Bridges, Glitter, and *Spaceship Noises*: Young Children's Design Ideas for Communication Across Distance

Benett Axtell

School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada, benett_axtell@sfu.ca

Cheng Yin Zhu

School of Information Studies, McGill University, Montreal, Canada, cheng.y.zhu@mail.mcgill.ca xxxx@gmail.com

Carman Neustaedter

School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada, carman@sfu.ca

Young children (3-5 years old) benefit from social connections with distance-separated grandparents and other family, but can struggle to connect in common digital settings like Zoom calls due to asymmetric needs of different generations. Additionally, they cannot currently engage independently with asynchronous family communication, such as texting or sharing media, because existing technologies rely on literacy and technical skills beyond their development. In this paper, we present the results of a co-design probe with 12 young children, collecting and analyzing their ideas for independent communications technologies. Our probe is based on age-appropriate pedagogy, using make-believe play and an original story about astronauts to create a design space that supported their agency as designers. Our young designers' detailed ideas incorporated broader systems of communication. From those ideas, we present design considerations, including making connection and transmission across devices transparent and integrating learning about wireless communication into their everyday use.

CCS CONCEPTS • Human-centered computing~Interaction design~Interaction design process and methods~Participatory design • Social and professional topics~User characteristics~Age~Children

Additional Keywords and Phrases: co-design, distance-separated communication, design with young children

1 INTRODUCTION

When families are separated by distance, we turn to technology to support communication and social connection. However, these tools often fall short of meaningful socialization, particularly when the social needs are asymmetrical, such as between grandparents and young grandchildren [1]. Video conferencing offers some connection, but requires parents to scaffold the call, acting as mediators and tech support [1]. Texting or other forms of asynchronous sharing are inaccessible to preschool-age children (3-5 years old), who are generally pre-literate and often do not have independent access to their own device.

Previous works have outlined the different needs of young grandchildren and grandparents for social connection [17], and asynchronous communication tools have been explored with older children [40]. These demonstrate the importance of commonly asynchronous modes of communication, like messaging, across generations; asynchronicity balances the uneven motivations and needs between grandchildren and grandparents [17], as we expand on in the next section. Though designed to support asynchronous use, messaging and similar modes of communication can be used synchronously and offer the flexibility to move between different levels of synchronicity [10].

We provide a new perspective on child-inclusive family communication by involving young children directly in the design of communication tools that prioritize their needs for connecting with family. In this paper, we seek to understand how young children imagine asynchronous communication technology in order to create tools that support independent social interactions with their grandparents and other distance-separated family. From their design ideas, we aim to create tools for family communication that include young children as users alongside older children and family. Our research question for this work is: How do young children imagine tools for their independent communication with distance-separated family?

We used a design probe study to collect design ideas from young children directly while prioritizing their agency and independence as co-designers. Our study is based in Magic Thing Participatory Design to encourage creative, unexpected designs [22] and in Play-Based Design to create a space that enables young children to participate as co-designers [32]. Our probe materials guided the child co-designers to imagine themselves in a team of astronauts and to propose tools that help them communicate with the other astronaut team far away. Imaginative play and storytelling are common in co-design studies (e.g., fictional inquiry [13]). In this case, make-believe further helps the co-designers to access their highest levels of focus and abstract thought for their developmental stage [5].

We collect their design ideas directly, without adults as proxies, by recording audio for the duration of the in-home design activities. The young children described detailed communication devices as part of larger systems of technologies. We saw shared consistencies across how these young co-designers conceptualized their designs, separating distinct elements and tasks. They used rich science-based metaphors to describe how devices are connected and how messages travel along those connections. Our contributions are descriptions of these young co-designers' conceptualizations of distance-separated communication and the design opportunities those present for modern communication technologies.

We present the detailed designs of the child co-designers. From our analysis of their ideas, we discuss how current design norms of digital communication will need to shift to include these younger users. We present design opportunities to support independent communication between young children and their distance-separated family. We propose expanding the purpose of communications technology to integrate learning how systems work into use. With these contributions, we expand the understanding of family communication to include young children's ideas, thus far excluded, and show new opportunities for distance-separated family connections.

2 RELATED WORK

Co-design works with participants directly giving them conceptual tools to support their collaborative design with the research and/or design team [43]. Co-design research with preschoolers explores how to support their agency to imagine and communicate design ideas while minimizing bias from adult researchers [15]. When designing with preschool-aged children (3-5 years old), some common co-design tools are less effective due to limited literacy and drawing skills [6] as well as limited communication and ability to understand abstract ideas [29,32]. So, design activities are generally based in play. Using Vygostky's definition of play[1] – make-believe play that incorporates imaginary roles, props, and extended stories – young children act at a higher developmental level than is possible outside of that play [5]. This includes longer focus time and more complicated abstract thought. With access to this higher developmental level, young children are clearly capable co-designers, but whereas co-design generally expects written or drawn outputs, young children's ideas are primarily expressed through speech as part of play [32].

Previous co-design and participatory design (PD) studies with preschoolers have incorporated storytelling and play to connect to this high end of the Zone of Proximal Development, or upper limit of what a child can complete without adult guidance [16,32]. Through this play and by building trust and respect between researchers and young designers [12], preschoolers are able to contribute rich, complex design ideas through their play and the language they use to describe that play.

In this section, we first present previous works on supporting young children's communication with family, then considerations for asynchronous communications for older users, followed by co-design studies with children, including asynchronous distributed PD, and finally cultural and/or design probes with children.

2.1 Distance-Separated Family Communications with Young Children

Many novel designs have been proposed to support different generations' social connections across households (e.g., [4,9,10,18,33,39,40]), but many of these target older children or adults and rely on writing. Here we focus specifically on preschoolers and other young children and on tools for asynchronous communications.

Previous research has investigated how young children understand the systems and technologies that support asynchronous communication. These have found that preschool-age children struggle to understand how larger networks like the Internet are separate from individual devices and how they connect across devices [8]. Work with slightly older children (5-7 years old), found that children described most of their activities as being done on computers, and did not generally accurately distinguish which of those was done on the Internet [28].

Considering young children's preferences and priorities for family communication across distance, previous work has found that 3-5 year olds are excited by the prospect of independently communicating with family [17]. The same study also found that parents, grandparents, and grandchildren all see various benefits of asynchronous connections as children could initiate an interaction themselves without needing to plan ahead for the grandparent's availability, and grandparents could choose how and when to reply [17].An exploration of preschooler's message making in email found that with access to their own way to make messages, they gained technical literacy skills and developed different, unexpected uses for emailing [4]. One project designed a jack-in-the-box device to share selfies from 2-4-year-olds to their family and hid the communication element from the children based in the idea that they lacked the developmental capacity to understand, but found that children wanted direct control over their interactions and communication [34]. Another project used a tangible doll to give 3-6-year-olds agency over their communication with a travelling parent [30]. Children adapted the doll interface, such as by removing the controller, and extended the doll metaphor, like by trying to make it jump.

The space of independent asynchronous communication by young children has only begun to be explored, and from the examples we have found, presented here, no research has engaged preschoolers to design their own

[1] Called "mature play" or "advanced play" by other child development researchers.

communication tools. These examples show that pre-literate children want and could benefit from independent access to family communications, but that communication has not been made available to them even within previous works. Our work asks pre-literate children directly to design and demonstrate what they want for such a tool.

2.2 Asynchronous Communication between Friends and Family

Considering how asynchronous communications have been designed for literate users, mostly adults, we see more research that assumes their independent use and agency as users and explores how to incorporate more transparency into the asynchronicity of these interactions.

A tool for sharing objects and written or spoken messages between older children (6-10-year-olds) and their grandparents found that having a means of independent communication made the children want to use that independence, sharing more often and in more detail than with phones [40]. Having a device specific to grandparent-grandchild (5-10 years old) communication led them to develop new routines around that communication, but also that they desired more direct messaging including a broader range of media [18].

Research has also considered how to enhance the asynchronous aspects of these modes of communication. Work with pairs of adults has found that there is pressure to be always available despite the asynchronous design, and designed status cues to improve this [10]. Other work has incorporated movement information as a way to visualize a user's potential availability for a conversation right then [9].

These works show the variety of considerations being explored for so-called asynchronous communication more broadly. In this paper, we will consider these works in relation to the priorities of young children for asynchronous communication that we find through our co-design probe.

2.3 Co-Design with Young Children

Co-design and PD methods are often used to support children's agency as designers. Traditional PD methods have been adapted for younger participants in a variety of ways, often based in child development and classroom pedagogy [15,32]. Storytelling is a common framing device across design work with preschoolers [2,12,20,29] and aligns with what is known about child development.

Working with preschoolers, researchers have adapted classroom pedagogies into Play-Based Design, a PD methodology that allows children to communicate design ideas through role play [32]. Others have found that the younger preschoolers (3-4-year-olds) struggled more than 5-6-year-olds to stay on topic and researchers struggled to understand their designs [20]. Though the imaginative play of preschoolers can seem chaotic, researchers have found this can benefit co-design activities and encouraged adults to be apprentices and let children be the stewards of their design processes [12].

Distributed PDs have been explored, both synchronously and asynchronously, especially during the COVID-19 pandemic. We consider these examples in comparison to cultural and design probes, described next, which also incorporate co-design ideas into distributed and/or asynchronous settings. Being remote from researchers, child co-designers (8-12-year-olds) may be more distracted, but can also draw inspiration from their diverse surroundings [21]. When distributed co-design is also asynchronous, the prompting materials and data gathering tools need to be created with that in mind. For child co-designers (7-11-year-olds), audio recording can better support direct documentation of their ideas over text [41]. Support from parents or other known adults can both be helpful, for documentation or accountability, but can introduce bias, such as providing a more specific prompt than what researchers provided [35].

Our research draws on the ideas of playfulness and agency seen across these works to design story-based prompts and data collection creating space for preschoolers to act as co-designers independently and with agency. Next, we explore examples of cultural and design probes with families and continue with this framing.

2.4 Cultural and Design Probes with Children and Families

Cultural and design probes have been used with families and children of various ages to explore topics including education technology [42], distributed play [39], and game design [24]. These studies are broadly similar to distributed, asynchronous co-design, creating and delivering a set of activities for participants to complete remotely, but each probe is meant to be completed individually and gathers individual perspectives as compared to the group collaboration of PD.

Probes can gather ethnographic knowledge or design ideas directly from children in their familiar context (e.g., home or school). As with co-design, probes use storytelling prompts to support children's agency [16], incorporate "magic" into the study design [39], and collect a broad variety of data in return [42].

The asynchronous nature of probes allows for flexibility and creativity in when and how children engage with and interpret activities [24,42]. This can both limit and benefit the design process as returns may not be relevant to the intended topic, but also represent children's ideas as the primary data [16], as with distributed co-design. Children's design probes can include support from parents or teachers to prompt the child to engage with the activities at appropriate times, read instructions aloud, and record their returns (e.g., through audio or photographs) [16,42]. Audio recording during children's probe activities can document detailed descriptions of designs without needing adults to transcribe or interpret for them [16], but has so far been used as a tool to record responses to specific prompts, leaving room for unintended bias and missing context as the activities before and after the recording are missing.

Our story-based design probe builds on these previous examples, using uninterrupted audio recording to gather their design ideas including the surrounding context as primary data and a known adult to help with communication and documentation. We also ground our activities in classroom pedagogy to access preschoolers' highest level of development and to create a familiar space for them to play and share ideas.

3 METHOD

We used a design probe, adapted from Play-Based Design [32], to understand how preschoolers imagine novel communications technology, specifically asynchronous communications, that prioritize their independent use. By using a foundation in Vygotskian play, we give the participating children access to higher levels of focus and abstract thought than are generally associated with these young ages [5]. We designed our materials to guide children through the design activities with the help of a known adult apprentice or steward to their design process [3,12]. Our motivation is to support their participation in family social communication over distance, focusing on asynchronous aspects of communication which could support their convenient, independent use, as seen in previous work [17]. We did not present this specific focus to our co-designers, as we did not want to bring preconceptions of how technology should or can work, similar to Magic Thing PD studies [22]. Instead of a family-based prompt, which would reintroduce the potential biases of perceptions of existing technologies and practices, we use a science fiction setting to encourage outside-the-box design ideas for communication between teams of astronauts. This topic remains relevant to the topic of independent asynchronous communication, as astronauts do rely on communication between teams [19].

As one of the teams of astronauts, the child co-designer's task is to design the teams' communication "gadgets".

Ethical considerations informed all aspects of this study, including provisions to confirm children's continued to assent. This protocol was developed following Canadian principles (TCPS2) and was approved by our university's Research Ethics Board.

3.1 Participants

Families were recruited in the Canadian metropolitan areas of Montreal and Vancouver in community centres, childcare centres, and public libraries. We recruited families with at least one preschool-age child (3-5 years old). Adults were compensated with $40 (CAD), and children were compensated with stickers custom-made to match the design prompt story. Participants (adult or child) could withdraw from the study at any time with full compensation.

We intentionally designed all recruitment and study materials to respect the diverse range of relationships between children and adults and only referred to "grownup helpers" to not assume any particular relationship as the norm. Though in this case all participating adults were parents to the participating children, we chose to continue to refer to the children's "known adults" when discussing their social relationship and otherwise use "child co-designer" to refer to the participating children as our collaborators in proposing novel designs, and use "grownup helper" to refer to adults in their apprentice role.

In total, 12 children completed the design probe with a grownup helper; including two pairs of siblings who did the activities together. Four families spoke multiple languages at home (i.e., English and French or Mandarin), which is common for these cities. Members of the research team spoke all these languages. One child (P2) withdrew from the study after receiving the activity box, as they were not interested in the activity. Children's ages and genders were collected from grownup helpers during the preliminary meeting with a researcher. We did not gather other demographic information from participating children or adults, such as familiarity with modern technology, as we are specifically seeking out designs for their independence, which is not currently available. Future work can investigate how children's access to or familiarity with technology varies their design ideas. See Table 1 for participant details.

Table 1. Participant details. Siblings participated together and are included on the same row.

PID(s)	Age(s)	Gender(s)
P1	3	Boy
P3	5	Girl
P4	4	Boy
P5	3	Boy
P6	4	Boy
P7	3	Boy
P8, P9	3, 5	Girl, Boy
P10, P11	3, 6*	Boy, Girl
P12	4	Boy
P13	3	Boy

*P11 was 5 at time of recruitment, and turned 6 before the activity box was delivered

3.2 Materials

Study materials were designed and written considering the target age range to create a space for preschoolers to share design ideas. The materials are made of two main parts: the audio recording website and the design probe box.

3.2.1 Audio Recording Spaceship

We chose to collect audio of the play-based designing to provide a first-hand account from the children. The make-believe play of these young ages includes verbal interactions between characters (in this case, between the child astronaut and the grownup helper astronaut) and these spoken interactions often include descriptions of their actions and the reasons for these actions [5]. To do this, we created a custom website to record audio directly to our secure university servers. Several technical and practical considerations informed this tool's design. First, each participating family had a unique link and audio was recorded and stored separately. Next, audio capture recorded five minutes at a time with 30 seconds of overlap between each file. This was done to protect from loss, as hour-long files can be difficult to transfer between devices and if internet connection was lost or recording was otherwise interrupted, an entire audio file could be lost. By creating multiple files, most of the audio would be saved in case of technical issues. Finally, we designed the website to keep the device screen on programmatically as going to sleep would stop the recording. We designed the look of the recording website to match the spaceship of the other team of astronauts (see Figure 1). This provided a simple explanation to as to why the screen was on and near the activity: a reminder that they are working with another team of astronauts far away.

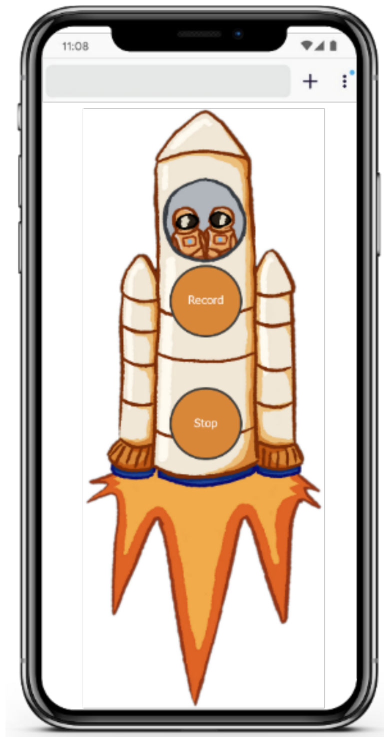

Figure 1: The audio recording webpage.

3.2.2 Co-design Probe Box and Activity Book

We designed the contents of the box based on STEAM (Science, Technology, Engineering, Arts, and Math) activity boxes (e.g., KiwiCo crates[2]), which deliver fun learning activities with colourful, playful materials to be completed with a known adult's guidance. We hired a children's book artist to illustrate both the activity book and stickers. Our co-design probe box (see Figure 2) contained the activity book, foam building blocks, markers, coloured pencils, blank pages, and stickers (the child co-designer's compensation).

[2] https://www.kiwico.com/

Figure 2: The contents of the design activity box.

The activity book was designed to establish the imaginative setting, the children as co-designers with agency, and our area of design focus (i.e., asynchronous communications technology). We describe the content of the book in detail in the next section.

Throughout the book, we used distinct fonts to indicate text meant to guide grownup helpers and text meant to be read to child co-designers. This does introduce some imbalance between grownup helpers and child co-designers, as instructions coming from adults could imply that adults are directing the activity for the children. We expected this to be mitigated by focusing the design activities around make-believe play accessing higher levels of development (defined in the Related Works section), in which children are generally comfortable to take the lead [32]. All child-focused language was written in consultation with two early childhood education and development experts to ensure it was age-appropriate and clear. See the supplement for the complete activity book.

3.2.3 Protocol

Before delivering the activity box, a member of the research team met with the grownup helper in a preliminary 30-minute Zoom meeting. The researcher explained the study, reviewed the consent form, and guided the grownup helper to familiarize themself with the audio recording website and test it with their device. The researcher also provided some guidelines to use during the activity, which largely followed common parenting practice. Grownup helpers were instructed to let children explain their designs without trying to make them seem plausible or possible. Since the majority of our data is audio, we also guided grownup helpers to repeat what a child had said when it was unclear (as young children are often difficult for strangers to understand) and to explain the children's actions if they were not clear from the audio. As adults often document their children's activities with pictures, we explained that they were welcome to do so during the activity and anyone who was interested in sharing those pictures with the research team could do so. One grownup helper (of P12) chose to transfer pictures to us, which we anonymized upon receiving.

This adult signed an electronic or paper consent form ahead of the box delivery, and confirmed that they would gather oral assent from the participating child before beginning the activity without pressuring them to participate. Families were expected to complete activities in one week, but could request to keep the box longer. The activities were designed to last 30-60 minutes, in line with preschool pedagogy [5]. Families completed activities by following the activity book's instructions in order.

The activity book starts with a letter to the grownup helper, reminding them of the study's purpose and their role as an apprentice (or helper astronaut). The letter also reminded them that design ideas can seem impossible or unlike familiar technology, and they should follow the child co-designer's lead and encourage the child's stewardship over the design processes. This reminder is often needed for adults, unlike child co-designers whose mindsets are often less limited [25].

The second page had a letter to be read aloud "to the astronauts", written in child-appropriate language (and the associated font). This established the imaginary setting from the start and communicated the consent form to confirm the child's assent. We intentionally designed all study materials for the child co-designer's informed and ongoing assent, as having a known adult directing activities naturally brings some pressure to participate even if that pressure is unintended [12].

The book then instructed the grownup helper to start the recording and to read the story. The story was a framing device for the make-believe play and design prompts. It also establishes the use of science fiction technology and need for asynchronous communication between teams. We chose the space theme to be familiar and exciting to our target ages, as outer space and astronauts is a common interest of preschool-age children [14], and to reinforce that the technology was not like our own. For these reasons, space is a common setting for children's design activities [13,20,32,38]. Astronauts exploring space is particularly relevant to the context of our work as communication between teams is crucial and astronauts will need to use their tools independently without easy access to others for support [19]. Our space theme is an on-topic prompt for the larger design space of independent communication that can encourage creative design ideas that are not limited by preconceptions about modern technologies.

The story is intentionally brief, considering the attention spans of preschoolers. We worked with the artist to depict the astronauts so that a diverse range of children could imagine themselves as those characters, including avoiding appearances that suggest a particular gender or race, as suggested by previous work [32].

The story establishes two teams of astronauts, green and orange, each with a gadget to help them communicate. The green astronauts (e.g., the team of child(ren) and grownup helper) are trying to communicate with their other team about a newly discovered flower (see Figure 3). We chose flowers to encourage designing for diverse types of media (e.g., smell, colour, texture). The child's task as co-designer was to design the gadgets used by the astronauts to communicate.

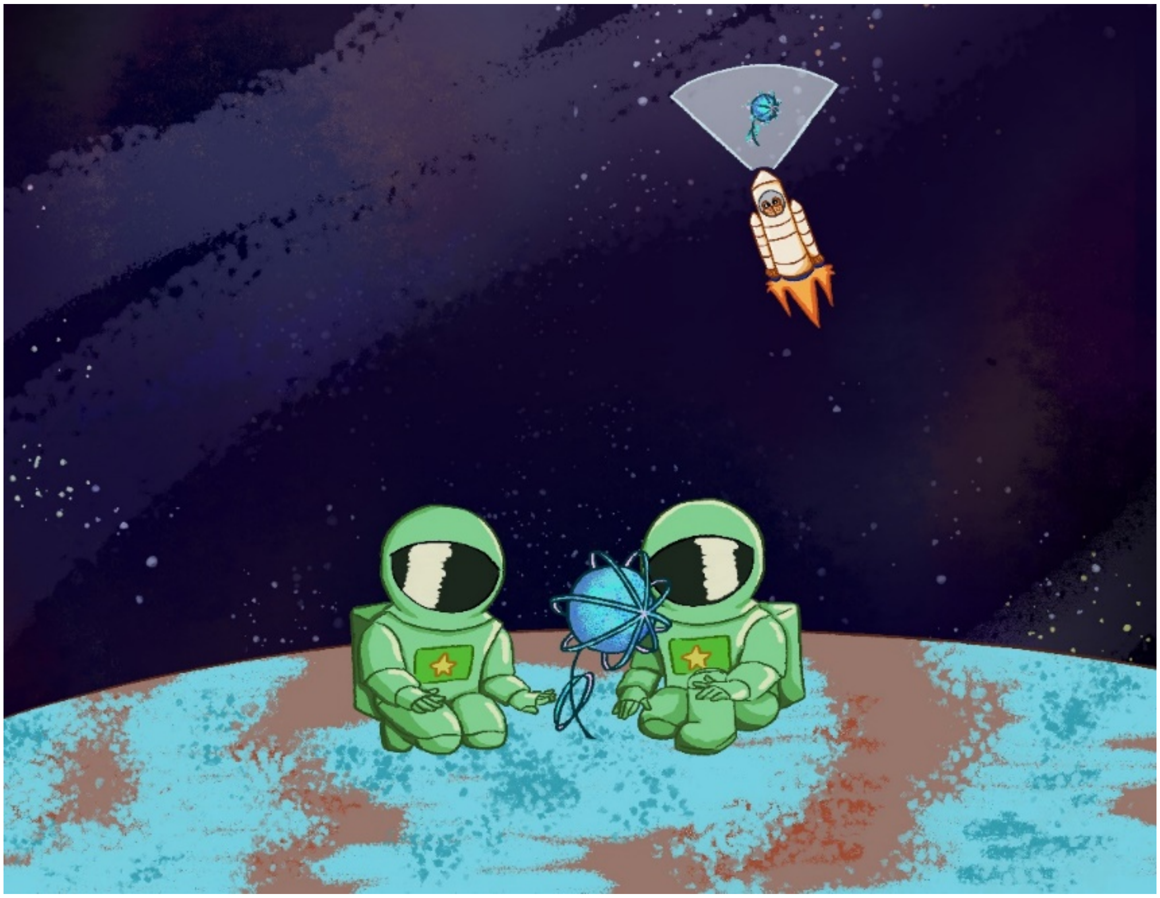

Figure 3: First illustration from the prompting story

Following the story, the book provided three design prompts (see Figures 4 and 5), each building on the previous one. We were careful to avoid prompt language that may bias the design ideas. For example, we chose to describe gadgets as “sharing” over “showing” to avoid bias towards visuals. Each prompt page includes the prompt, a space to draw with some story elements around it, as well as notes for grownup helpers. The notes reminded grownup helpers that they are helper astronauts and included example prompts to keep play on topic (e.g., “What does the gadget need so it can do that?”), as recommended by our child development experts and pedagogy [5].

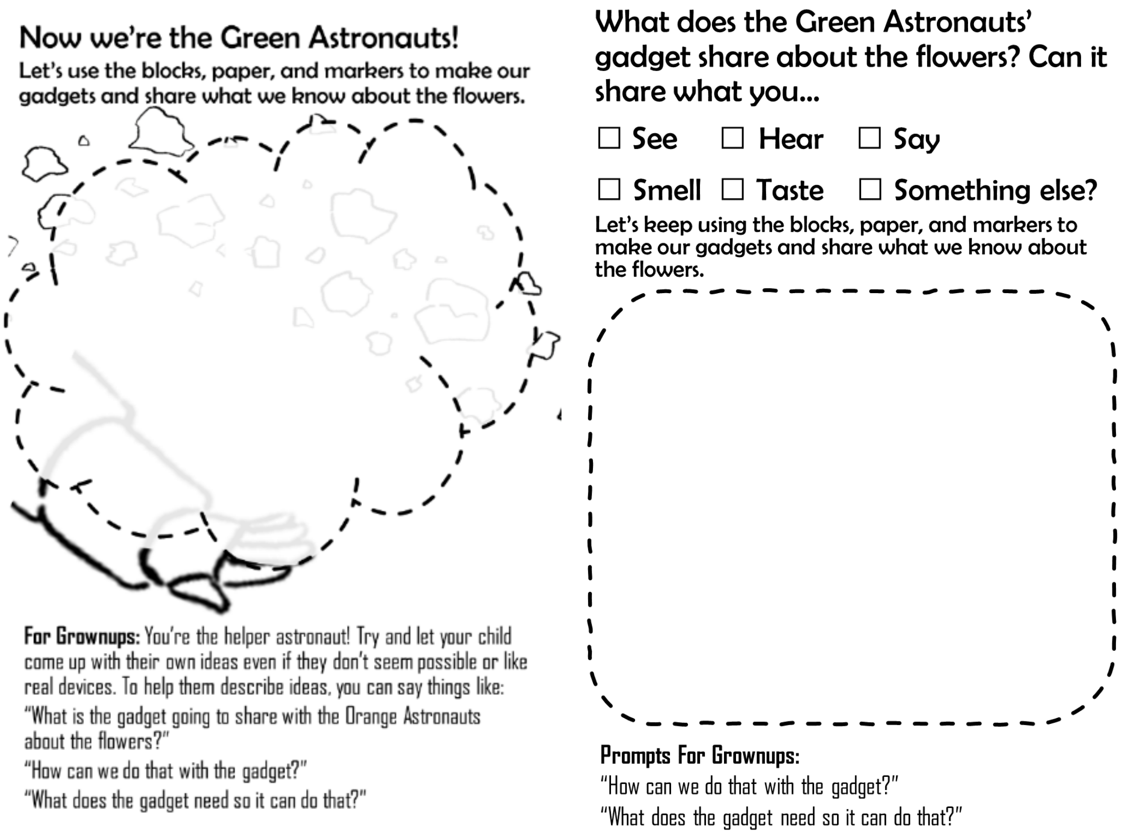

Figure 4. First (left) and second (right) design prompts in the activity book.

The first prompt (see Figure 4, left) was meant to encourage open play and imaginative ideas without prompting in a particular direction:

"What does the Green Astronauts' gadget look like? What does it share about the flowers?"

The second prompt (see Figure 4, right) builds on their initial ideas and asks specifically about what senses might be included. This page was not visible during the first prompt (i.e., the page needed to be turned) so the most open-ended prompt had to be considered first:

"What does the Green Astronauts' gadget share about the flowers? Can it share what you… See? Hear? Say? Smell? Taste? Something else?"

The final prompt (see Figure 5, left) asked co-designers to consider the two teams' gadgets together:

"What do the Orange gadget and the Green gadget do together?"

The book closed with two pages for unprompted drawing (see Figure 5, right) and lastly a reminder to stop the audio recording. These pages allowed for overflow design ideas or for any drawing at all.

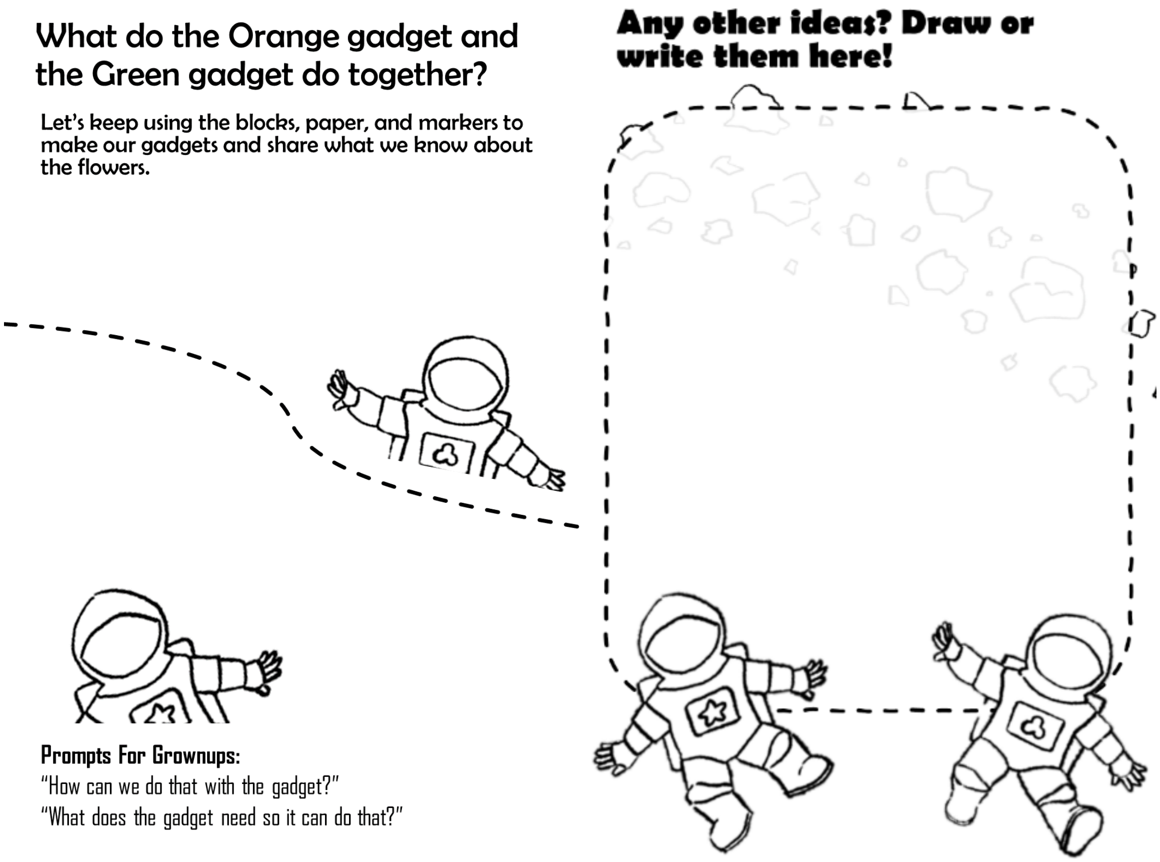

Figure 5. Third design prompt (left) and open colouring space (right) of the activity book.

Once completed, the box and all materials were returned to the research team and the grownup helper was compensated.

Two families included sibling pairs within our target age range (P11 was 5 at time of recruitment). As we based the study design in classroom pedagogy it was simple to adapt the protocol and materials for two children to complete together. We guided the grownup helpers of each sibling pair to have one child on each team of astronauts (i.e., one green and one orange), and included additional blocks and markers as well as two sets of activity books and stickers in the box. As they were interacting as separate teams of astronauts, siblings' design ideas were complementary, but not identical, to each other.

These activities were tested in a pilot session with three children, for which the first two authors were present as the known adults, resulting in the addition of colouring pages on the prompt pages. After the first participant, we made two minor changes to the book to focus on the desired topic. First, prompts were reworded to always mention the design focus on the flowers. For instance, the second prompt was initially "What does the Green Astronaut's gadget share?" without specifying flowers. Second, the green and orange astronauts on the final page were moved further apart (see Figure 5, right), as the child co-designer noted the astronauts were holding hands and therefore would not need communication gadgets.

3.2.4 Analysis

The collected data included audio recordings and completed activity books. Families had the option to keep the book, in which case the researcher digitized each page, digitally removing any identifying information. The audio was transcribed verbatim and participants' names or other identifying information were replaced with placeholders (e.g., "P1"). In the case of audio including multiple languages, transcriptions included the original language with English translations alongside.

The first two authors analyzed the data with inductive coding and thematic analysis [7]. We coded the first transcript together to create an initial codebook. We coded the remaining transcripts individually and met regularly to maintain a consistent codebook, following common practice for such small-scale qualitative data with a specific focus [26]. Example codes include "message goes into or onto gadget", "gadget sends message wirelessly", and "using logic from real world technology". When all transcripts were coded, we collaboratively grouped codes into themes based on our focus on understanding preschoolers' design ideas for their independent use of communications technology. In the next section, we describe each of these themes, supported by specific findings.

4 FINDINGS

Our child co-designers demonstrated detailed ideas of how their gadgets would work not only in communication with another team's gadget but also as part of a broader system of communication. We focus our findings here on the details of their designs in line with our goal of creating tools that support their independent communication with distance-separated family. As we are interested in the young children's independence, we do not include an analysis of the role of the grown-up helper in this work. As the audio recording included the full context of what was said during the activity, we are able to confirm that grownup helpers did not change the prompt wording provided so did not introduce additional biases or prompts to the activities. The child co-designers described the design and use of their gadgets verbally as part of their play, and throughout this section we use quotes from these descriptions to illustrate their points.

Many participants were initially hesitant to describe designs or unsure of how to start, and responded to the initial prompting saying, *"I don't know"*. We had expected this initial reluctance, common in co-design studies, and had instructed grownup helpers to repeat prompts and be patient as it can take some time for co-designers (of any age) to feel comfortable in the design space [25,32].

From our thematic analysis, we developed five themes, reflecting the detailed gadget ideas and consistent design elements seen across the ideas of the 12 child co-designers:

1. **Designing gadgets within a larger system**: Our child co-designers often described the surrounding world and technology around their gadgets first and then described gadgets within the context of that larger system of technology.
2. **Gadgets are standalone and multipurpose**: Many distinct tasks could be done in sequence with a single gadget, with elements for distinct tasks described as separate components of that gadget, similar to apps within a smartphone.
3. **Interactions with gadgets**: While describing gadget use, children showed the different parts and interactions required for it to work on its own, with another gadget, and within the larger system.

4. **Explicit connection between gadgets**: Children described how gadgets were connected across distance, often explained with visual or science-based metaphors.
5. **Messages move along connections**: Messages were delivered by or between gadgets along that connection and co-designers considered different ways that gadgets can manage that process.

Next, we provide an overview of gadget designs. We then detail the five themes with support from specific findings along with participant quotes and illustrations. Translated quotes are indicated after the quote with "+".

4.1 Gadget Design Overview

Our play-based activity successfully enabled children to describe at least one design for communication-based gadgets. Most used a combination of drawing and building with blocks to create visual representations of gadgets. As expected, these visual representations were generally not interpretable as a gadget design without description and demonstration by the child co-designer. This is in line with the developmental stage of 3–5-year-olds [5]. Designs from younger participants mostly resembled scribbles, while older participants' drawings were often interpretable with some guidance (see Figure 6).

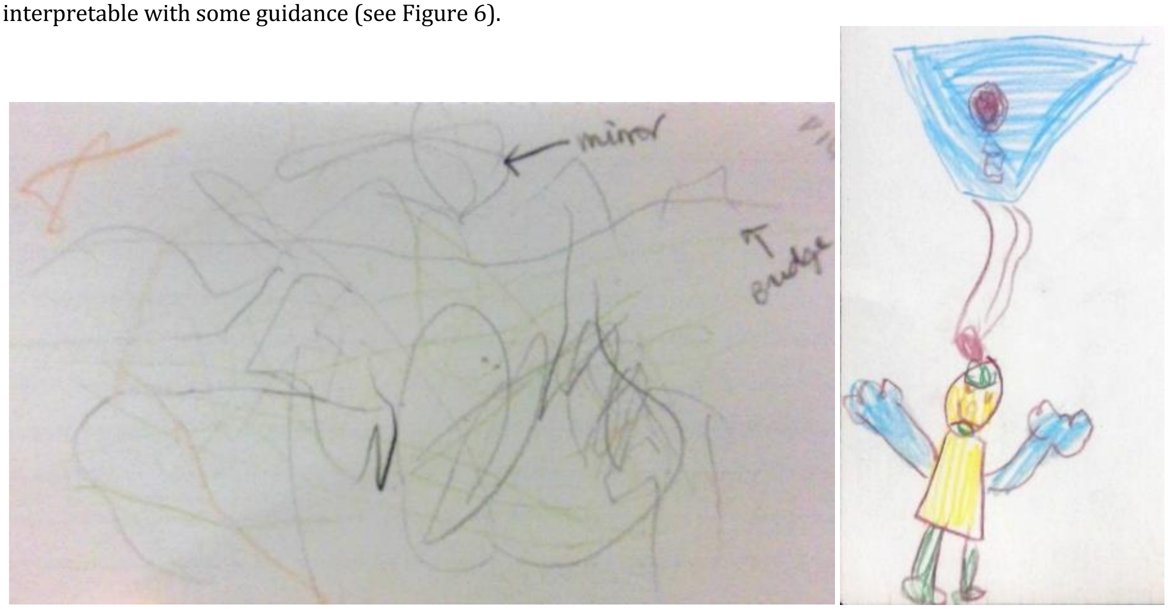

Figure 6. Age differences in drawn designs. Left, P12's (three years old) gadget including a mirror and a bridge (labeled by the grownup helper on P12's request), and right, P3's (five years old) gadget can attach to the astronaut.

The children demonstrated ownership of their imagined gadgets and of their design processes as co-designers. They used provided materials in diverse ways, often mixing drawing and building materials, such as using a marker to push the message (a block) to the gadget. They also incorporated their own toys and art supplies into their designs. P13 used his toy truck to act out the gadget use: *"I can put my flower in my truck. … I can drive it and put the flower out."* Along with their practical descriptions of gadgets' functions, child co-designers often included aesthetic elements: gadgets were made *"with glitter"* (P12) and included *"decorations"* to *"look beautiful"* (P3). These aesthetic details did not change the function of the gadget, but were equally important to document and describe (see figure 6, right).

4.2 Designing Gadgets within a Larger System

Children did not restrict themselves to describing just their gadgets. Their explanations regularly included external details to demonstrate important context for how the gadget functioned. Some children drew or built the flowers, planet, astronaut, and/or spaceship before beginning on the gadget design itself. This allowed them to create gadgets in the context of the astronauts' environment and to explain their purpose and use within that context. Children also took care in recreating the correct or accurate context for their gadgets. Some consulted the activity book illustrations or asked grownup helpers for details about outer space, seeking out knowledge to support their gadget's creation within the given setting.

Gadget designs were clearly placed within some existing world and system of technologies. This world was reflected in how children considered the gadgets' physical forms. Many children's initial responses to the first design prompt were that the gadget was the spaceship. P7 initially described, *"I guess I can do it with a rocket!"*. This often led to distinct gadget designs using different forms and more detailed interactions, as seen in P7's later idea: *"[The gadget] will shoot all besides the rocket ship. … And then we can open the door and that way we can share the flower."* Others considered the type of content the gadget could share to inform the gadget's formfactor, such as a straw-shaped gadget that *"absorbs the fragrance that you smell[+]"* (P8). Overall, child co-designers consistently designed gadgets that made sense for the provided setting and prompts.

Many designs reflected children's understandings of actual technology, such as inferring the gadget's need for a power source (e.g., gas or batteries) and to connect to other gadgets or devices to transfer information (e.g., plugging into the other gadget or an astronaut's helmet). From children's descriptions of gadgets' interactions with the larger technology landscape, we see that these young co-designers were aware of existing communications technologies as part of a network of tools, and drew from that to support and motivate their designs for the astronauts' technology.

Several child co-designers considered the multiple users that use the gadgets collaboratively in their designs. Most gadgets incorporated colour coding to distinguish between the different teams' gadgets and to show the connection between the various components of the same gadget. Preschool-age children recognize colour coding as a form of categorization, and we suggest that the children in our study brought this to their designs [23]. Though this could have been an extension of the story's colour coding (e.g., green and orange astronauts), some children specifically chose their own colours, such as P8 who explained *"This is me. I have a pink helmet.[+]"* Colour coding was also used to ensure fairness between teams. In one design, the buttons on the gadget had to match the team's colour, but the gadget itself could be any colour because otherwise *"someone will be sad"* (P3).

Gadgets clearly existed as part of a system of communications technologies that had to be used together, and the existence of this imagined system informed children's designs of their gadgets. Children showed an understanding that a single tool for communication must exist within the bounds of an existing system, so explained those bounds to create meaningful designs.

4.3 Gadgets are Standalone and Multipurpose

Children considered the different technical parts making up their gadgets, describing specific hardware and software needed within to support the tasks of making, sending, and receiving messages. Gadget designs consistently completed all these tasks, but the interactions for each task were separated, similar to various apps available within a smartphone.

Most children described how gadgets used different components to capture whatever they wanted to share about the flowers and *separately* described how gadgets sent that captured media as a message. Most of these app-like components were to capture some media for a message, including a camera, a printer, a writing surface, a microphone, a speaker, and a mirror (as a screen). Some single components were used for multiple types of media, for example a speaker that emits smells as well as sounds (P11). Some components for capturing media also explained the connection between gadgets, like a tube that sends the smell of the flower between gadgets (P8). Children described how messages were created by capturing media (e.g., taking a picture) and then sent with the gadget, often acting out the message with a separate prop, like a block.

Messages were seen as a container for any content the astronauts wanted to communicate, and young co-designers proposed diverse media as message content. The most common media types were pictures, spoken messages, and the flower itself or a piece of it. We saw three broad categories of content:

1. Actual objects or sensory experiences (e.g., sending a petal or its smell),
2. Descriptions of objects or sensory experiences (e.g., describing the flower's sound without sending audio), and
3. Messages created directly onto gadgets by drawing or writing.

A gadget may have several different components to capture various media, but across the children's descriptions of their designs each message was sent and received using the same component (e.g., the same interaction and technical process) whether it contained, for example, the flower's smell, a drawing of the flower, or the flower itself. Gadgets were consistently tools with two distinct tasks: first, to capture different types of media (or objects) to create a universal message, and second to send and receive those messages across connections between it and other devices. Children clearly demarcated putting content into a message from sending that message. In one gadget, a camera took a picture, which was printed by another component, placed into a different part of the gadget, and sent (P11).

We were surprised that most children added other story elements as part of designing their gadgets, We designed the space flower prompt to help young co-designers focus on using make-believe to describe gadgets for multimedia sharing and asynchronous communication across distance. These new story elements largely stayed relevant to the design focus and included characters and items typical to the science fiction setting (e.g., additional teams of astronauts, robots, and aliens) but also less expected ideas (e.g., dinosaurs, treasure, and hay bales). With these additions, children took a broader view of what gadgets could communicate, including components that shared their location using maps and alerted teams of danger. A sibling pairs of co-designers explained that one team of astronauts (i.e., one sibling) was being attacked by aliens and their gadget alerted the other team:

P11: "Mine can send information to [P10]'s. ... If there's danger with-"

P10: "No! And mine. Can send information to yours if there's danger."

...

P11: "Yeah. And one of us will send robots to the other person's planet to help."

Our materials and prompts were specific to our design focus (i.e., communication between distance-separated families), and our child co-designers interpreted those in creative ways while staying on topic. This demonstrated a wider view of what can be considered social communication. The various content included in messages and the distinct components they required show the potential range of what could be included in communications technology. Interestingly, few of the children's designs rely on the ability to read or write. Children imagined communication across distance within a system of interconnected technologies matching the needs of that system while fitting within their current capabilities.

4.4 Interactions with Gadgets

Children's make-believe showed how different component features were used in sequence to create, send, and receive messages as part of rich, detailed interactions. Almost all child co-designers used sound effects to portray how gadgets work and how astronauts interact with gadgets, such as a gadget flying through space, receiving a message, or transmitting a message. They used individual blocks to represent other parts of the interaction, like the flower or message, and showed how that was sent by placing it into or onto the gadget.

Gadget components incorporated diverse modalities. Some gadgets components were triggered with motion (e.g., jumping), speech, or by drawing onto the gadget itself. A few gadgets physically attached to astronauts to send or receive messages. Children combined blocks and drawing supplies to show messages passing between gadgets, such as using an index card as a message and carrying it out of one block gadget to the other with a marker (P11). Some components acted without a button press or other direct interaction, sensing the proximity of an astronaut to capture media (e.g., a picture) (P11) or sensing a message being placed on the gadget to send it (P12). Several components included features not directly triggered by nearby astronauts, including using sound to notify when a message was sent or received.

A block could also represent a gadget button to establish connection or send, receive, or display a message. Buttons were not described as part of the work of captured media, as media capture stayed contained to individual components. Components based in real technology which generally include buttons, like cameras and printers, were described in less low-level detail than sending or receiving messages (e.g., *"You can either take a photo… or write something down"* (P3)). Young co-designers did not need to specify how these interactions worked because the separated nature of that component from the other gadget tasks implied its interactions (e.g., it works like a real camera works). One child explained how astronauts could misuse gadget buttons, saying if too many buttons were pressed there would be *"so many sounds"* (P5).

These detailed descriptions of outcomes of specific actions and how to complete tasks with the gadgets show designs considering the different low-level steps needed to support communication between two devices. The child co-designers considered how their actions and the actions of others would interact with their gadget. Children explained specific interactions made directly with gadgets without metaphor, unlike their explanations of more passive aspects of use, like connections between them, as we explore next.

4.5 Explicit Connections Between Gadgets

Most children illustrated how their gadget connected to the receiving end (be that another gadget, an astronaut, or a spaceship) using familiar metaphors, mostly from real transportation. These include bridges, paths, and tubes that astronauts use to walk or blow messages across to the other end (see Figure 7). P12 described: *"[The gadget] lands to their city. So we need to make a bridge for them to cross to the green ones' house."* Though these descriptions often describe a literal and physical connection, the make-believe play or design justifications often clarified that these are metaphors explaining both how gadgets are connected and how messages are sent between them. When asked why the gadget had a bridge, P6 explained *"that's for sharing"*. These metaphors seem to aide young co-designers to explain *how* gadgets work without having precise technical knowledge.

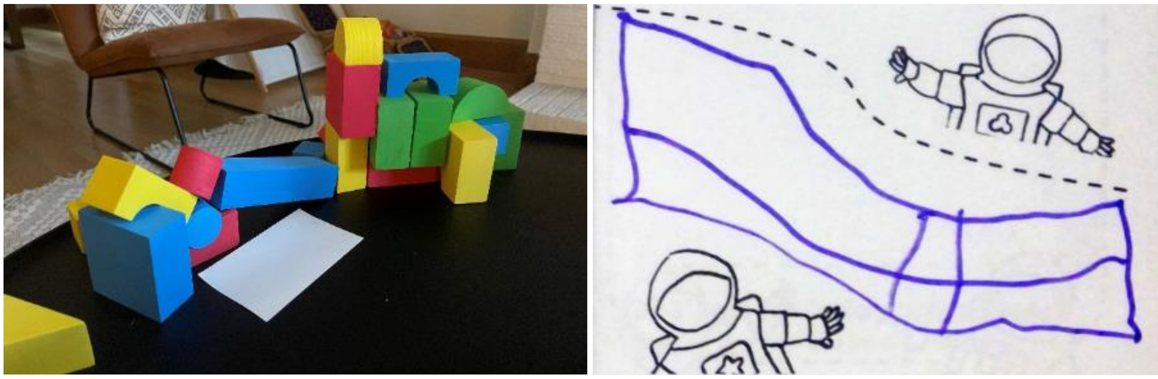

Figure 7. Examples of bridge connections between gadgets built with blocks by P12 (left) and drawn by P6 onto prompt page 3 (right).

These metaphorical representations of physical connections allowed children to explain how messages start from either team's gadget and travel to the other side. This connection allowed astronauts to communicate despite teams' change locations in space and the large distance between them. Some children explained how their designs supported use over that distance by placing gadgets up high or pointing them towards each other. To connect across distance, P12's treehouse-like gadgets were used up high *"like a giraffe"* and had ladders so astronauts could access them. Other children removed the distance between teams by teleporting messages. When asked how the astronauts could communicate if they were very far away, P1 initially struggled to explain a design *because* the distance was too large. He used sound effects to demonstrate removing the distance barrier by moving the gadgets and astronauts through space, saying, *"With other astronauts next to them … when they want to connect … *spaceship noises*.[+]"*

The emphasis on describing and maintaining connection shows an awareness that distance between teams is significant to gadget use. The child co-designers explained that user awareness of the connection between gadgets is central to gadget use.

4.6 Messages Move along Connections

Most designs sent messages between gadgets by traveling along the metaphorical connection. Children considered messages to be conceptually and sometimes physically separate from gadgets. Astronauts triggered gadgets to send messages by placing them into or onto a designated part of the gadget. P11 described how a picture taken (presumably digitally) with the gadget needed to be printed and placed back into the gadget to send– physically separating the tasks of creating and sending: *"You put a picture of a flower. … Then as soon as- as something touches, it sucks it in and brings it to the other astronauts … spaceship."*

Children acted out gadget use to show how gadgets moved messages across the distance between teams. Some designs carried messages on or inside gadgets which fly or otherwise move to the other team so they could retrieve the message. Other designs kept each gadget with its team and described how gadgets had to do something to messages in order to send them, again using various metaphors to explain this wireless transmission, including lightning bolts, evaporation and beams of light.

Flying gadget designs often described a single gadget moving back and forth, whereas wirelessly transmitting gadgets generally required a pair. One outlying flying design used two matching gadgets, but one had to physically connect to the other to pass on the message, requiring one gadget to be at the destination: *"One stays on the ground.*

And the other one goes. And then sometimes it switches for the other one. [The astronaut] could take it off and you could put it on another helmet." (P3). Flying gadgets can carry items to deliver, even the astronauts themselves, by travelling along the bridge-like connections between gadgets.

Wirelessly transmitting gadgets do not travel and instead send messages across the connection between gadgets. These gadgets often needed to break down messages in order to transport it wirelessly. P10 described: *"[The gadget] evaporates [the message] to it. … It makes the paper in- into dust."* A few child co-designers described sending messages piece by piece and reassembled by the receiving device, like sending a flower petal by petal, similar to how digital messages are send in packets of data.

Some co-designers specified that messages took time to travel across connections, but sending messages is faster than transporting a person, justifying the use of gadgets over the spaceship for communication. P13 described how a gadget can send some data faster than others, showing how it receives a notification that a message is coming before the message itself can arrive: *"When [the astronauts] hear the beeping noise they come over and wait for the message"*.

These two design directions, flying and transmitting gadgets, highlight similar ideas about how messages must move from one gadget to the receiving person. They both present conceptualizations of a connection between two gadgets and a message traveling along that path. The evaporation-type sending of transmitting gadgets is more realistic to practical use, even within science fiction, considering the time needed to transport people or items across distance. However, the single flying gadget designs show other important considerations, such as the simplicity of keeping a message intact. While it may not be practical to fly gadgets back and forth, something will have to move across the connection, and flying designs open interesting questions for the imaginary design space, like what would happen if two messages passed each other in space (physically or wirelessly). These ideas also show how these young co-designers recognized core technical concepts of wireless communication, including establishing a connection, as part of gadget design and use.

These designs highlight how young co-designers saw the act of sending from start to finish as a part of the gadget's technical work. Gadgets were consistently described as tools for making, sending, and receiving messages, matching the given prompts. However, our prompts did not distinguish between these tasks. The clear separation in designs, not only of these tasks but also of the message itself from the gadget, is consistent across our co-designers' ideas, indicating some consistencies across their conceptualizations of these communications tools.

5 DISCUSSION AND DESIGN OPPORTUNITIES

In this section, we present considerations developed from our thematic analysis. From these we draw design opportunities for communications technology allowing young children to interact independently and therefore connect socially with distance-separated family. Much previous work has focused on the connections between grandparents and grandchildren across distance (e.g., [18,40]), which is a key motivation of our work. As our work here seeks children's own ideas for their independent communication separate from that specific setting, we present our discussion around communication with distance-separate family generally and future work will explore how various generations experience these design opportunities when communicating with young children. Our motivation focuses on so-called asynchronous technologies like messaging, which can also be used synchronously, as those modes of interaction better support the asymmetrical needs of older and younger family members [17]. From the science fiction setting of the design study, children designed detailed gadgets, and while clearly based in the imagined astronauts story we provided, their designs show the child co-designers' insights into how they conceive devices for asynchronous and distance-separated communication in general.

First, we discuss the conceptualization of connection between gadgets and messages traveling along that connection. Next, we expand on the idea of a message object that magically contains any type of content. Finally, we discuss the system-wide perspective of our young co-designers and how that can be incorporated into the design of everyday interactions. We ground these in the five themes presented above as well as previous research to contribute a novel perspective on what to consider when designing for digitally mediated communication for families in order to include young children's independent use.

5.1 Making a Magic Message

Our young co-designers proposed a wide range of content that could be communicated with gadgets. The variety of content is similar to modern messaging, which supports text, image, voice, and video sharing in a single app. In family chats of adults, this variety of multimedia is key to communication as it helps different generations to share simple social connections [37]. Our child co-designers also saw the benefits of including diverse media, particularly since the most common modality of messaging apps, typed text, is inaccessible at their age and was completely absent from their designs.

In children's designs, messages are something that will be sent by the gadget, like a magic envelope that remains the same regardless of what is put inside. This magic was pushed in unexpected ways, as children incorporated more diverse ideas of communication than our simple prompt. They interpreted the gadget's role as a communication device to include any possible information astronauts needed to share, including status updates and calls for help. This type of creative appropriation shows that co-designers felt ownership over their design process [36]. Other explorations bringing digital communication to young children has similarly found that young users developed uses for systems beyond what was expected and intended [4]. The creativity and flexibility of our child co-designers as to the purpose of communications tools shows us that communication covers a broad variety of activities and ideas. This also demonstrates the power of design activities that step away from "real" use and use science fiction or magical prompts as the children described functional designs for communications tools *and* expanded on what we consider digital communication.

Our child co-designers used our prompt as a starting point to design for their idea of communication as a whole, showing clear understandings of both practical and social uses of distance-separated communication. From that understanding, we show that young children can engage with communication across these uses and likely develop more uses that older users (e.g., adults and older children) have not considered.

The designs of the gadgets' interactions with each other and with larger systems of communication rely on the universality of messages. Children explained different metaphors and designs to illustrate how gadgets were connected *because* a message needs to travel along something between gadgets. Making the message a consistent type of object supports these metaphors, simplifying the complicated steps of sending different content to one shared process. Lacking precise technical knowledge to describe how devices connect did not limit design detail. Instead, child co-designers presented the complicated nature of communications technology through these rich metaphors. We show that young children can describe designs in great detail using intuitive metaphors to fill in gaps, much as digital metaphors connect to something familiar to fill in gaps in user knowledge [27].

Gadget designs demonstrated that this universal message was also used by the larger technology system, as it could be received by spaceships or different gadget types. This was also reflected in the two discrete steps of creating and sending messages. Each different gadget component that can capture content can output that as part of a universal message. Without this consistent message format, the lines between steps would blur, as the task of sending messages could vary depending on the content. The message being a single type of object makes the separated sending step possible. Some young co-designers may have first imagined these as separate steps and created designs supporting that (including the universal message), or they may have started from the universal message and separated the creation and sending steps reflecting that. This distinction has to some extent been seen in other work with young children into their explanations of what can be done on computers or the Internet, as communication tasks like writing an email were seen as computer tasks rather than Internet tasks [28].

In general, our child co-designers gave more detailed understandings of their imaginary gadgets than similar ages have shown when explaining existing technologies, like email [4]. This high level of detail, including the rich metaphors, likely comes from our play-based setting, which gave our co-designers a framework to express detailed ideas that may not be available without play [5].

5.1.1 Design Opportunities

Young children's consistent separation of the acts of creating and sending messages should be clearly distinguished in the design of visual and interactive elements. **Designers considering tools for family communication across distance should incorporate the idea of a consistent, universal message across systems**. Rather than using a messaging app to select and send media captured earlier, users could capture media and have the option to place it in a message in that same app. The user can then bring a completed message into a messaging app to be sent. Moving messages between creation and sending may be literal, such as moving a tangible token from one part of a device to another, or more metaphorical, such as dragging media to an envelope or other message icon, which is then available to users when they open the messaging app.

Looking at the creative interpretations of what messages might contain beyond our prompts, we suggest bringing this creativity into digital communications with distance-separated families by **avoiding restrictions on what can be considered a message**. The message as a container should be left as open as possible so users can discover what can be created and sent themselves as they interact with each other across devices and develop their own norms and uses.

Reflecting users' understandings of the tools and systems they use supports their agency over interaction with their devices [31]. To include young children in family communication across distance, their conceptualizations should be reflected consistently across devices, regardless of users' ages. Differing interaction designs between young children and older users confuses young children as they, reasonably, presume all users are interacting with similar interfaces [30]. Our work here shows **the concept of a universal message needs to be incorporated into designs of family communications tools** in order to include young children.

5.2 Connection Between Devices is a Pathway for Messages

Across designs, we saw child co-designers' priority on connection between gadgets. Their conceptions of gadgets were not limited to their perspective as users (i.e., creating and sending a message). They considered how other teams would receive messages (on another gadget or otherwise) to be part of their gadget's functioning; a message arriving successfully at its destination was part of the sending gadget's task. Children described how connections were established, maintained, or broken, sometimes including that as part of the sending process, such as pointing gadgets to send messages. Modern communication tools show a receiver's availability as a reaction to messages being received by the device (e.g., with a sent and/or read receipt). This leaves the reason for the lack of response up to interpretation by the sender [11]. Messaging between couples or friends has used reactive status messages to explain why they are not able to respond after the fact [10]. Our young co-designers took a proactive approach, demonstrating that the connection is active and messages will be received before a message is sent or even created. Adding live status information, like showing how the other person is moving, can help conversation partners know what to expect ahead of time [9]. In our study, young children's conceptualizations of gadgets included a connection between those gadgets, so use of a single gadget relies on knowing the connection is active *before* messages are made.

In the rich metaphors used to describe transmission, we found that connection was central to successful communication because the message travels along it. In contrast to our child co-designers' consistent descriptions of connections between devices, other research has shown that young children have inconsistent understandings of Internet connections being external to a device [8]. Again, we see how our play-based setting gave young children the tools to communicate ideas precisely.

Children considered interactions with a larger network of technology, but specifically described a connection directly between gadgets without a network in between, with metaphorical bridges and evaporation providing a path for messages to follow from one gadget to the other. These metaphors explained the invisible aspects of wireless communication in familiar terms. They also further emphasize the importance of connection between devices for these children. In some cases, the means of connection was described before any explanation of making a message. Messages were transmitted along a connection because the existence of that connection ensures the message's arrival. With this emphasis on establishing and explaining a direct connection between two gadgets (not just a connection to the broader network), we suggest that this connection is the gadgets' primary and most important task. The priority of knowing connection is established means gadgets might not be used unless there is a known connection *between* those gadgets even if there are connected to a network.

5.2.1 Design Opportunities

In designing for family communication including young children, we should consider the connection between devices as an explicit and constant part of the interaction. This connection is not an indication that a device is online, but specifically that these two devices are connected to each other and able to communicate. The connection between devices indicates that the receiving device is working and available and that sending messages will be successful. This status should be a constant presence throughout use of the device, so whether capturing media, sending a message, or viewing an incoming message, the status of the two devices as a pair of communication tools is consistently present.

The connection between devices should also represent how messages travel between them, to incorporate young children's understandings of these systems. From our child co-designers' ideas, the path of a message could be presented metaphorically, like travelling along a bridge, flying through space, or being evaporated and reassembled on arrival. Connecting to the science-based explanations that these children reached for, this path could also be communicated by demonstrating the actual technical process. We see an important opportunity here to **integrate demonstrations of how wireless communications truly work into this representation of a traveling message**. Designs can demonstrate how digital messages are broken into packets, sent and then reassembled by the receiving device. Using a scaffolded approach, this can begin with a high-level representation, perhaps by showing a photo being divided up and put back together, and introducing more details as the device is used more.

Representing messages as linked to the connection between devices reflects the consistent conceptualizations we saw from the young co-designers. We suggest that representing this explicitly demonstrates the outcomes of their device use (i.e., that their message was sent), highlighting their independent use and agency as a user.

5.3 Making Interactions with Systems Transparent

Children's make-believe play often included information about the systems of communication surrounding and supporting gadgets' functioning. In co-design with older children, other researchers have observed that participants wanted to "explain the world" with the details of their designs [35], much as we saw with our younger children. Child co-designers inferred that the gadgets were unlikely to work without other technologies, perhaps drawing from their understandings of everyday technology or from the other technology presented in the prompt story, like spaceships. The co-designers clearly considered core technical concepts of wireless communication, such as how messages could move between gadgets, as part of their designs and explained those as part of using their gadget. Again, this demonstrates more complex understandings of systems than is commonly seen in young children [8].

Children considered the larger system before our specific prompt. They created representations of other technology, like the spaceship, before designing the gadgets, and explained how gadgets were connected to each other before demonstrating how they made messages. This world-building of creating a context for the prompted design has not been described in other co-design work using astronauts and outer space as a magical design space [13,20,32,38]. It may be that the play-based setting gave the young children in our study the context and higher developmental skills to explain their designs at this higher level of detail. Establishing the surrounding system first shows us that children see that gadgets need to exist in this larger system and would not consider designing or using a gadget without that. Despite being separated by great distance, the existence of other devices working with a single gadget was incorporated into the visual design, seen in colour coded gadgets that were unlikely to ever be in the same place. From the consistent presence of larger systems of communication in gadget designs, we show that these young children were constantly aware of gadgets as communications devices that cannot function alone.

5.3.1 Design Opportunities

As we discussed earlier, the connection and existence of other devices should be made a constant status within the visual or interactive design of family communications devices, so that younger users see their understandings of connection reflected in the communications tools they and their families use. There is also an opportunity to show how wider networks of tools are connected to a device by various wireless connections with various purposes. Designers can consider how to **represent the connection between two devices by showing how those connections are made with different signals** that can span multiple networks. This could again be leveraged to incorporate educational aspects of use, such as showing points along the connection between devices representing moving between multiple networks.

Finally, the aesthetics of family communications devices should not be overlooked or underestimated in what they can communicate to users of all ages. **Designers should support young children's independent use with symmetrical designs across communication devices supporting conceptualizations of matching gadgets working together, even when devices themselves may differ**. Within those matching designs, designers should incorporate distinctive elements identifying a single device or account as belonging to that user. Giving control of this aesthetic element to users could also support their agency and device ownership, and as an extension of that, their independent communication [36].

5.4 Limitations and Future Work

In the design of our co-design probe, we prioritized children's agency as co-designers and focused on supporting informed and ongoing consent throughout the activities. We chose to use written materials to communicate the study information, such as design prompts, and this required the young co-designers to be dependent on their grownup helpers to communicate the information, as all child participants were pre-literate. Though this limited their ability to independently engage with the prompts, the activities were designed using established classroom pedagogy and with the help of child development experts so that the activities themselves could be completed independently by the children as co-designers. Future work can explore using audio or video recordings as prompts, though this should consider how introducing more technology into the study materials can create distraction from the intended activities [32].

Our study had a sample of 12 children from 10 families which may not necessarily include a fully diverse group. Nonetheless, this number allowed us to gain detailed knowledge and was appropriate for a first study in this area to open up the design space and provide an initial understanding. Future work can use similar design probe activities to include children from different cultures, which may show different conceptualizations and ideas of how communication technologies could work. Additionally, future work could investigate how children's access to and use of various modern technologies effects their design ideas.

Finally, in our future work, we will create prototype devices or applications incorporating these design opportunities and deploy them with distance-separated families to observe how they are used by children to communicate with their grandparents or other relatives, focusing on the differing needs of users of different generations. Future work will also explore how these design ideas, like the bridge metaphor, are used socially as part of communication across families.

6 CONCLUSION

We present design opportunities for young children's independent asynchronous communication with distance-separated grandparents and other family, which we draw directly from the design ideas of 12 3-5-year-old children. To support their agency and ability as co-designers, we use a play-based design probe and an imaginative story set in outer space. These young co-designers presented detailed and creative designs for the astronauts' "gadgets". They demonstrated consistent conceptualizations of gadgets having consistent connections between them, which they explained with various metaphors, and messages that travel along those connections to reach their destination. From these ideas, we suggest how digital family communication can integrate young children's conceptualizations to allow them to connect independently with their families across distance. We also show how the design of these tools can incorporate educational aspects to teach users of all ages how wireless communication technologies work as a part of their use.

7 SELECTION AND PARTICIPATION OF CHILDREN

We recruited preschool-age children with flyers in community centres, childcare centres, and public libraries. Known adults, generally parents, responded to these flyers by email, and we provided assent scripts for them to confirm their child(ren)'s interest in participating. Grownup helpers signed digital consent forms and children verbally assented to a read-aloud consent letter written in age-appropriate language approved by child development specialists. Children completed design activities in their own home with the support of a known adult, and were compensated with a sheet of stickers custom-made for this project. Adults were compensated $40 (CAD). This research protocol was approved by our university's Research Ethics Committee.

ACKNOWLEDGEMENTS

We wish to acknowledge the Kanien'kehá:ka/Mohawk, Musqueam, Squamish, Tsleil-Waututh, Katzie, Kwikwetlem, Qayqayt, Kwantlen, Semiahmoo, and Tsawwassen peoples on whose unceded traditional territories our researchers and our three campuses reside. We want to thank the children who co-designed with us and their grownups for facilitating their participation. We also thank Clare Huang for the illustrations of our astronauts story and colouring pages.

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