Designing Collaborative Technology for Intergenerational Social Play over Distance

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Collaborative play not only provides entertainment but also nurtures connections and strengthens community ties. In family and intergenerational contexts, collaborative activities and play can engage family members in quality conversations and meaningful connections over distance. To explore participants' preferences, practices, and interaction dynamics when playing remotely, we conducted a design probe study with 15 groups of parents and children from 16 families. Our findings highlight both similarities and notable differences in the use of communication methods, workspaces, and objects between parents and children. Specifically, we observed distinct patterns in gestural and verbal communication and identified specific challenges encountered by children in a simulated remote setting. Our findings also revealed the dynamics of play sessions, particularly when co-located participants are involved, shedding light on the complexities of remote intergenerational communication and play. Our work contributes empirical insights into designing more effective and engaging remote collaborative platforms for families.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: intergenerational communication, social connection, social play, children, adults

ACM Reference Format:
Ye Yuan, Qiao Jin, Chelsea Mills, Svetlana Yarosh, and Carman Neustaedter. 2024. Designing Collaborative Technology for Intergenerational Social Play over Distance. *Proc. ACM Hum.-Comput. Interact.* 8, CSCW2, Article 492 (November 2024), 26 pages. https://doi.org/10.1145/3687031

1 INTRODUCTION

Collaborative and shared activities play a crucial role in people's everyday social experiences. When children read books with their parents or grandparents, couples watch movies together, friends play board games on a Friday night, or colleagues participate in an escape room during a team-building event, these activities provide shared contexts for participants, improving the quality of communication and leading to better social outcomes. As people transition to technology-facilitated remote communication, they often adapt these offline traditions and social practices to online

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ACM 2573-0142/2024/11-ART492
https://doi.org/10.1145/3687031

formats, continuing these activities during remote communication. Previous research investigating social technologies for family connectedness found that shared and collaborative activities can improve the quality of time spent during remote communication, especially for younger children who may struggle to engage in videochats or audio conversations [7]. Collaborative activities such as storytelling and play can engage younger generations in conversations with their older family members, providing more opportunities for connection during remote communication. These activities have thus remained a common practice for social connections among distributed family members, such as between parents and children in divorced families [70], siblings with large age gaps [35], and grandparents and grandchildren [7]. Although most children returned to in-person activities after the COVID-19 pandemic, many continue to engage in technology-facilitated remote communication and activities (e.g., drawing, crafting, reading, playing chess, solving puzzles) with distant family members to maintain these practices. Given the benefits of supporting collaborative activities in remote communication, many systems have been developed to facilitate shared activities for children, such as video-based systems that allow children to connect with family members through collaborative storytelling and play [23]. In activity-based communications, social outcomes are often tied to the activity experience; therefore, creating an engaging activity experience is considered a key design goal when researchers investigate communication and collaborative technology for children.

Compared to in-person collaborative activities, remote formats can pose challenges in communication and coordination over shared activities, where people must constantly negotiate and work together on shared tasks and content. Communication and coordination methods such as gestures, eye contact, or awareness of others' actions in the activity space can be difficult to support with traditional communication technology. To address these challenges, researchers have explored novel technology interactions to enhance communication during collaborative activities, including supporting shared eye gaze with eye tracking [44] and providing various gestural instructions during tabletop interactions [67]. Some studies on collaborative and social technology have investigated novel system designs to support remote activities for children with tangible interactions and an augmented tabletop space (e.g., [58, 72]). However, there has been limited research on children's preferences and usage of various coordination and communication methods at the interaction level during remote activities, or on how children's usage aligns with or differs from that of adults. Furthermore, most system designs supporting intergenerational collaborative activities focus on dyadic communication, while communication in intergenerational settings often requires a hybrid setup (e.g., children communicating with both grandparents, or siblings communicating with each other and parents). We aim to address these gaps in collaborative technology design by examining the interaction needs of both children and adults to better support remote intergenerational play, which might involve some hybrid setups. Specifically, we focus on parent-child interactions and dynamics within the intergenerational context and seek to answer the following research questions:

- **(RQ1a)** How do children's and parents' usage and preferences for communication and collaboration differ in remote play?
- **(RQ1b)** How do children and parents use a connected workspace with tangible and digital objects to play remotely?
- **(RQ2)** What are the dynamics between children and parents when playing remotely in various remote and co-located setups?

To investigate these research questions and understand design opportunities for collaborative technology to support intergenerational social play between parents and children over distance, we conducted a design probe study with 16 families of parents and children aged five to ten years old. We designed and built three probes that incorporated various system features for shared communication, workspace, and play objects to support remote play. Through a qualitative analysis of parents' and children's play sessions using these three design probes, along with post-study interviews, we identified differences in parents' and children's usage of verbal and gestural communication during social play. Our findings also highlight the importance of supporting a connected but independent shared workspace for remote play and provide insights into the various roles parents play in different settings for an enhanced experience. With these insights, our work aims to contribute an empirical understanding of children's and parents' usage and preferences for communication and collaborative technologies in remote play. Our findings also offer design implications for collaborative technologies that can better support these usage patterns and preferences, enhancing quality time during remote play and potentially applying to various intergenerational settings and remote collaborative activities. In the following sections, we first describe related literature that contextualizes our work. We then provide a detailed description of our design probes, participant information, study setup, and analysis process. Following this, we present our findings, structured around our research questions, and discuss design opportunities, limitations, and future work.

2 RELATED WORK

2.1 Technologies for Intergenerational Communication

Technology-facilitated remote intergenerational communication offers unique opportunities for bridging the communication divide between generations, including children and their parents (e.g., [5, 6, 25, 58]), large age gap siblings [35], grandchildren and grandparents (e.g., [7, 57, 62]), and younger individuals with older adults in the community [14, 45]. Such communication is vital in fostering and reinforcing bonds, contributing positively to the overall health and well-being of family and community members [5].

Various activities can be supported in facilitated remote intergenerational communication formats, such as reading [58], storytelling [62], and play [36, 57, 72]. These shared activities not only strengthen intergenerational connections during remote communications but also address the educational and emotional needs of younger members [11]. The activities can be either structured (guided by a set of guidelines or rules) or unstructured. For example, *Family Story Play* [58] is designed to support structured activities for children to read with distant grandparents. The system combines a physical book, a sensor-enhanced frame, video conferencing, and a facilitator character to guide interactions between grandparents and children. Unstructured activities such as open-ended or free play, can foster children's creativity and spontaneity by allowing them to explore and express themselves freely without rigid constraints in facilitated communication (e.g., [35, 62]). Video-based systems like *ShareTable* platform [72] and *Video Play* [23] are designed to enable children to spontaneously initiate conversations and share objects or activities in a shared virtual space. In this setting, the activities are often not strictly defined, allowing children to lead the interaction based on their interests and imagination.

Prior studies have specifically highlighted technological opportunities in supporting synchronous activities, which have been shown to effectively engage young children, sustain their interest [22], and provide shared contexts for communication, thereby enhancing communication quality and connection outcomes. Among these technologies designed for intergenerational communication, an asymmetric design is often adopted due to its potential to accommodate different accessibility and usage needs associated with age-related factors. For example, interfaces designed for older adults may prioritize simplicity and larger text for the ease of use [46], accommodating their technology literacy [69]. In contrast, interfaces for children often need to be more physical and visually engaging, allowing them to easily and spontaneously initiate connections [35, 72]. However, there remains a lack of clarity regarding users' preferences and needs at the interaction level during remote intergenerational play from a collaboration perspective. Our research addresses this gap by providing empirical insights to inform and guide the design of future intergenerational communication systems.

2.2 Technologies for Collaborative and Social Activities

The CSCW community has investigated various systems to support a broad range of collaborative activities remotely, including everyday productivity tasks and social activities such as writing [43, 63, 65], interaction and visual design [39], coordination in camera work [37], learning [33, 49, 73], and social gaming [40, 68, 74]. These remote activities are often supported by enabling a shared workspace among remote collaborators [9]. Technologies such as videochat [3, 4, 8] and messaging platforms like *Slack* and *Discord* are frequently examined for creating a shared workspace. Virtual Reality (VR) [33, 52, 56, 59] and Augmented Reality (AR) [16, 20, 30, 47] technologies can further improve the quality of collaboration with augmented visualizations and immersive environments. Camera-projector systems have been investigated to support collaboration with a shared tabletop space. These systems often foster a collaborative environment where participants can work together in a seemingly physical space by allowing more tangible interactions with digital content [54].

In addition, researchers have been exploring rich communication methods across multiple modalities to support a more collaborative and social experience within the shared workspace. Such communication spaces are integral to the success and outcomes of these collaborations. For instance, media spaces systems [4, 8] and systems featuring asynchronous annotations and integrated chats [13, 21, 39] have been designed to meet the requirements of a dedicated communication space. Previous research has also explored facilitation and coordination among participants in remote collaborative activities. These collaborative systems often encompass various methods and modalities of communication and interaction for effective collaboration, including spatial audio [33], gestures [53], and eye gaze or eye tracking [1, 15]. Our work explores children's perspectives and their unique coordination and communication needs in technology-facilitated collaborative activities. Specifically, we investigated various shared workspace and communication design considerations, focusing on supporting remote intergenerational play to understand children's needs.

2.3 Supporting Collaborative Play for Children

Among various collaborative activities, collaborative play is recognized as a crucial developmental task for children, which can be integrated into various social environments such as classrooms, schools, or broader communities [19, 48, 66]. This concept is anchored in the belief that through play, children learn to negotiate, cooperate, and understand the perspectives of others, thus fostering essential social and emotional skills. Many studies highlight the multifaceted benefits associated with collaborative play. For example, when children engage in joint play activities, they develop better communication skills, enhance their problem-solving abilities, and exhibit higher levels of empathy [32]. Collaborative play also provides a space for children to express themselves and understand the dynamics of group interactions, which is fundamental in shaping their social identity and relational skills [55].

A variety of technology systems and designs have been explored to support collaborative play for children. In co-located settings, interactive technologies are designed to encourage physical collaboration among children. These include systems like interactive floor games [27, 28], where children must work together to solve puzzles or complete tasks, or interactive workspace that allow multiple children to draw [41], write [38, 42], or code [17, 64] simultaneously, fostering a sense of teamwork and shared creativity. Many technologies are designed for co-located collaborative play in the household (e.g., [26]). One co-located collaborative play system, *Mobile Stories* [18, 61], is designed to create a collaborative environment for children to engage in both reading and creating stories together.

Technology designed for remote collaborative play, on the other hand, often takes the form of online games, with or without physical components. These technology-facilitated remote collaborative play activities cover many scenarios in the contexts of children's learning and communication in family settings, such as reading and playing with family members through interactive stories [22], which can help yield better connection outcomes through the experience. Previous research highlights the requirement of maintaining children's engagement in remote play with system design. Co-located family members, such as parents and grandparents, are often essential in engaging children in remote conversations and mediating technology use [24, 26, 58]. Additionally, embodied interactions, such as physical touch, gestures, and nonverbal cues, are important in building social connections and emotional bonds in collaborative play, especially for younger children [2]. In this work, we explored technology design for intergenerational collaborative play through a design probe study, considering the distinct communication and interaction preferences between different generations. By examining the nuances of their interactions and usage with different system design features, our goal is to contribute to the understanding of remote collaborative technology design that can enhance their play experience.

3 METHODS

In this section, we describe the rationale behind our probe designs and their connections to previous literature. We then provide an overview of our recruitment process, participants' information, study setups, data collection, and analysis process.

3.1 Considerations for Design Probes

We followed the design probe approach, where we designed and built quick system prototypes leveraging available technology solutions and resources to support a range of different system design features based on prior literature in technology-supported intergenerational communication and collaborative play over distance. These system prototypes allowed us to probe in-depth understanding of our research questions and generate insights about people's interactions and preferences of different collaborative systems features from observing their usages in action.

Our design probes follow the system design considerations to support distributed collaborative work [12], including a shared "task space" for collaborative play and a shared "person space" for communication and coordination over the shared work for collaborative activities. Because we were specifically interested in investigating children's and parents' usage and preferences of different communication and coordination methods, the design considerations for our probes focused on these two spaces:

- Supporting **a shared communication and coordination space** over remote play: prior work in collaborative technology (e.g., [9, 74]) emphasizes the importance of having a communication space with various modalities (e.g., gesture, video, audio) in remote activities. Considering the video-based technology used in our design probes, we included three methods of communication and coordination for remote play: 1) visual reference of the other side's workspace, 2) verbal instructions and conversation enabled by audio communication, and 3) gestural instructions and interaction captured and streamed by video cameras.
- Supporting **a shared workspace and shared objects** for remote play: the ability to work and play together in a shared workspace is a vital part that constitutes the social experience during remote communication. Previous studies in supporting children's interactions with technology also highlight the importance of enabling tangible interactions and the usage

of physical objects for an engaging experience (e.g., [58, 72]), while digital interactions still constitute an important part of technology design for children, given the ease of the setup and access. We designed a shared workspace for remote play with connected controls for choosing design probes or toggling activities to which all participants have the same access. We also wanted to include both tangible and digital formats of play objects in our probe designs, and augmented the tangible objects with visual awareness in the workspace for a sense of connectivity between shared objects.

We included a variety of communication and coordination methods for collaborative social play in all design probes to ensure children's engagement and the study's successful completion. Hence all design probes supported visual, verbal, and gestural communication enabled by video cameras, microphones, and a video conferencing system. We wanted each individual workspace to be shared among children and parents, hence the basic workspace controls were all connected in our design probes. Based on prior literature in designing technology to support children's remote activities, we varied the design of play objects (in distributed workspace) in our probes with their tangibility (i.e., digital versus tangible) and connectedness (i.e., one connected set, two sets with and without shared awareness). These design considerations were organized into different design features in a system with three variations to support remote tangram puzzle playing for the study.

We specifically chose to support structured play because of the required rules participants need to follow, which can provide an existing structure and scaffold during the remote play for better communication outcome [22, 23]. The reason we chose tangram puzzle as an example from various structured play activities for our study is based on considerations of children's ability in contributing to the puzzle solving at our selected age group (having opportunities to participate equally as their parents during the social play), the simplicity of the playing rules, as well as the flexibility to have a variable session length (so we could construct a relatively long play session with various smaller chunks of individual sessions during the study). Additionally, by supporting structured puzzle play, we were able to engage children's different interests (by providing a good amount of puzzle themes), and build in opportunities for breaks to switch design probes, or stop if children want to.

All three design probes follow the same device setup (*Zoom*, tablets, and mobile phones), where the station hosts a system that supports a connected workspace captured by the video camera to present to the remote participants. The system hosts 30 different puzzles for participants to solve and has connected controls in the shared workspace that both sides have the same access to toggle for changing puzzles, or switching design probes. The video communication (i.e., *Zoom*) in the system setup allows the usage of visual reference, verbal communication, and gesture in all design probes. The differences between three specific design probes in the system are mainly in the shared play objects and their connectivity in the shared workspace:

- **Design Probe #1** (*Base* in the workspace controls) provides two similar sets of tangible objects for each side in remote play. Although the workspace controls are connected, the two sets of tangible tangrams are independent and only shared through visual references captured by the video cameras;
- **Design Probe #2** (*Pointing* in the workspace controls) provides two similar sets of tangible objects as well as an augmented awareness of where the other side is interacting within the shared workspace. In addition to the connected workspace controls, the tangible objects are augmented in the shared space with visual indicators for pointing awareness to communicate the idea of "connected objects" in collaborative play;

Fig. 1. Our design probe setup includes a shared workspace with play objects (the flat tablet on the table) which is captured by a phone camera placed on a desktop stand and shared with the remote participants. The captured workspace is then displayed on a second tablet (tilted one on the stand) in the station setup. The three design probes support different formats of interactions with the play objects (from left to right): tangible, tangible with augmented awareness, and digital.

- **Design Probe #3** (*Digital* in the workspace controls) provides one set of digital objects that both sides can manipulate virtually at the same time in addition to connected workspace controls.

Figure 2 provides a summary of different communication and workspace features that each design probe is designed to support [1]. To build the design probes, we used *Zoom* for video and camera-related system features, in addition to building a custom web app so one tablet can be used as a shared workspace for remote play. The tangible puzzle pieces were laser cut with MDF wood. Figure 1 shows details of the system design as well as different components involved in the three design probes.

3.2 Participants and Recruitment

We recruited a total of 15 groups of parent and child participants from 16 families for our design probe study. Among the recruited 16 families, there were 13 boys and six girls between five and ten years old, with an average age of 7.4 years old (*SD* = 1.68). Our participants included more mother-child pairs/groups (15 families) than father-child pairs/groups (2 families). The average age of parents was 40.8 years old (*SD* = 7.17). Participants were recruited through social media posts, information flyers posted in community libraries, as well as snowballing with existing participants. All participants were recruited from a metropolitan area in Canada, and each recruited family was provided with a study compensation of 50 Canadian dollars for completing the study. All of

[1] A brief demo video of our design probes and their usages is available at https://vimeo.com/1002281936/25d3971d57.

	Communication	Play Objects		Workspace
	Visual, Verbal, Gestural	Digital	Tangible	Controls
Design Probe #1 Tangible Puzzle Objects	Supported		Two Sets	Connected
Design Probe #2 Augmented Tangible Objects	Supported		Two Sets; Augmented w/ Pointing Awareness	Connected
Design Probe #3 Digital Puzzle Objects	Supported	One Set; Connected		Connected

Fig. 2. A summary of communication methods (visual, verbal, gestural), objects (digital and tangible), and workspace (shared controls) features that each design probe supports.

the recruited families had multiple communication and technology devices at home, including desktops/laptops, tablets, and mobile phones, while most families (10 out of 16) also owned smart home devices (e.g., smart speakers) and robots. Most families (except F6) reported that their children used video-based technologies, either on a daily basis or several times a week, for activities including video chatting with remote family members and online learning. Fifteen families reported that parents played with children at home. In five families, parents reported that their children sometimes played remotely with other family members as well (e.g., grandparents, parents).

Since one of our study goals was to understand how parents and children play remotely in settings that involve co-located participants (e.g., one other parent, siblings), we specifically recruited groups that involve more than one child, parent, or family. Five groups of participants were recruited to include co-located participants in a "remote" social play session. Among these five groups of participants, one group included both parents, three groups included siblings, and one group included two families (F14 and F15, who were friends with each other and their children often played together). When setting up these groups that involved more than two participants, we let participants choose how they wanted to arrange themselves with the consideration of ensuring most participants could equally participate in the play. If siblings had a relatively large age gap (e.g., F4C1 and F4C2), parent participant often would sit with the younger child to ensure their active participation in the study. Table 1 provides a summary of our participants' information, with their age and gender. We also arranged the table so participants who were co-located in the study setup were put in the same row in the table (e.g., F1C and F1P1, F4C2 and F4P, F5C2 and F5P, F14C and F14P, F15C and F15P). F7 was the only group with both children co-located and played with a "remote" parent.

3.3 Study Setup and Procedure

A total of 15 group sessions were completed between February and April, 2023. Each group of participants completed a "remote" intergenerational play session using our design probes. We simulated the "remote" communication by setting up a divider between two stations hosting design probes, either on two different tables (in our research lab, Figure 3 (a)), or on the same table (at participants' place, Figure 3 (b)). We chose to set up both stations in the same space and simulate the "remote" condition for easier facilitation of the study, as well as the ability to respond and manage potential conflicts and disengagement with our child participants. We did not require all participants to complete the study from our research lab and provided them with the option of completing the study from their own places to have the opportunity to observe their play in a more

	Children			Parents			
Family	Participant	Age	Gender	Participant	Age	Gender	Relationship
F1	F1C	5	Boy	F1P1	36	Male	Father
				F1P2	35	Female	Mother
F2	F2C	10	Girl	F2P	50	Female	Mother
F3	F3C	6	Girl	F3P	46	Female	Mother
F4	F4C1	8	Boy				
	F4C2	5	Girl	F4P	38	Female	Mother
F5	F5C1	10	Boy				
	F5C2	5	Boy	F5P	36	Female	Mother
F6	F6C	8	Boy	F6P	41	Female	Mother
F7	F7C1	8	Boy	F7P	50	Male	Father
	F7C2	8	Boy				
F8	F8C	8	Girl	F8P	36	Male	Father
F9	F9C	8	Girl	F9P	37	Female	Mother
F10	F10C	5	Boy	F10P	33	Female	Mother
F11	F11C	9	Boy	F11P	51	Female	Mother
F12	F12C	7	Boy	F12P	36	Female	Mother
F13	F13C	7	Boy	F13P	36	Female	Mother
F14	F14C	9	Girl	F14P	54	Female	Mother
F15	F15C	9	Boy	F15P	47	Female	Mother
F16	F16C	6	Boy	F16P	32	Female	Mother

Table 1. Parent and child participants' demographic information and their relationships (age and gender). F1, F4, F5, and F7 were groups that involved more than one parent or child from their families, where F1, F4, and F5 had one parent co-located with one child (placed in the same row in the table), and F7 had both children co-located on the same side. F14 and F15 were two families that participated in one group session (each family located on the same side).

natural setting. Ten groups of participants completed the study at our research lab and five groups completed the study from their own places.

Each session of our design probe study lasted for about 45 to 50 minutes, including three activities:

- **Instruction session**: researchers explained the usage of each design probe and let participants complete one puzzle using the explained design probe. The instruction session often took about 10 minutes for participants to play with all three design probes. Participants were allowed to talk to and ask researchers questions during the instruction session.
- **Free play session**: participants were asked to use the design probe they preferred and play freely for about 20 minutes without researchers' interruptions. Participants could also switch design probes during the play. Although researchers mostly observed with minimum interruptions during the free play session, participants were still allowed to ask researchers questions or seek help to ensure a good play experience.
- **Post-study interview**: following the free play session, we asked parent and child participants separately to collect their feedback on our design probes, as well as questions about their thoughts from the play session. The post-study interview for parents took about 10 to 15 minutes and about 10 minutes with children on average. We also collected background information on families' technology usage and activity practices during the post-study interviews.

Fig. 3. Our study settings: (a) demonstrates an example study room settings for participants who completed the session in a lab. Participants were separated into two groups and joined the session from the two stations separated by the divider to simulate a remote setup; (b) shows an example setup for a session conducted at participants' places, where two groups sat on two sides of a table with two stations and divided by a desktop divider to simulate a remote setup.

All of the instruction and free play sessions were recorded using *Zoom* [2] which we set up as part of our design probes. The recordings captured participants' faces, actions, as well as their interactions with the shared workspace (with two cameras on the devices at each station). Researchers also took notes when observing the instruction and free play sessions. The post-study sessions were audio recorded for all participants. Following each study session, the research team debriefed the session and kept memos for ongoing reflections.

3.4 Data Collection and Analysis

To understand how children and parents use various design features provided by our design probes during a remote play session, we took an qualitative approach to analyze our data. We followed an iterative coding process to analyze all video recordings. The first two authors first open-coded four play sessions (26% of the collected data) then clustered the open codes to create a codebook related to our research questions. The codebook includes a total of 60 individual codes, covering areas including parents and children's coordination and communication over puzzle solving (usage of visual reference, verbal communication, and gestures), working dynamics between remote participants as well as co-located participants, conflicts and negotiations among parents and children as well as content of their conversation exchanges during the remote social play. We provide a detailed version of the codebook in the appendix (Appendix A). The first two authors then separately applied the codebook to three sessions (20% of the collected data) to calibrate the understanding of the established codes in the codebook. Inter-rater reliability for these three sessions was 0.86, which demonstrates a good understanding and agreement of the codebook between the two authors [50]. Each author led the analysis for half of the sessions. For the recording data that could not be covered by the codebook, we created new open codes and clustered them for findings. To analyze post-study interviews, observation notes, debriefing memos, and collected questionnaires, we first converted audio recordings into transcripts and then followed a qualitative coding process to open code these data and iteratively clustered them into common themes to supplement the insights generated from our video recording analysis. Some examples of themes include challenges in working with the same set of digital puzzle pieces, the need of independent but yet connected workspace, and the need of awareness in the workspace for social

[2] *Zoom* is a cloud-based video conferencing application that enables users to conduct and record virtual meetings, webinars, and real-time messaging.

experience. We structured our findings from video recordings and all other data following our research questions, which we describe in the following section.

4 FINDINGS

Our participants, on average, spent 14 minutes completing the instruction part of the study, where they were required to learn and use each design probe to solve a puzzle, and 24 minutes with the free play session, where they could choose any probe to play. On average, each group completed 11.6 puzzles (*SD* = 0.95), of which 11 were solved correctly. Unsolved puzzles were due to situations such as participants thought they solved the puzzle correctly and proceeded to the next puzzle, or lost patience with the current one if they spent too long solving it. All groups used the first two design probes during the free play time, while only three groups also played with the third design probe. Regarding participants' preferences for different design probes, most parents (15 out of 17 parents) preferred the probe with basic video and audio setup because of its ease of use and the physicality of the puzzle objects. While most child participants (11 out of 19) considered the same probe as the easiest and most fun to play, some children (7 out of 19) thought the probes with a more connected workspace (design probe #2 and #3) are more fun because of the ability to "*mess around with the other side*" (F7C2).

In this section, we present findings about parents and children's communication and coordination over collaborative puzzle solving facilitated by our design probes (RQ1a), their usage and preference of the shared workplace and objects (RQ1b), and the observed collaboration dynamics, conflicts, and negotiations among parents and children during the social play session (RQ2).

4.1 Communication and Coordination over Puzzle Solving

4.1.1 Usage of Visual References to the Remote Workspace. We found all child and parent participants made frequent visual references to the other side's workspace during the play. Parents and children used this visual reference when they wanted to check in on the other side's work (e.g., F2, F3, F5), struggled with solving the puzzle by themselves (e.g., F5, F9, F13), or when verbally communicating with the other side about the puzzle (e.g., F6, F8, F12). We also observed that in all 15 groups, when parents completed the puzzles before their children, they sometimes waited and watched their children complete the puzzles in silence, without any additional actions. The visual reference of the other side's workspace and children's actions was enough for parents to monitor and understand their children's current status when playing remotely.

4.1.2 Usage of Verbal Instructions and Communication. Both parents and children used verbal instructions to coordinate with their remote and co-located partners during the play sessions. Overall, we found that parents used verbal instructions more frequently than children during 14 groups' play sessions. Parents in these groups often took more leads when solving puzzles or engaged children more through verbal communication during the play. For one session where both parent and child contributed more equally to the play, leading the puzzle-solving process and helping the other side out, we observed a similar amount of verbal instructions between parent and child (F9). In the post-study interview, F9P commented that such good verbal coordination and equal play contribution between her daughter and her came from their previous experience playing chess together over videochat when F9C was staying with grandparents.

Among the different types of verbal instructions used by parents, we found more parents used guiding or indirect instructions (e.g., "*Can you figure out which piece go into the tail?*") than direct instructions (e.g., "*You should move the small triangle there.*"). These guiding instructions often involve telling children a systematic way to solve the puzzle (e.g., "*Can you figure out where to put the big triangles?*"), or asking children to examine a specific place on the puzzle to see if they can spot some problems or figure out a solution (e.g., "*Can you spot the differences between our puzzles?*").

Regarding how parents and children referred to various objects during the play, we found that most parents (10 parents) used both detailed references and deictic references in their verbal instructions. Fewer children (3) used detailed references compared to deictic references (8) in their verbal instructions and coordination. A detailed reference in the verbal instruction often involved describing a puzzle piece using detailed information such as "*the big blue triangle*" (F13P) where a deictic reference needed to be understood in the context (e.g., with visual reference or gestural communication) such as "*this part should fit this triangle*" while child also holding the triangle in the workspace (F6C). Since all of our design probes provided a visual reference to children's workspace, there were no difficulties for parents to understand the deictic reference in children's verbal instructions when they could get the additional information from the visual reference. In some sessions (e.g., F5, F12, F13) we observed that children sometimes need additional clarifications about the referred objects when following parents' verbal instructions. This need for additional clarification could be caused by the cognitive challenge for children to process and understand visual reference and verbal instruction at the same time during video-mediated communication that involves multiple screen spaces and devices.

Besides verbal coordination and instructions on how to solve the puzzles during the play, verbal communication was used to check in on the other side's status (e.g., "*Do you want to take a break?*"), confirming that the system was working (e.g., "*Can you see my puzzle here?*"), specifically asking the other side's opinion on their work (e.g., "*Am I solving this part correctly?*"), as well as for encouragement and celebration when a puzzle was solved (e.g., "*Good job!*"). We observed these conversation exchanges happened more between remote participants compared to between co-located participants, where the verbal communication was more focused on puzzle solving and rule settings (when parents needed to resolve potential conflicts), which we describe in detail in section 4.3.

4.1.3 Usage of Gestural Interactions in Verbal Communications. Both parents and children used gestures to refer to specific puzzle pieces or parts of the workspace when discussing how to solve puzzles during the play (13 out of 15 groups). Overall, we found parents used gestures more frequently compared to children, since gestures were often used with verbal instructions and we observed more verbal instruction usage among parents compared to children. When having deictic references in their verbal instructions, parents often used gestures such as pointing to the puzzle piece to complement their references to an object for clearer communication (8 groups). However, fewer children (2) used gestures with verbal instructions during the play, compared to parents.

Besides using gestures for object reference during the play, we found some children also used gestures when asking their parents to clarify some instructions. For example, F13C used gestures to ask which alignment F13P was talking about when she asked him to "*place a triangle piece with the longest side on the bottom.*" F8C also used gestures to ask if F8P was referring to a specific puzzle piece in her instruction. Unlike parents who used gestures mostly in the workspace (i.e., the tablet used during the play for hosting all puzzles and design probes), children (e.g., F9C, F12C, F13C) used gestures outside the workspace defined by the tablet, and more directly with the cameras. For example, when using gestures to ask F12P for clarification on the instruction, F12C directly placed his hands close to the phone camera (which captured the tablet workspace) when talking to F12P. Similarly, F13C brought the puzzle piece to the phone camera for it to capture, when he tried to confirm if it was the piece which F13P was referring to. In both examples, children interact with the camera more closely when talking directly with their parents using gestures, rather than staging something in the tablet workspace.

We observed that children also used gestures for social interactions with their parents when playing “remotely”, while parents primarily relied on verbal communication when interacting with their children remotely. For example, when F12C and F12P finally solved a difficult puzzle during the session, F12C did an air high-five toward the tablet used for displaying his mom’s workspace. F14C often raised hands when celebrating a puzzle was solved successfully as well as saying “*yay*” during the session. Being able to communicate with gestures to allow social and emotional expressions during these moments is important for children in social play.

4.2 Usage of the Shared Workspace and Shared Objects

All of our design probes provide symmetric access to the connected workspace and objects for both sides in a remote play. The level of connectedness between the workspace and objects varies among the three design probes: the probes using tangible objects (design probes #1 and #2, *Base* and *Pointing)* provide symmetric access to two sets of connected objects, while the probe using digital objects (design probe #3, *Digital*) provides symmetric access to the same set of virtual puzzle pieces. Among all 15 play sessions, we observed that the level of connectedness between workspaces and objects affects the types of collaborations between remote participants in all setups. We observed more loosely coupled collaboration between remote participants and with tangible objects, where parents and children often focused on their own movable pieces, especially at the beginning stage of a puzzle. In most groups (14 out of 15), we observed more tightly coupled collaboration, with more frequent verbal and explicit communication about turn-taking and discussions on how to solve the puzzle when using digital objects. Some families (e.g., F1, F8) did not explicitly talk about whose turn it was. Parents just observed their children’s actions and movements before they attempted any actions with the digital puzzle objects.

Although we observed mostly loosely coupled collaboration between parents and children during the remote play (where parents and children played at the same time using the tangible piece, and communicated when running into challenges), we found that F9 collaborated more tightly when using tangible puzzle pieces with the design probes. When working on the puzzle, F9P specifically offset her actions with the workspace, by letting and watching F9C complete one part of the puzzle first, then moved to another part of the puzzle and took the lead in solving it. F9P also explicitly divided the work at the beginning of a puzzle, where she talked about assigning the tasks of solving the left side of the puzzle to F9C while she was working on the right side of the puzzle. Both our parent and child participants preferred the tangible objects with the connected workspace, because the interactions with the tangible puzzle objects aligned more with their mental model of how to manipulate a geometric object during the play, compared to manipulating digital objects where they needed to consider rotation and movement in two different steps. Parents also preferred tangible objects for their requirement of interactions with hands, which made it different from applications with only digital interactions and added additional screen time for children.

Notably, all parents in our study let their children take the lead and interact with the workspace controls throughout the play session, for switching design probes, or going to the next puzzle, often after they discussed and reached an agreement on these actions verbally. For some parents (e.g., F1P, F6P), these small interactions with the workspace, although highly connected between remote participants, did not need verbal agreement between parents and children before children took action, as parents often assume they played a more helper or secondary role and let children lead the action during the play.

We found participants often have difficulties managing the play when using the connected workspace with highly-connected digital puzzle objects during the play, which also was one of the main reasons parent participants ranked the probe with digital puzzles as their least favorite probe. The connectedness between workspace and objects can lead to a lack of independent workspace for

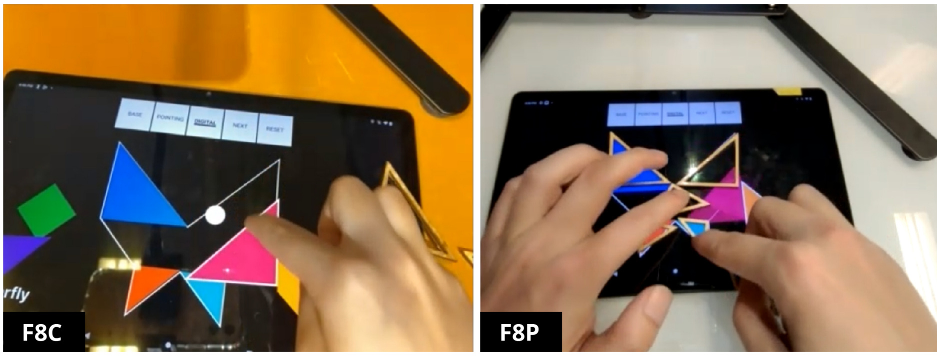

Fig. 4. Example of puzzle setup of parent and child of F8. While F8C was manipulating digital puzzles, F8P used tangible puzzle pieces in the shared workspace so he could solve the puzzle at the same time.

remote participants as well as co-located participants during the social play. When playing with the digital puzzle objects, we observed both F8P and F9P used the tangible puzzle objects in the shared workspace, and let F8C and F9C just use the digital puzzle pieces when working together (Figure 4). F13C similarly used a tangible puzzle piece when F13P was working on figuring out how to fit in the shape of the puzzle using the digital version, as he wanted to try figuring out the solution as well. F13C and F15C even further attempted to break the connection of the shared workspace by blocking the video camera that captured their workspace or asked the researcher to turn the visual reference tablet to the side. Similar challenges were observed in co-located setups as well during a play session, especially when children were co-located together with another "remote" parent. While F7C1 was leading and taking control of placing puzzles on the workplace, F7C2 used a separate set of tangible puzzle objects to play on the side, and tried to continue engaging in the session. During the post-study interviews, parents (e.g., F5P, F9P) commented that they would prefer a more independent workspace, or the ability to work independently before playing together when solving puzzles. However, the connectivity between remote workspace and objects is still an important part that contributes to a good play and social experience. F9C specifically toggled between the first two design probes to turn on the visual object awareness feature so she could better talk to F9P about how to solve a puzzle. And for important moments like finishing the last piece of the puzzle, parents and children often did that together, even using separate sets of the puzzle objects.

4.3 Collaboration Dynamics, Conflicts, and Negotiations during Play

We observed examples of parents leading the play (14 out of 15 groups), as well as both sides contributed equally to the play (1 group) when playing collaboratively. During the play sessions, parents often helped explicitly divide tasks among themselves for solving the puzzle, such as delegating different parts of the puzzle for each one to solve (e.g., F3, F8, F9) or different puzzle pieces for each one to control (e.g., F4, F6, F10). Since our child participants were still developing their collaborative and social skills at their age stage, parents often took the lead in managing the collaboration and play among participants (e.g., between parent and child as well as between child and child) during the play session. For example, both F4P and F5P set up rules between the child co-located with them and the child located "remotely" during the play. F5P asked F5C2 to let F5C1 take the lead in the solving process for the new puzzle when using tangible objects, while F13P talked about both sides taking turns to control one puzzle piece at a time when using digital objects. Parents also distributed tasks explicitly for managing the play, such as assigning different parts of the puzzle to different children. These examples of parent participants taking on management responsibilities were observed in both tightly and loosely coupled collaborations. When parents and children worked relatively independently using tangible objects, we found parents would engage children in the play by coming up with tasks for children to complete or asking children for help with a problem during the play. For example, both F3P and F8P asked for their children's help when they ran into challenges with finishing the last couple of pieces in the puzzles. When F11C started losing patience because he was struggling with completing the puzzle, F11P asked him to compare their solutions and see if he could find any difference.

When the play session involved more than one child participant, they often had conflicts over accessing and controlling the shared objects, in both remote and co-located setups, where parents would step in and help resolve the conflicts. The location of parents in the setup might affect the dynamics between children during the play. F5P commented during the post-study interview that when F5C1 and F5C2 played together at home, F5C2 (the younger brother) often followed F5C1 (the older brother)'s words during the play. However, during our study, because she was with F5C2 on one side, F5C2 felt like "*he has a backup*" and gave more instructions to F5C1 when playing together. F4P specifically asked to sit with F4C2 on the same side (the younger sister) to play with F4C1 (the older brother) "remotely", so she could access the puzzle pieces and participate in the play (who had challenges accessing the puzzles as F4C1 was protective of his access when they were on the same side).

The main conflicts we observed between parents and children or between children include disagreements on whether a puzzle was solved correctly (or which side had the correct solution), whether they should move on to the next puzzle, and whether the other side (either a remote or co-located person) was interfering with their actions (e.g., both trying to use the same puzzle piece simultaneously). When there was a conflict, we found that parents often took the lead in verbalizing and raising attention to the situation then starting a negotiation in most of the sessions (10 out of 15). Most conflicts we observed during the play were solved easily and quickly, such as deciding which puzzle to play or which design probe to use, when parents were willing to compromise during the negotiation. For example, when F6C and F6P were deciding which puzzle to solve next, and F6C did not seem to be willing to follow the parent's suggestions and kept tapping on the next button, F6P finally stopped talking and waited for the child to stop "flipping through" puzzles and make the decision. During these conflicts, both parents and children also used visual reference to the other side's workspace and actions when trying to resolve the conflicts quickly, instead of verbally negotiating with others to resolve conflict. When F13C continuously complained about F13P's interference with his control of a puzzle piece, F13P stopped trying to explain her action and just used the visual reference captured by the camera to work around F13C's controls to the puzzle pieces. After F14P asked F14C to let the "remote" side (F15C and F15P) lead the control of the puzzle pieces, F14C started to use the provided visual reference to navigate around F15C's and F15P's ongoing actions without F14P's reminder, to avoid potential conflicts. However, conflicts on how to solve the puzzle, as well as whether a puzzle was solved correctly often took longer time for parents and children to resolve. We found that our child participants were often more protective with their solutions and ways of solving the puzzle, and sometimes could be difficult for parents to persuade or talk to without any additional support or an objective guiding solution from the system (F9P, F11P). And when it was difficult to persuade children into re-thinking their solutions, parents like F11P and F13P just let children move on to the next one without further asking them to go back to the previous incorrect puzzle.

Besides the role of managing and facilitating the play, parents played the helper role in correcting and guiding the puzzle solution as well when playing either remotely or co-located with a child participant. In remote setups, parents often used verbal and gestural communication to provide guidance and direct instruction that can help children solve the puzzles. When co-located with children, we found parents often took the role that helped reduce children's cognitive load when they focused on their own workspace. F1P2 helped monitor the visual reference tablet which showed F1P1's workspace, and verbally guided F1C to solve the puzzle. F14P played a similar role, where she helped "translate" the actions she observed from the visual reference tablet into verbal instructions so F14C could keep focusing on their own workspace. This helper role that co-located parent played can be extremely helpful for children during the play session, since we observed that some children (e.g., F2C, F12C), when they were by themselves, sometimes had difficulties mapping their remote parents' solution from the visual reference tablet to actions and their own workspace, and often took longer time to follow the other side's actions compared to parents.

5 DISCUSSION

We discuss opportunities for collaborative technology design to support intergenerational play in various settings (e.g., tangible, digital and augmented tangible) in this section, as well as limitations and future work.

5.1 Opportunities to Support Social Structured Play in Various Settings

With the findings in parents' and children's usage of shared communication space, workspace, play objects, and the dynamics of their interactions, we discuss opportunities in designing collaborative technology to better support intergenerational social play over distance, including supporting different intergenerational communication usages, lowering cognitive requirements for children, and supporting a diverse of remote and co-located setups.

5.1.1 Support Different Preferences of Communication Usage between Generations. Through the design probe study, we found that parents and children shared a similar usage set of communication and coordination methods/modalities over collaborative play, with differences in types of verbal and gestural communication and preferences. Existing video-based communication systems and applications such as *Zoom* and *Facetime*, are designed mostly to address adult users' needs. Thus, there are opportunities to consider children's preferences in communication methods in system design that can better support intergenerational remote play. For example, considering children's usage of mostly deictic references in their verbal instructions, systems can help children specify the reference with their parents and other adult family members more effectively by automatically adding complementary contextual information to their verbal communication. Such systems could interpret the child's environment and gestures to provide contextual information automatically. For instance, when a child points to an object or area, the system could identify and highlight it for the adult, thereby bridging the contextual gap in communication [31]. Another solution is developing systems that can recognize and interpret children's gestures and then convey these gestures effectively to the adult to enhance understanding or awareness. This technology could translate a child's physical actions into digital signals that are easy for adults to notice and comprehend, even if they're not visually obvious. Moreover, since children often need more video-facilitated communication (e.g., for social gestures) rather than simply relying on audio-enabled communication to maintain engagement [72], collaborative systems, especially ones that involve multiple cameras, should consider supporting features such as automatic configuration of the cameras [60] for children's needs in gestural and visual communication during remote intergenerational play.

5.1.2 Lowering Cognitive Requirements for Children during Remote Play. Prior work in collaborative technology design to support children's play has identified cognitive challenges for children to understand their partner's action through a feedback screen in video-mediated free play [71]. This challenge becomes more pronounced during structured play where children must process visual references from a remote parent's workspace and respond appropriately. Therefore, system designs must aim to minimize cognitive strain during these video-facilitated play sessions. One promising avenue is the use of AR technologies. AR can overlay visual cues directly onto real-world objects, thereby aligning digital information with physical elements in the child's environment. It can be helpful for systems that incorporate tangible objects and interactions in intergenerational play [29, 34]. Alternatively, considering system design with an overlapped shared communication and workspace for intergenerational play might help children understand the remote participant's actions with pre-processed information [51]. Also, echoed the prior work of involving co-located adult family members as facilitators [24, 35], we observed parents like F1P1 and F14P played a "translator" role when co-located with their children. They helped translate visual references into verbal instructions. This finding suggests opportunities to leverage resources from co-located participants to meet the cognitive requirements for processing information for children's successful play during remote intergenerational communication. This translator role also suggests that systems could incorporate AI-driven features to interpret visual cues and provide verbal explanations or suggestions, helping children understand and respond to the remote participants' actions.

5.1.3 Support Hybrid Setups for Intergenerational Social Play. Supporting hybrid setups is a common requirement in technology design for family communication, such as siblings videochat with remote grandparents. In these remote family communications, parents are often involved as co-located participants as well to provide help and facilitation for children [35]. The requirement of supporting hybrid setups also became more common in technology-facilitated communication after the recent COVID-19 pandemic, after people became used to considering remote options for in-person activities. Although parents are often used to playing the role as facilitator to help resolve potential conflicts between children during activities, a system with flexibility to support co-located participants' equal access can help reduce the burden on parents to manage conflicts in hybrid setups. Our findings also suggest that similar access to the shared workspace does not necessarily mean similar formats of interactions—as we observed our participants (e.g., F8, F9) use tangible and digital puzzle sets to play together in a shared workspace. Providing a range of formats with similar access in a system design can be helpful especially for supporting different preferences of interactions between generations. To support equal access to the play content in the system design for remote and co-located participants, researchers also need to consider the balance between connectedness and disconnectedness of the shared activity content—as we observed that our participants had more challenges when playing with a fully connected puzzle set and preferred the design probes where they could work more independently.

When assigning co-located participants with different roles for processing information and communication from different modalities (section 5.1.2), there are opportunities for collaborative systems to better support such distribution of communication among co-located parents and children. Systems can leverage works from supporting multi-device setups (e.g., [10]) and consider having a structure to help distribute the communication to multiple co-located participants for hybrid setups (e.g., supporting multiple screen or device configurations with different part/modality of communication for co-located participants).

5.2 Supporting Intergenerational Connection over Distance beyond Structured Play

Our study chose a specific example of structured play as the context to understand technology design opportunities, because the rules and tasks associated with structured play can often help provide a good and existing scaffold for intergenerational play over distance, and result in better connection outcome. The specific example of tangram puzzle that requires children to manipulate objects to solve certain problems also helped us investigate the digital and tangible formats of objects in system design considerations. Unlike structured play, unstructured and open-ended play, like drawings and other forms of free play, can provide children with the benefits of developing creativity and encouraging curiosity [41]. Our findings in intergenerational remote play were affected by the specific type of structured play we chose. However, some insights, especially regarding the design of the shared workspace, and the dynamics among parents and children in hybrid settings can be helpful when designing systems to support unstructured play as well. Unstructured play, such as creative games and imaginative play are important in children's everyday activities and development. Understanding technology design considerations in remote and collaborative settings for unstructured play can be helpful for enhancing children's and adults' experience in more contexts for children's communication with remote family members or remote learning activities. Our findings of parents' and children's needs for a connected yet separate shared workspace echo the need to support managing the visibility of their play stages for children in video-facilitated open-ended play. Systems that support a shared workspace and objects with the ability to manage the connectivity and awareness between participants can be helpful for unstructured intergenerational play as well. Besides, the insights on children's cognitive requirements in video-facilitated play and various co-located roles that parents play from our study can provide design implications for supporting video-facilitated unstructured play as well. System designs that allow distributing play and communication among co-located participants can potentially provide benefits for unstructured intergenerational play in hybrid setups.

5.3 Limitations and Future Work

Our findings were constrained by the specific choice of activity and design probes in the study. The use of tangram puzzle, while effective for structured play, may not capture the breadth of interaction dynamics present in other forms of play or collaborative activities. Additionally, the simulated remote environment of the study, including the laboratory setting and technology setup, might not accurately reflect a natural condition for remote intergenerational play. The simulated remote social play settings allowed parents and children to interact with each other more naturally with the presence of researchers, but brought potential interference between the two simulated "remote" sites to the play sessions. Besides, collaborative social play in an actual remote setting might have other challenges such as voice quality (e.g., children might have challenges keeping talking directly to the microphone). Future studies can investigate similar play activities in natural remote settings to help validate and extend our results to real-world scenarios. Our findings mainly focused on collaborative social play among parents and children (including siblings), while social play in intergenerational settings can potentially include older family members like grandparents, who might have different challenges playing collaboratively with the younger generation compared to parents. Future work can further investigate more and broader intergenerational settings to help generalize our findings.

In addition, our research did not delve deeply into the nuances of gesture usage by children (e.g., gestures for pointing, iconic representation, spatial distance, or motion in collaborative work). Gestures are a crucial aspect of non-verbal communication, especially in remote interactions, to convey emotions, emphasize points, and enhance understanding when verbal cues may be insufficient. While our design probe setups allow sharing all gestures through video cameras, the visual augmentation of the tangible objects (in Design Probe #2) and the specific play activities we used for the study emphasized more on the usage of pointing gestures in collaborative play and communication. Our specific study design did not capture details on how different types of gestures contribute to collaborative play and communication over distance. This oversight might limit our understanding of the role that gestures play in enhancing or hindering remote intergenerational interactions. Future work can investigate this direction in greater detail, exploring how different types of gestures contribute to the collaborative experience and communication process in remote intergenerational play.

The study did not fully explore participants' engagement during play, as it primarily focused on immediate interactions during the sessions. Variations in engagement, both within and across sessions, could provide valuable insights into the effectiveness of different design probes and the dynamics during remote play. Future research should examine how engagement varies within and across sessions to gain insights into the effectiveness of different design features, using both quantitative and qualitative measures of engagement to provide a more comprehensive understanding.

Finally, our work is limited by the specific observational approach and the simulated remote study setting we chose. Although we collected observation notes and allowed participants to talk and ask questions during the play sessions, our method did not let us understand participants' motivations and reactions to our design probes in situ, compared to a similar study setup with a contextual inquiry approach. Our work also did not investigate the long-term effects of remote intergenerational play using the design probes. Understanding how continuous use of these technologies affects intergenerational relationships, children's skill development, and sustained interest in remote play is crucial for evaluating the long-term utility of the proposed technology design. Hence there are opportunities for future research to examine the long-term effects from the usage of these system designs for intergeneraitonal play in everyday family settings.

6 CONCLUSION

To explore design opportunities in collaborative technology for intergenerational remote play, we conducted a design probe study with 16 families of parents and children. We observed the interactions between parents and children during collaborative social play, which was supported by visual, verbal, and gestural communication, as well as a shared workspace with digital and tangible play objects. Our findings reveal differences in how parents and children use and prefer verbal and gestural communication during play. We also identified challenges in using a connected workspace and recognized the need for a "disconnected" space when playing together. These insights from the design probe study provide detailed implications for the future design of technology that supports intergenerational remote play in hybrid settings.

ACKNOWLEDGMENTS

We thank our child and parent participants for their support and contribution to this work, Ruotong Wang for her help with the study, as well as our reviewers and colleagues from the Connections Lab at Simon Fraser University for their valuable feedback in improving this work. This work was funded by NSERC Discovery Grant (# R611600).

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A CODEBOOK FOR ANALYZING COLLECTED VIDEO DATA

Area	Category	Code	Description
Basic Study Information	Session Information	Number of puzzle completed	Number of puzzle completed
		Number of puzzle solved correctly	Number of puzzles solved correclty
		Instruction session length	Instruction session length (mm:ss)
		Free play session length	Free play session length (mm:ss)
	Setup Information	Basic Setup with separated parent and child (remote)	0 - not applicable 1 - applicable
		Setup with co-located parent and child	0 - not applicable 1 - applicable
		Setup with co-located children	0 - not applicable 1 - applicable
	Probe Usage	Which design probes were used during free play session	1 - probe #1 with tangible puzzles 2 - probe #2 with object awareness 3 - probe #3 with digital puzzles
Coordination Usage for Puzzle Solving	Visual Reference (when parent or child looks up and refers to the other side's workspace)	Parent made visual reference to the workspace (frequency)	0 - never 1 - sometime (< 5 times) 2 - frequent (> 5 times)
		Child made visual reference to the workspace	0 - never 1 - sometime (< 5 times) 2 - frequent (> 5 times)
		Who made more visual references	P - parent C - child
	Gesture Usage (when parent or child point at their workspace when coordinating over the puzzle)	Parent used gestures as visual indictors (frequency)	0 - never 1 - sometime (< 5 times) 2 - frequent (> 5 times)
		Child used gestures as visual indictors (frequency)	0 - never 1 - sometime (< 5 times) 2 - frequent (> 5 times)
		Who used more gestures	P - parent C - child
	Verbal Instructions (when conversation is clear instruction about how to solve puzzles)	Parent gave verbal instructions (frequency)	0 - never 1 - sometime (< 5 times) 2 - frequent (> 5 times)
		Child gave verbal instructions (frequency)	0 - never 1 - sometime (< 5 times) 2 - frequent (> 5 times)
		Who gave more verbal instructions	P - parent C - child
		Deictic references usage in instruction	P - parent used during the play C - child used during the play
		Detailed references usage in instruction	P - parent used during the play C - child used during the play
		Direct instructions on how to solve	P - parent used during the play C - child used during the play
		Guiding/Indirect instructions on how to solve	P - parent used during the play C - child used during the play
		Correcting instructions on how to solve	P - parent used during the play C - child used during the play
		Coordination related instructions	P - parent used during the play C - child used during the play
		Instructions with visual aids/gestures	P - parent used during the play C - child used during the play

Area	Category	Code	Description
Coordination Usage for Puzzle Solving	Task Objects Usage	Use a separate set of puzzle to work on the side	P - parent used during the play C - child used during the play
		Use a separate set to work on the shared space	P - parent used during the play C - child used during the play
		Reset the workspace/puzzle pieces	P - parent reset during the play C - child reset during the play
	Silent Waiting	Wait and watch for the other side to catch up with puzzle solving	P - parent waited C - child waited
		Wait for the other side to do something instead of doing it by oneself	P - parent waited C - child waited
	Other Coordination Usage	Other	Open code
Working Dymanics	Work Separately	Block the phone camera	R - in the remote setup C - in the co-located setup/side
		Work by oneself first	R - in the remote setup C - in the co-located setup/side
	Work together	Take turns to solve	R - in the remote setup C - in the co-located setup/side
		One side is aiding / helping the other	R - in the remote setup C - in the co-located setup/side
		Who led the solving process most of the time	P - parent led C - child led
	Coupling	Loosley coupled collaboration	R - in the remote setup C - in the co-located setup/side
		Tightly coupled collaboration	R - in the remote setup C - in the co-located setup/side
	Other Working Dynamics	Other	Open code
Conflict and Negotiation		Conflicts happened during puzzle solving (verbalized)	R - in the remote setup C - in the co-located setup/side
	Negotiation Content Type	Who is controlling the virtual puzzle pieces	R - in the remote setup C - in the co-located setup/side
		Who is controlling the physical pieces	R - in the remote setup C - in the co-located setup/side
		Which puzzle to solve	R - in the remote setup C - in the co-located setup/side
		How to solve the puzzle	R - in the remote setup C - in the co-located setup/side
		Whether the puzzle is solved correctly	R - in the remote setup C - in the co-located setup/side
		Which tech probe to use	R - in the remote setup C - in the co-located setup/side
	Status of the Conflicts	Any unresolved conflicts	R - in the remote setup C - in the co-located setup/side
		Who raised/verbalized conflict most of the time	P - parent did C - child did
		Who started negotiation most of the time	P - parent started C - child started
		Who compromised most of the time	P - parent compromised C - child compromised
		Did parent step in if between children	0 - not applicable 1 - applicable
	Other Types of Conflicts	Other	Open code

Area	Category	Code	Description
Session Breakdowns	System Related Breakdowns	Mis-tapped buttons in the app	0 - not applicable 1 - applicable
		Accidently exit the app	0 - not applicable 1 - applicable
	Task Related Breakdowns	One side didn't want to continue the task	0 - not applicable 1 - applicable
	Other Breakdowns	Other	Open code
Conversation Exchanges	Conservation Content Type	Setting up a competition	R - in the remote setup C - in the co-located setup/side
		Setting up rules	R - in the remote setup C - in the co-located setup/side
		Checking status/let the other side know what they are doing	R - in the remote setup C - in the co-located setup/side
		Calling for attention	R - in the remote setup C - in the co-located setup/side
		Confirming the system is working	R - in the remote setup C - in the co-located setup/side
		Asking whether they are doing things correctly or not	R - in the remote setup C - in the co-located setup/side
		Encouragement (often from one side)	R - in the remote setup C - in the co-located setup/side
		Celebration (together)	R - in the remote setup C - in the co-located setup/side
		Other types of conversation	Open code
Other Social Interactions		Other types of social interactions	Open code

Received January 2024; revised April 2024; accepted May 2024