User Interfaces for Tangible Characters: Can Children Connect Remotely through Toy Perspectives?

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ABSTRACT

What if children's make-believe characters could keep in touch when the children were apart? We propose a novel concept for children's use of technology through imagination play: user interfaces designed to be used by children's character toys rather than directly by the children ("doll-computer interfaces"). We apply this model to the challenge of remote communication for children with an enhanced dollhouse containing small-scale interfaces for the dolls with a variety of fully functional multimodal communication functions. Using this interface as a technology probe, we explore a variety of design decisions with remote pairs of children. Our preliminary results suggest that toy-perspective and manipulable toy elements are particularly helpful in supporting play and successful use of communication technologies, while the "true-to-life" toy aspects are sensitive to individual frames of reference and more flexible interfaces that still fit within the toy context lead to creative communication strategies. We found that different communication channels offered interesting tradeoffs between uninterrupted play and rich verbal description. We also learned that the concept appeals to a wide age range but that the youngest children may need additional scaffolding for successful remote play.

Categories and Subject Descriptors

H.5.2 User Interfaces.

General Terms

Design, Human Factors.

Keywords

Children, remote play, storytelling, tangible interfaces, doll-computer interfaces.

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INTRODUCTION

Imagination play helps young children work through challenging new ideas about the world. Interactions through the intermediary of make-believe characters create a distance between the child and the narrative, a safe space to try multiple scenarios and to process interactions, to take risks while "disclaiming seriousness [3]." The type of distance and control imagination play provides is often missing when children use technology: there may be a right or wrong way to use a computer program, the requirements for correct use may end up dictating the interaction, or the technology can be so appealing and immersive that there is no chance to step back and reflect.

Supporting young children in maintaining meaningful, rich connections to distant family and friends is a well-established need. At the same time, children today are gaining access to existing communication technologies such as cell phones, text and instant messaging, social networking, and video chat at increasingly young ages. Are they successfully able to negotiate the social and emotional challenges of all these different types of connectivity (including perspective-taking, what information to share, what not to share, the real impact of communication even over anonymous channels)? Are they indeed able to create meaningful connections? The long-term impact of this recent shift is not yet known.

Imagination play where children project an identity onto make-believe characters creates a unique opportunity for recontextualization of technology. We propose the model of communication tools for character toys as a way to enable young children to "play about distance" and about distance communication technologies before they have to use them in earnest. These tools are designed to fit naturally into the context of make-believe stories with physical character toys such as dolls, stuffed animals, or action figures. The design model is to imagine what the world looks like from the character's point of view and to create effective "doll-computer" interactions. (Of course, this design process must operate on multiple levels: interfaces must ultimately be created for the child so that he

or she can successfully enact the character's use of the interfaces). This model would allow children to learn how to use the technologies by making them more accessible and engaging, while giving them the opportunity to work through the social and emotional challenges of communicating remotely.

This paper presents a first step towards the creation of such an interface: a study of children's interaction with technology in this context and the development of design guidelines for doll-computer interfaces.

As a probe, we iteratively designed a series of dollhouses augmented with technologies to support a range of communication styles. The first version included a telephone for the dolls, which was actually connected to another dollhouse using voice over IP. The dollhouse also included a mail system where dolls could deliver physical letters to the remote dollhouse through a scanning and electronic transmission system. Additionally, building on video conferencing trends for children's communication, another dollhouse included a live video chat system. We user tested these systems with a broad age range, varying the interface to observe the affordances of multiple communication channels, the use of toy-perspective, and the tradeoffs between different approaches to realism.

BACKGROUND

Pretend and imagination play have significant developmental benefits. These include learning self-regulation, self-control, language skills, creativity, communication skills, social skills, and the ability to create mental models [12] [5]. The effect of play lasts longer than the play years, increasing creative thinking, problem solving, and success in reading and writing later in life [17]. Pretend play also offers an outlet for children to enact situations beyond their realm of experience [9].

Play with character toys such as dolls, stuffed animals, or action figures represents the projection of an identity onto a physical object. Research points to this specific type of play as appealing to a wide range of ages because it provides the realism needed to help young children more easily initiate pretending, and allows the creation of complex micro-worlds by older children. Character toys are often used beyond the age children lose interest in play-acting [12]. We choose to focus on physical character toys in order to appeal to a range of ages and because of the ability it offers to designate that the physical tools are for the characters.

As children develop, they pretend in increasingly complex ways. They transition from imitation of simple gestures to complex transformations of objects and identities [12]. Children typically begin to engage in pretend play around age 2-3, at this stage primarily playing alone or in parallel. They begin to play together around 3-4. Around age 5, their narratives become more complex and stories are developed cooperatively. Children begin to internalize imagination play around 7-10 (sometimes later) and generally stop engaging in socio-dramatic play at that stage [3]. Ethnographic research on family communication [1] suggests that age 4 is when children begin to be included in the family's remote communication. This age is also close to the start of social imagination play. Based on this, our initial target age range is between 4 and 10 years old.

Our work builds from related work on gestural character toy interfaces, remote communication technologies for children, and tools to support imagination play and storytelling.

An example of a successful “doll-computer interface," though it was not explicitly described this way, is Picture This! [22] This work is an authoring tool for video capture that uses doll-sized cameras and backpacks to allow children to record video from the dolls' point of view and control the recording using "anthropomorphic" doll gestures. The use of visual toy perspective prompts the children to act out conversations between the dolls. The control gestures take advantage of natural gestures children make while animating toy characters, for instance: "The dolls need to jump in synchrony at completion and shake for attention, as if the doll wants to say: “film me, film me!”" (Vaucelle referred to this model as Gesture Object Interfaces). At the same time, the interface is designed to be easy to use for the children themselves: they have a large video screen on which to see the video feed. Vaucelle described this work as allowing the children to explore "atypical perspectives": what characters "see" in the context of a make-believe world. This success of this work in user tests with children suggests this model has significant potential.

PlayPals [6], a system of dolls that remotely communicates gestures as well as multiple communication channels, uses miniature doll "accessories" (phone and video camera) as metaphors to understanding how to use the interface and "make the interaction more intuitive." This addresses making the interface easy to understand, but not specifically that these accessories are intended to be handled and used by the dolls or that the communication is from their point of view. This work also addresses the idea of (remote) character toys as "safe" communication intermediaries. Children asked how they would use the interface said: "I can have my friend’s doll ask my friend’s mom something I am too shy to ask myself." Children do this with ordinary character toys, but the remoteness adds an additional layer that is worth exploring.

Another interface using toy gestures is SenToy, where emotion-expressing physical poses of the toy are detected and used to control a screen game character. In the design of this interface, emotional toy gestures were identified and then the system was built to recognize these [2]. Children were able to perform most of the gestures and found this a compelling way to interact with the game [14].

There is a well-established need for remote communication interfaces which are accessible to children and which support compelling and playful interaction. Mainstream distance communication systems are overwhelmingly intended for adult-to-adult communication. They are

designed for work and conversation, not play, and they do not support physical/spatial interaction with the communication partner. Particularly affecting acessibility with regards to younger children, they require knowing how to read and write, start up a chat program, or dial a telephone number, and the motor and cognitive skills to hold a telephone, type, or speak at the right level into a microphone.

Our research specifically addresses child-to-child communication, but it is worth describing approaches to family communication because they also address the issues present in facilitating distance communication for young children. A common design issue is the need to give the children something to communicate *about* in order for them to stay engaged. For instance, study of Family Story Play, a physical interface for reading together at a distance, shows that children have more extended remote time with their family members when there is "something to talk about"--in this case, the book they are reading together [15]. Another issue is the challenge of maintaining awareness of the communication partner's perspective and altering one's own actions accordingly: for instance, raising one's voice to be heard or staying in the camera's field of view. Young children are still developing the ability to see from another's perspective, and while they normally practice through co-located social play, remote communication and the incorporation of technology makes the interaction even more challenging. Work on Video Playdate, an investigation of free play at a distance over video channels, identifies the difficulty of playing naturally when there is a need to stay within the camera's frame of view, and describes the children "staging" their play area by setting up pillows or other objects that they know are in the video frame and then playing within those boundaries [12].

Recent work has explored tangible and unconventional interfaces to address these challenges, making physical interactions possible, making the interface familiar and easy to use, and making it appealing and engaging. Some are innovative indicators of presence, include remote-hugging pajamas [11], asynchronous multimedia messaging centers [20], enhanced digital picture frames, remote-controllable teddy bears. Other systems for child-to-child communication, such as Message Bubbles, have explored remote video communication designed for very young children to operate with an intuitive physical interface, [19].

Another category this work draws from is the rich history of technology interfaces for encouraging pretend and storytelling play. Our system is closer to a traditional toy design in that it only provides scaffolding through context and prop cues, and does not guide the story creation directly. However, using a passive interface may allow us to discover areas that might benefit from additional scaffolding. SAM, a virtual storytelling peer, helps its child playmate develop richer stories by taking turns telling a story about a shared dollhouse character [7]. Other systems scaffold play by recording and playing back previous stories, either in a character-centric way as in Rosebud [10] and DollTalk[21], or a setting-based way as with StoryMat [18]. Another approach is with non-tangible computer game interfaces that allow children to build stories. A particularly relevant example in terms of character perspective, the FearNot system presents the perspectives of multiple story characters to "induce perspective taking as a reflection tool to allow and promote social learning in children [16]."

SYSTEM DESIGN

Interface Versions

We built three versions of the system over the course of the study. These systems were designed iteratively, with the previous dollhouse informing the design of the next.

We started with a simple dollhouse. Based on user feedback, later versions included more rooms and props so that the characters would have more to "do" (more story prompts for the children). We also changed from small bear characters in the first dollhouse to families of dolls in the next one. In terms of alternative features, we user-tested one version with voice but not video communication and after requests from the children to be able to see each other, later built a version to explore what affordances video offered. Because of these variations between the interfaces, when analyzing the user study results we extract and discuss specific interaction patterns rather than comparing play content or amount. In the future a more quantitative study strictly comparing specific interface features or communication channels may be desireable, but for this preliminary study the goal was to explore the design space of the idea in a relatively broad way, informed by the children's use and feedback.

We give an overview of the different versions of the system followed by a discussion of design approaches.

Figure 1: Dollhouse Version A (phone and mail)

A pair of dollhouses contains a telephone and mail system:

Telephone: The telephone has a small movable receiver connected to a microcontroller which will start or end a voice-over-IP connection (Skype) when removed or replaced (for the user trials, because of robustness concerns, the VOIP connection was left in an "always-on" state rather than being connected to the receiver state).

Mail: The mail system consists of an input interface capable of scanning "letters" (small sheets of paper and miniature colored pencils are provided to create these) and then transmitting them to the remote dollhouse, where they

are printed on a miniature photo printer and come through the "front door" mail slot akin to a postal delivery. Each of the two dollhouses features a different version of the mail scanning interfaces, which we will discuss.

Figure 2: Dollhouse Version B (video)

A pair of dollhouses contains a video conferencing interface. This is a portable internet tablet housed inside a wooden box, with cutouts for the local video preview and the remote video feed. The box can be moved vertically along the side of the dollhouse from floor to floor.

Figure 3: "Video desk" in Dollhouse Version C

The same dollhouses as in Version 2 contain a "computer desk" instead of the sliding box. There are again cutouts for the local and remote video feeds, but the front panel is decorated so that the local video feed appears to be the screen of a tiny laptop and the remote video screen that of an external monitor, with a small keyboard and mouse.

Toy-Perspective

The first approach we took to emphasize a toy perspective was scale: using dollhouse dolls and small bears rather than larger toys as the characters made it possible to miniaturize the phone, mail system, and video screens to show that they were not devices for humans. This introduced the challenge of making sure the props were still usable for the children: first that they were large enough to manipulate, and second that the viewing area was large enough in the case of the printed letters and video screen.

The microphone and camera also needed to be placed so that they were usable by the children but showed a toy perspective. In the case of the phone, the (hidden from view) microphone is located closest to the miniature phone but can pick up sounds anywhere in the house. In the case of the video camera, it is positioned so that it can see into the dollhouse at a close range.

In the first video interface, the sliding panel enforces a camera orientation into the dollhouse. It is possible, but not obvious, to move it outside of the dollhouse levels. The default view, however, is of the inside of the dollhouse at the level of a doll's face. With the second video interface, the camera is placed approximately at a doll's eye level, but the desk can be lifted, rotated, and moved.

Contextualization

A major question we wanted to address is whether situating the communication channels in a specific context has an impact, and whether it makes a difference if the context is a realistic/"real world" one, or if the form of the object with the technological capability can be freely invented by the designer and later incorporated by the children into distant pretend play. We were interested in exploring the tradeoffs these approaches in terms of richness of play based on the idea that while realistic toys promote fewer object transformations, they elicit greater amounts of play in which the objects are used within a pretend context [8].

In the first pair of dollhouses, two systems were built for children to exchange mail with each other, but each system features a different design. One follows a more open-ended design, whereas the other is a more realistic copy of an existing domestic snail mail system (with mail slots and mail boxes). The systems differ in the interface for sending mail. The open-ended one has a webcam suspended above a doll table with a drawing area, and a button to trigger sending the mail. A webcam that does not look obviously like a webcam was chosen, so that it could hang over the table like a lamp and thus match the dollhouse scale, but no attempt to make real-world sense of this was made. The second mail sending interface is shaped like a blue United States Postal Service mailbox, and has a slot that automatically detects mail placed in it and triggers sending of the mail. The webcam is hidden inside the mailbox, and not visible to the children.

Figure 4: Mailbox from A1; Scanner-table from A2

Our hypothesis was that the mailbox system would be more intuitive to use and more likely to be less transparent, in the sense that play would explicitly discuss sending mail and more of the communication would occur between the characters rather than between the children. We also thought children might come up with their own explanations and contextualized interactions for the open-ended interfaces.

Contrasting interfaces were also designed for the video communication. The first version is a frame holding an

internet tablet, with rectangular cutouts for the part of the screen that displayed the remote video and the local video. This frame can be moved up and down along the side wall of the dollhouse, allowing the camera access to every floor. With some effort, it can also be pulled out for a view of the area outside the dollhouse or to directly face the children.

Figure 5: Sliding window from B; video desk from C

The second video interface is contextualized as a computer desk running a video chat program on multiple monitors. The desk itself can be freely moved around the dollhouse. Our hypothesis, similar to our hypothesis for the mail interface, was that the interaction would be less transparent with the video desk in that the children would incorporate the remote interaction into the play (for example, the dolls would sit at the desk and have a pretend conversation). However, we thought the open-ended interface might give them the opportunity to invent the medium over which they were having the conversation.

Features of each version are summarized in the table below.

System ID	Features	Form	Other
A1	Voice Text/ drawings	Phone Letters and mail slot, *mailbox*	One floor Inhabitants are small bears
A2	Voice, Text/ drawings	Phone Letters and mail slot, *"scanner-table"*	One floor Inhabitants are small bears
B	Voice Video	(no physical object) Sliding panel	Three floors Inhabitants are a doll family
C	Voice Video	(no physical object) Video desk	Three floors Inhabitants are a doll family

Table 1: Dollhouse Versions

USER STUDY

Overview

We recruited children at a local afterschool group, through researcher contacts and family friends, and through teachers at local public schools. The children whose guardians responded ranged in age from 5 to 12. Although we did not collect specific data on this, the children were also from a range of cultural backgrounds. We asked for both boys and girls, but received more responses from the parents and teachers of girls, perhaps because dollhouses are perceived as primarily female toys.

The system was introduced as a "way to play when your friends are not in the same place as you." The researchers were nearby to observe and answer questions about how to use the interface.

In three of the sessions, the children were at separate houses. In the other sessions, children were in the same house or space but in different rooms where they could not hear or see each other. They were paired with either a playmate or a sibling (by their parent's choice or their own).

The following table summarizes the trials.

Group #	System ID	Gender/Age	Setting	Time with system
1	A1	F/9	After-school program	30 min
1	A2	F/10	After-school program	30 min
2	A1	F/9	After-school program	1 hour
2	A2	F/10	After-school program	1 hour
3	A1	F/10	Research lab	1 hour
3	A2	F/12	Research lab	1 hour
4	B	M/6	Home	20 min
4	B	F/5	Home	20 min
5	B	F/9	Home (remote)	20 min
5	B	F/8	Home (remote)	20 min
6	B	F/8	Home (remote)	20 min
6	B	M/8	Home (remote)	20 min
7	C	F/7	Home	1 hour
7	C	F/9	Home	1 hour

Table 2: Study participants by age, location, and interface version. Dark borders group the pairs of children who played in the same trial, each at one dollhouse.

Scenario Summary

To sensitize the reader for the style of interaction for each system, we summarize two sessions below which represented the broadest range of interactions.

Group 3 Session (telephone and mail)

Group 3 consisted of 10 and 12 year old sisters (E and F) who reported that they play imagination games together at

home. One child was at each dollhouse in the same space, but not the same room at our research lab.

The play is mostly driven by E, who describes what her bear is doing then asks F what hers is doing. E consistently uses her bear to manipulate the objects . She holds the receiver to his ear, wraps his paw around the pencil to write, and holds the printed letter in front of him so he can read it. F does this occasionally with the receiver.

Figure 6: Child uses bear to manipulate objects

The girls refer to the bears as friends: "what did you name your friend? Mine is called Bob." They have a conversation between the bears and themselves, including themselves as characters in the pretend scenario. E holds the little phone to "Bob's" ear and speaks to F in a deep voice. Then "Bob" asks to speak to F's bear.

E has the mailbox interface, and needs an explanation of how to use it. While describing the dollhouses, they discover F has a pillow on her bed, and E does not. E tells F: "send me a pillow!" F responds "how?" and E says "figure it out." F places the pillow on the scanner table and transmits the image to E, who puts the image on the bed.

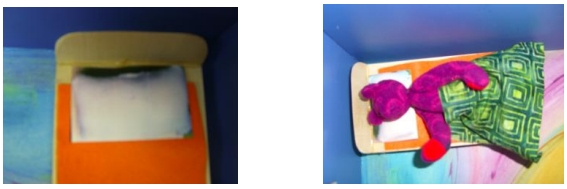

Figure 7: Children discover they can send objects: photograph of pillow placed on bed.

E says her dollhouse needs a trash can, she folds one out of the paper backing from the mail printout.

Group 5 Session (video)

Group 5 consisted of one 9 year old girl (C) and one 8-year old girl (D). The 9-year old was at her home and the 8-year old was at her babysitter's home. They are friends and frequently play together. Both have cellular phones on which they are used to calling each other.

They are both interested in setting up the furniture in the dollhouse. When D arrives and the video/audio connection is made, C has already set up her dollhouse. C asks D to position herself for a moment so she can see her in the video screen: "*put your face in the thing*." D leans in to do this. D focuses on setting her dollhouse up, giving brief answers to C's questions (what did you name your characters? What do you want to play?) until she is done. They then take turns giving each other house-tours by sliding the video screen down the side of the dollhouse, comparing furniture and describing which space they had allocated to which character (*"This is the grandparent's bathroom.").*

Both children appear to understand how to use the local video screen to see what their friend is seeing, and take actions to make sure they show what they want to: for instance, they move dolls and furniture out of the way so the furniture farther away can be seen. Girl C shows D what she refers to as a saltshaker (a wooden bottle from the dollhouse kitchen). D says "wow, that's a *big* saltshaker!" C has her dolls walk around the dollhouse and animates their actions, while D prefers to pose her dolls (sleeping in the bed, sitting around the kitchen table). When C speaks, she stops walking around the dollhouse and holds her dolls up to the camera.

Both girls name their dolls. They introduce the dolls to each other by holding them up to the camera. They speak as the characters (changing the pitch of their voices) during the introductions, but primarily metacommunication discussion ensues about what the characters are doing as the children animate them. They describe scenarios, but not extended narratives. At one point, they stop to play "rock, paper, scissors," a simple sequence game with hand gestures, through the video screen. C describes the sliding panel as a "window" into the other house.

Interaction Characteristics

We group our observations into the following major themes we observed: play types, characters as communicators, object play, sharing toys and spaces, and communication challenges. We analyze these themes in the next section.

Play Types

Two groups engaged primarily in parallel play (4 and 6), one group communicated but did not play (1), and the remaining four groups engaged in both parallel and shared pretend play (2, 3, 5, and 7). In the case of the children who did both shared and parallel play, the parallel play occurred when they occasionally began to move characters and arrange the dollhouse props without the other child being able to see them. This would turn into shared play when one of the remote children would prompt the other to describe what she was doing and they would begin a dialogue. Some of the shared play interactions in the parallel/shared groups were between the make-believe characters, who sent each other letters, spoke to each other, and introduced themselves (2, 3, and 5).

Groups 4 and 6, the youngest groups (5-8 years) and the only two groups including male children, engaged mostly in parallel play. They oriented and animated their characters in front of the camera, but this appears to have been in part out of an interest in seeing them in the local video screen (*"I'm on TV!"* said one child from group 6). They could hear each other playing, evidenced by comments to the researcher about what the remote child was doing, but did not engage in a shared narrative.

Characters as Communicators

During several of the sessions, children demonstrated that they perceived that the doll was the primary communicator.

For example, one child said *"My bear is talking on the phone."* (Group 2). This communication very frequently happened in conjunction with physical manipulation of the communication accessory: for instance, the children held the receiver to the character's ear. (groups 2 and 3). Some of the letters were addressed from one bear to another ("Do you want to come over to my house for a sleepover? Love, Berry") (Group 3) In some cases the children held the small letter in the bear's paws. (Group 3) As in the first scenario with the bear named "Bob," children also sometimes changed the pitch of their voices to indicate that the character was the one speaking ("multivocality").

Object Play

When children had the constant voice channel, several signaled pretend play conversations by picking up the receiver and holding it up to the bear's ear. (groups 2 and 3). During the video chat when the children did not have a phone interface, they did not pretend they were speaking on the phone and engaged significantly less in multivocality. The video table was contextualized, but none of the accessories (laptop, mouse and mousepad) were movable. One child in group 7 posed her doll in the chair in front of the video table. When asked what the doll was doing, she said, "*he is sitting at the computer,"* but she did not play-act that he was speaking to another character. Rather, she continued to use the video and voice transparently to discover the remote dollhouse. None of the three groups who used the blue mailbox interface understood what it was, and had to ask the researchers what to do with it.

Sharing Toys and Spaces

Much of the interaction across the video sessions was centered around describing and comparing the dollhouses. In addition to the display of the saltshaker (Group 5) we also saw comparison of other dollhouse elements ("does your house have a bunkbed?") In the voice and mail interface, a similar interaction often took the form of eliciting a description of the remote house ("*What color is your house?" "Draw me a picture of your bear."*) (groups 1 and 2) In group 7, the one group where the children were both at home but in separate rooms, after comparing the furniture and discovering that her sister had the crib she needed for the doll baby, one girl could not resist running upstairs to physically retrieve it. Paralleling the desire to share a physical object, one child in group 3 "sent" a pillow to the other through the mail system.

Communication Challenges

Some of the children, particularly those above 9 years old, appeared to have a impressive grasp of how to make sure their remote friend could see and hear what was intended in both the video and voice versions of the interface. They were able to use the local preview screen to position their dolls and furniture so they could be seen (groups 4, 5, 6, and 7 to varying degrees). They were able to adjust their voice level and repeat themselves so they could be heard (groups 2, 3, and 5). Group 5 was able to accurately perceive scale through the video screen ("what a big saltshaker!"). They used the voice channel to discuss the mail transmission, asking each other if it had arrived yet, and through comparison discussions noticed that the colors changed upon transmission and the size of the paper was very slightly different (groups 2 and 3).

Some of the children struggled more with these challenges. One child in group 6 was not able to speak loudly enough to be heard by her friend. The younger child from group 7, using the video desk, said she did not know how to show her friend things in the house. She tried picking up the furniture from different places in the house to put in front of the video screen (in which case she could not show the house as a whole) and tried picking up the desk and moving it above the dollhouse (in which case she could not see the preview screen).

DISCUSSION

We will first address our primary questions about perspective and contextualization, describe the observed affordances of each communication channel, and finally explore other variables that might have had impacts.

Perspective

Here we distinguish between the window and desk video interfaces in terms of their orientation inside the dollhouse--either with a relatively constrained view of the inside of the dollhouse from the doll's perspective or with a completely movable view. As discussed above, children appeared to find it easier to share their dollhouses with the sliding window interface (oriented into the dollhouse) than the desk, which could be positioned in any orientation. These findings are preliminary, but suggest that constraining the camera so that it defaults to a character perspective, or one that makes sense in the context of the toy characters' setting (here, the dollhouse) is an effective way of helping with orienting the camera to the intended view. This is a possible design approach to the challenge presented in the Video Playdate paper [12] about how to make staying in the camera view easier: make the video views appropriate for the world of the toy the child is playing with (in this case, the multiple floors of a dollhouse viewed at a doll's eye level). The children also spent more time posing their dolls in front of the screen with the interface that oriented the camera into the dollhouse than with the movable version, suggesting that displaying character-perspective may help trigger pretend play.

Contextualization (Realism versus Open-Endedness)

We were interested in exploring the tradeoffs of open-ended versus realistic interfaces, based on the idea that while realistic toys promote fewer object transformations, they elicit greater amounts of play in which the objects are used within a pretend context [10]. Our hypothesis was the "realistic" interfaces (video desk, mailbox) would elicit more pretend play and use of the interfaces by the characters, but that the open-ended (but still dollhouse-scale) interfaces might support the children in coming up with interesting explanations and models for the distance communication.

We discovered the unexpected challenge of creating a universally recognizable realistic interface. None of the three groups who used the blue mailbox interface understood what it was, perhaps because they do not send mail or had not seen the postal boxes before, or perhaps because the interface did not look realistic enough. Our experience shows that even simple realistic interfaces must be carefully designed to be recognizable to the children and represent an object or utility they are aware exists.

It did not appear to bother the children that the webcam/scanner-table interface did not "make sense." They used it fairly transparently, engaging in pretend play only about the writing and reading of the letters. Because part of the mechanism even in the open-ended interface was "realistic" (physical letters, printing out the mail slot), it is possible that those took precedence and the overall experience was realistic rather than open-ended. However, the scanner-table did enable the creative use of sending a pillow, which the mailbox could not have because of its small letter slot.

Children described the sliding window interface as "a window into the other dollhouse" or "a TV," but they again interacted with it fairly transparently (dolls faced and talked to each other, but did not mention that they were speaking through a window or television).

We noted the significance of interfaces that contained manipulable objects for the characters. The phone receiver and the mail, including the physical letters and the pencils used to write them, were very successful in becoming part of make-believe interactions. In contrast, the computer desk, which was "realistic" but did not have any kind of manipulable element, was less successful in this way.

Communication Channels

The telephone channel made possible verbal aspects of play: multivocality, storytelling, meta-communication about the story. It also enabled children to negotiate use of the technology in both the mail and video interfaces, for instance to ask if the mail had been sent yet or ask their friend to show them something in the video screen. Several of the children used the receiver prop to transition between character-speak and speaking to each other. A technology-specific challenge was speaking loudly enough and close enough to the microphone to be heard. This required discussion (over the voice channel) and sometimes repetition. This appeared to be easier for the children 9 years and above.

The mail system added a potentially asynchronous free-form content creation possibility to the dollhouse. The children used this to write pretend letters between the characters and to speak to each other directly about the interaction. They also used it to show the remote characters to each other (drawing of the bear) and share physical objects (sending of the pillow). The challenges included the time it took for the mail to arrive and the sometimes-imperfect copies of the letters. The children relied heavily on the voice channel to elicit, clarify, and interpret the mail.

The video channel allowed the children to show and see physical aspects of character play: the dolls, their props, and the house itself, as well as posing and animating characters, orienting them towards each other, and moving them around the space. It also allowed the children to see each other. When the video camera was oriented into the dollhouse, the children would occasionally put their faces into the view to see each other or pull out the camera box so they could see around the room, but primarily interacted with the screen with their characters and other dollhouse items.

The voice channel appeared to be the most critical, although we did not test the system without it. All of the remote communication modes required some discussion during the course of the play so that the children could use it effectively. In addition, the children appeared to strongly desire a view of the remote dollhouse and a way to share dollhouse items, both of which they improvised with the mail system when they did not have video (by drawing each other pictures of the dolls or "sending" the pillow). The mail and video systems had interesting tradeoffs: the mail system promoted creative communication solutions, but the video system allowed more physically-engaged shared play because the characters could "see" each other in motion, and required less interruption of play by verbal description.

Other Factors

We did not collect data on this factor for all of the children, but we noticed that one group of 8 year olds had cell phones. Group 7 readily recognized the "video desk" as a computer. Children in groups 5, 6, and 7 reported they frequently played computer games (we did not ask the other children). Prior experience with technology interfaces likely has an impact worth investigating further.

Another factor that may have had an impact was the gender of the children: in both of the groups who played only in parallel, there was one boy and one girl. Prior play experience likely had an impact: both groups reported not normally playing imagination games together, but rather more physical play. Age may have been a factor in these groups as well: they represented children ages 5, 6, and 8, younger than the other groups. These groups also had communication difficulties, including in speaking loudly enough to be heard. It is not clear whether the primary reason for the parallel rather than shared play was the children's lack of desire to play together or the difficiculty of the remote communication.

Not surprisingly, we found that the children who were most engaged in pretend play were the pairs who reported they played imagination games together at other times (groups 2, 3 and 5).

In trying the interface with a wide range of ages, we learned that children 9 and above were very familiar and comfortable with the communication technologies, whereas children under that age struggled more with some remote communication aspects of the system. While the interface

was appealing to a wide age range, future variations on the interface will benefit from being differentiated in order to provide more scaffolding for young children and for children less familiar with pretend play, and adding additional communication challenges for older children. We will need to conduct further studies with younger children (4 to 8 years), as we currently do not have enough data to determine how to best design these interfaces for them.

CONCLUSION

We set out to apply the model of user interfaces for toys to the challenges of supporting remote imagination play between children. Our goal was to discover design guidelines for this approach using a technology probe consisting of pairs of dollhouses with various functioning communication features.

We observed that children were very interested in a view of the other dollhouse, and improvised creative ways of describing and showing them to each other over all channels available when video was not available. This presents a tradeoff between eliciting this rich, creative communication and allowing more seamless play.

We looked for the impact of specific design decisions about perspective and interface realism. We discovered that it is difficult to create "true to life" interfaces that fit within a universal frame of reference. We showed that emphasizing the character's perspective and providing toy-scale interactible objects, not realism, had the most significant impact on make-believe with the contextual objects. We expected that orienting the video camera into the play location from a character perspective would lead to more pretend play; this did occur, but we also discovered this was a very effective way of supporting the remote communication challenge of orienting the camera correctly.

We observed some parallel rather than shared pretend play but do not have enough information to determine which of several factors (age, gender, lack of experience or interest in playing together, lack of prior experience with the technology, or difficulty with the remote communication) was the primary reason for this.

We plan to apply these findings to the refinement of these interfaces and to the creation of remote communication interfaces appropriate to the age and developmental stage of children.

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