexts such as tabletop telepresence robotics, would produce more intuitive and engaging experiences. However, we find that the complexity afforded by mixing metaphors actually enriches children's experiences with these platforms.

This idea of combining metaphors for child-robot interaction is unique. Although past works have explored how children conceptualize robots through metaphor, in order to facilitate the design of experiences with robots that children can relate to [26], the metaphor sandwich model considers how *mixing metaphors can strengthen children's experiences with tabletop telepresence robots*.

This conclusion echoes how tabletop telepresence robots for children cut across existing knowledge bases in the literature, encouraging designers to simultaneously acknowledge: (1) the robots' strengths and weaknesses, like other child-robot systems [4, 62, 64]; (2) the use of cultural forms to guide interaction, as tangible interaction systems for children [32, 33]; and (3) the impact of remote control on children's' perceptions of one another, as explored in telepresence robotics research [66]. By making metaphor sandwiches, designers can produce experiences that children can connect to and immerse themselves in. For example, asking children to drive the robots (agency) like zoo animals (role) that are acting out a play (role), using their magical ability to speak (capability) provides a richer experience than merely asking children how the robots could act like zoo animals (role).

However, just as a sandwich can be disgusting if the flavors inside clash, even if it is made of delicious ingredients, we highlight the inherent risk involved with the added complexity of mixing metaphors. Although defining effective metaphor combinations is outside the scope of this pictorial, we underscore the need for careful "culinary" or creative practice from designers using the metaphor sandwich model. Rather than formulaically picking metaphor "ingredients" and assuming they will function well together, designers of child-centered tabletop telepresence robot interactions must consider whether their mixed metaphors are compatible. Like a chef tastes their own recipes before serving them to others, we encourage designers to reflect on whether their metaphor sandwich is inspiring or overwhelming before introducing it to children, and to incorporate children's feedback to refine their "recipes".

LIMITATIONS AND FUTURE WORK

This pictorial provides insights about how children conceptualized tabletop telepresence robots during 2-years of online PD with KidsTeam UW to produce a tabletop telepresence robot system for children. We see potential for the metaphor sandwich model to be relevant for broader child-robot interaction and child-centered telepresence communities. However, our research is limited by its specificity. In particular, our conclusions are bounded by the context (online Cooperative Inquiry) and technical approach (tabletop telepresence robots) of this study. As a result, more research is needed to understand whether the metaphor sandwich model we propose might apply to children's interactions with technologies other than tabletop telepresence robots.

That said, we hope that the specific insights from this work will inspire the development of future child-centered tabletop telepresence platforms. We believe these technologies represent a promising avenue for child-centered telepresence, as they are relatively easy and low-cost to build and deploy. Because advancements to child-centered telepresence can improve the accessibility of education [18, 75], as well as children's socio-emotional well-being [57, 78], we hope to contribute to the continuous improvement of this domain. Specifically, we highlight the need for further research to define best practices when applying the metaphor sandwich model. Our study does not address *how* to make a delicious metaphor sandwich, merely that child-centered tabletop telepresence activities can be strengthened by the use of mixed metaphors.

CONCLUSION

In this pictorial, we analyzed a longitudinal participatory design effort to produce a tabletop telepresence robot platform for children–taking a close look at the metaphors children used when discussing and interacting with the robot platform. Through this analysis, we gained clues into how children make sense of tabletop telepresence robots. Specifically, we found that children made connections to describe what the robots were capable of doing (their magical characteristics and knowledge, or their weakness), what roles the robots played (competition, storytelling, and creative practice), and the robots' agency (controlled by a colleague or autonomous).

Finally, we introduced the metaphor sandwich model–highlighting that designers of tabletop telepresence robot systems for children should consider mixing metaphors to address a combination of robot capability, role, and agency to produce experiences that are familiar and intuitive for child users. We underscore that care should be taken to ensure that "ingredients" of the sandwich (mixed metaphors) are complementary by engaging children to iterate on "recipes", as clashing "ingredients" (component metaphors) may diminish the benefit of this approach.

SELECTION AND PARTICIPATION OF CHILDREN

Children at KidsTeam UW are recruited through word-of-mouth, mailing list, and posters. Parents/guardians provided consent and were briefed on study goals, safety, privacy risks, and confidentiality during the consent process. Parents were also informed that children could withdraw anytime. Our undergraduate, graduate, and faculty researchers were all trained in child ethics and safety. When these adults facilitated co-design sessions, they made sure children did not feel any pressure to participate with the study activities. The study was approved by our university's Institutional Review Board, and all child data was anonymized and securely stored on the University of Washington server.

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