Developing a Media Space for Remote Synchronous Parent–Child Interaction

Svetlana Yarosh, Stephen Cuzzort, Hendrik Müller, Gregory D. Abowd
Georgia Institute of Technology
School of Interactive Computing, GVU Center
85 5th Street NW
Atlanta GA 30332, USA
{syarosh3, scuzzort3, hendrik, abowd}@gatech.edu

ABSTRACT
While supporting family communication has traditionally been a domain of interest for interaction designers, few research initiatives have explicitly investigated remote synchronous communication between children and parents. We discuss the design of the ShareTable, a media space that supports synchronous interaction with children by augmenting videoconferencing with a camera-projector system to allow for shared viewing of physical artifacts. We present an exploratory evaluation of this system, highlighting how such a media space may be used by families for learning and play activities. The ShareTable was positively received by our participants and preferred over standard videoconferencing. Informed by the results of our exploratory evaluation, we discuss the next design iteration of the ShareTable and directions for future investigations in this area.

Categories and Subject Descriptors
H5.2. User Interfaces: Prototyping

General Terms
Human Factors, Design

Keywords
Parents and children, computer-mediated communication, media space, distributed families

1. INTRODUCTION
Many events may separate a parent and a child. Business travel represents a common reason for short-term separations. Though, travel for work may require more extended periods spent apart—for example, in military families, a parent may be away for several months at a time. Long or frequent periods of separation are also common for parents and children in divorced or separated families. For example, in the United States 32% of children live apart from one of their parents [3]. About 25% of these children live in a different city from their non-residential parent, making frequent in-person contact difficult [8]. In this work, we report on the development and exploratory evaluation of a media space system aimed at supporting contact between parents and children during periods of separation.

We begin by motivating the need for such a system beyond currently available technologies. We discuss previous research in supporting distributed families to position our work in this space as one of the few systems exploring synchronous interaction. We draw on previous investigations of synchronous communication in the office setting and our own formative work with families, to offer a novel system for parent–child interaction. The ShareTable is a prototype media space for families that combines audio/visual communication with a workspace for shared activities.

We present an exploratory lab-based evaluation of the ShareTable with seven parent-child pairs aimed at investigating three questions. First, we explore whether the shared workspace benefits the interaction. To do so, we compare how parent-child pairs complete a homework task using the ShareTable system versus using just plain videoconferencing. Second, we were unsure whether young children would be able to understand and manage the unfamiliar interweaving of physical and virtual spaces created by the ShareTable. To investigate this, we observed how parents and children manage turn-taking and access to physical artifacts while playing a board game remotely. Finally, we were interested in finding out how the participants would spend unstructured time with the system to see which attempted activities are supported or hindered by the ShareTable. We conclude with a discussion of how the results of our evaluation informed changes to the design of our prototype and consider opportunities for future investigations in this area.

2. MOTIVATION
Quality contact with both parents is important to the development and well-being of a child [13]. While there are many styles and philosophies of raising children, developmental psychologists have used the term "authoritative parenting" to describe the combination of monitoring and support that is likely to lead to positive behavioral and academic outcomes for children. Gray & Steinberg isolated and examined the behaviors that characterize this construct to find that the *amount of communication* and the *act of showing interest* in the child's life were the most influential constituent behaviors involved in authoritative parenting [9]. Additionally, frequency and variety of contact are also important to maintaining relationship quality. Kelly & Lamb advise that parenting arrangements should provide "opportunities to interact with both parents every day or every other day in a variety of functional contexts" [13:6].

Unfortunately, methods of remote communication currently available to families rarely provide opportunities for the amount and type of contact parents and children require. The telephone is

IDC 2009, June 3–5, 2009, Como, Italy
Copyright 2009 ACM 978-1-60558-395-2/10/08… $5.00.

the most commonly used technology for family communication [14], but it often fails to keep the child engaged for any significant length of time [17, 28]. This is not surprising, as children usually spend less than one hour a week participating in "household conversation" [10]. We cannot expect them to stay engaged for significantly longer in a remote conversation. Rather than relying on verbal communication, Dalsgaard *et al.* found that parents and children build closeness through daily care and play interactions [4]. Parents give care by providing resources for learning and assisting with everyday tasks. Children and parents together participate in play interactions that include collaborative activities (e.g., doing a puzzle, cooking together), playing with shared artifacts (e.g., action figures, board game), and physical play behaviors. This suggests that a remote communication solution for parents and children would falter without providing support for shared activities and tasks.

Our goal is developing a communication system that engages the participants and meets the unique needs of families. We share this goal with a significant number of other prototypes—in the next section, we situate our contribution in the context of this previous work.

3. SUPPORTING REMOTE FAMILIES

The majority of research in supporting remote family communication has focused on asynchronous interaction. One theme in previous investigations has been that of maintaining peace of mind and awareness by automatically sharing certain activity information. For example, the Digital Family Portrait [18] allowed an adult to view a noninvasive representation of their elderly parent's motion about the house. Similarly, Shared Family Calendars [20] supported awareness between three generations of the same family by digitizing and sharing already maintained calendars. In contrast to these projects, we focus on supporting explicitly initiated contact, rather than automatic sharing.

Another theme in technology for distributed families has been providing means for asynchronously exchanging messages in the form of audio, text, images, or video. Though it did not focus specifically on children, the InterLiving Project [11] explored how two households used a digital note/sketch message board and a video messaging system to stay in touch. Hermes@Home [22] combined a digital note/sketch message board with a networked camera to allow the remote family member to capture snapshot images of home while away. Several systems, including ASTRA [21], eKiss [5], and Collage [26] allowed users to capture and send images with a mobile device to be displayed for other family members at home. These systems focused on maintaining closeness and awareness without creating new obligations. Virtual Box [6] added a twist to sharing images—the interaction unfolds as a game of hide-and-seek in which an adult family member "hides" images on a virtual floor plan of the child's home. Later, the child attempts to "find" these images in the physical space using a location-aware PDA. Several systems incorporate explicit affordances and suggestions for types of information to share. SPARCS [2] suggests a random photo from the user's library to be potentially shared. Peek-a-Drawer [23] encourages sharing images of physical items. When a user puts an object into the upper drawer of the chest, an image of that object appears on the screen of the lower drawer of the paired chest. The CASY project [29] structures sharing based on the intended context of the message by allowing parents to record messages to be played in specific situations when triggered by the child (e.g., bedtime, dinner, etc.). These systems informed our work in the space of supporting distributed families, but are different from ours in that we focus on designing for synchronous, rather than asynchronous communication.

The telephone still forms the primary way through which synchronous remote interaction occurs in most families [14]. Recently, videoconferencing [8] and online virtual worlds [19] have risen in prominence as potential communication tools for families. We know relatively little about the prevalence of these tools, though we have seen only a few families that regularly use these in our own investigations [28]. In creating technology prototypes for families, synchronous family communication has remained largely unexplored with few exceptions. Collage [26], mentioned above, synchronously displayed image manipulations, allowing users to see when remote others were interacting with the system. The Globetoddler [17] system allowed a child to interact with a special doll while a parent interacts with a mobile phone to play synchronous video games or view photos captured by the parent. However, unlike both of these systems, we focus on supporting synchronous communication by leveraging existing activities rather than creating new activities for remote interaction. We describe our system in the next section.

4. SHARETABLE

In contrast with the home, technologies for synchronous communication have had a relatively rich history of exploration in the office environment. We compare and contrast our system with this work and highlight specific implementation differences that emerged from our formative work with children and parents. Finally, we present the ShareTable, a system that augments an audio-visual connection with a shared workspace created by projecting a video of one table surface onto the other.

4.1 Related Work in Media Spaces

We drew our inspiration from the significant body of research work that addresses supporting remote communication in the office, particularly the concept of a *media space*. A media space is an audio and video connection between two distributed locations for the purpose of maintaining social and work connections. Media spaces have been used since the mid-80s to synchronously connect workplaces and to support collaborations between geographically distributed offices [1]. The audio-video connection can be supplemented with a shared workspace to support collaboration over documents, data, etc. There are a number of such media spaces which share implementation aspects with the ShareTable, including TeamWorkStation [12] and Videodraw [25]. Like the ShareTable, these systems create a shared workspace through video; however, our system is different in that it overlays physical artifacts from *both* surfaces, therefore requiring top-down projection (we discuss this in more detail as we describe the implementation challenges).

The PlayTogether [27] system is most similar to ours in its use of top-down projection and a light-weight approach to removing visual echo (we describe this challenge in the next section). PlayTogether uses an IR emitter and filter in order to remove visual echo, but this solution removes color from the video. Because perceiving color is important for a number of childhood activities, we implemented an alternative light-weight approach that preserved this characteristic. Our work expands on the PlayTogether project by applying the technology to a new domain and providing empirical insight into how such a system may be used. In contrast to the systems above, our development of the ShareTable was driven by the unique needs of parents and children, which we describe below.

4.2 Formative Work & Design Requirements

To understand the needs of families who live apart, we interviewed fifteen parents and children from separated families. We present in-depth results from this study elsewhere [28], but we briefly discuss findings relevant to the ShareTable below.

4.2.1 Requirement 1: Provide Multiple Visual Channels for Communication

The most common theme reported by both parents and children in our study was dissatisfaction with audio-only communication. During the middle childhood, children are still developing the conversational competencies to interpret irony, humor, and fantasy [24]. Providing options for multiple channels and modalities of communication, particularly video, affords additional cues for the child.

4.2.2 Requirement 2: Simple Enough to Operate without a Co-Located Adult's Help

Videoconferencing was not used regularly by the families we interviewed, because the system is complex enough to require a co-located adult's involvement to arrange a chat session. Additionally, some parents saw it necessary to supervise videoconferencing, since the child could potentially contact or be contacted by a stranger. Our goal is designing a dedicated communication system with a minimal control interface that reduces the need for a co-located adult to assist the child with setting up and maintaining the connection.

4.2.3 Requirement 3: Support Diverse Play Activities

Keeping the child engaged and seeding conversation were two major challenges reported by parents. We seek to support engagement by leveraging activities that the parent and child are already used to doing together. We emphasize the system's ability to support a variety of activities, rather than incorporating interfaces for specific games or requiring specific accessories.

4.2.4 Requirement 4: Provide Opportunities for Care Activities on the Parent's Part

There is strong evidence that instrumental involvement of both parents correlates with positive outcomes for children [13]. Many care activities require physical presence; however, there is a clear opportunity for remote instrumental care in providing homework assistance. The challenge to us as designers is to afford transitions between the physical artifacts of homework that the child possesses (e.g., textbook, worksheet) and digital versions of these artifacts which the parent can view and annotate. We discuss how we addressed this challenge in the next section.

4.3 Implementation Details & Challenges

The ShareTable system consists of two identical table setups in different households. Each shared workspace consists of an overhead camera that records any activity over the surface and a projector that displays this video on the paired table in the other home. The video from each camera is aligned precisely with the projection, so that artifacts placed on one table appear projected in the same location on the other table. The tabletop is coupled with a videoconferencing system (*i.e.*, monitor, webcam, speakers, and microphone) that let the users see and hear each other "face-to-face" (see Figure 1). As in other videoconferencing systems, each user also sees a smaller video window showing how they appear to the other person. The basic idea behind the ShareTable is simple, but multiple implementation challenges were addressed in developing a functioning prototype.

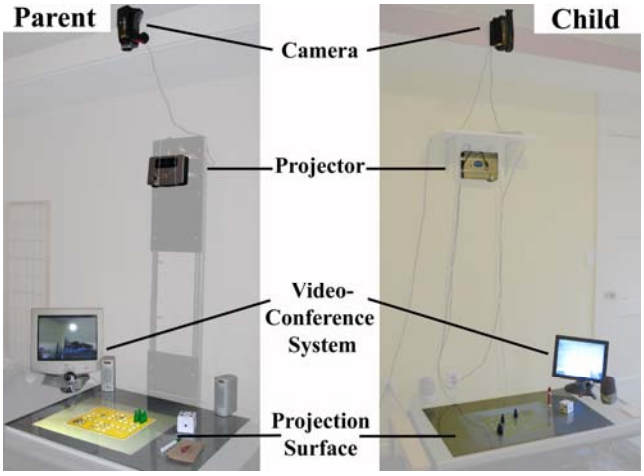

Figure 1. The physical components of the ShareTable system are highlighted.

4.3.1 Challenge 1: Layering Physical Artifacts

In order to support layering physical artifacts in a realistic way, we implemented the ShareTable using top-down projection. For example, if the parent places a physical token on a projected game board, top-down projection allows the projected token to appear on top of the child's physical board rather than projected unseen on the board's bottom. Similarly, if a parent writes a comment on top of a projected worksheet, top-down projection allows this annotation to be displayed on top of the physical worksheet.

4.3.2 Challenge 2: Removing Visual Echo

Visual feedback or "echo" is a major concern in a camera-projector system. Unmodified, the camera records an image of the projected artifact and sends it back to the originating surface. If the physical artifact is moved, an echo of its projection remains on the surface. If projected images are re-projected without any intervention, the resulting image keeps getting brighter and less clear. Without some way to filter projected artifacts from real ones, the ShareTable would be unusable due to this feedback effect. We wanted a lightweight way to eliminate visual feedback, so we used linear polarizing lenses to filter out the projected artifacts from the physical ones. Light that passes through the lens becomes polarized and cannot be seen through a lens with the opposite polarity. Thus, by attaching lenses with perpendicular polarization to the camera and projector, we prevent artifacts from being re-projected. In order to preserve the polarization of the light once it strikes the table surface, we use a non-depolarizing silver lenticular projection screen as the surface backdrop.

4.3.3 Challenge 3: Minimizing Complexity

In designing for families, it is important to minimize complexity and cost. We sought to do so by leveraging existing systems and off-the-shelf components. The face-to-face audio-visual feed uses a computer with a standard videoconferencing software (Skype™) and hardware (a webcam and a microphone). Any camera and projector could be modified for use with a shared surface just by adding linear polarizing filters. Any tabletop could become a ShareTable through the addition of the non-depolarizing projection surface. Writing or drawing on the table surface is accomplished through dry-erase markers rather than with computationally-intensive computer vision techniques. Most importantly, the ShareTable does not require any specifically

designed accessories: most board games, books, and school worksheets are usable with it.

Though our prototype is functional, there are more technological challenges to be resolved before such a system could be deployed for long-term use in an actual household. To inform the design directions and priorities for our continued work on this system, we performed an exploratory evaluation to see how the ShareTable functioned when used by parents and children in a controlled setting.

5. METHODS

Though lab-based evaluations are inherently limited, the questions that motivated our investigation could reasonably be approached in a controlled setting. First, we wanted to observe ways in which interaction with the ShareTable is different from plain videoconferencing. Second, we wanted to establish that children would be able to understand and manage the interweaving of physical and virtual space created by the ShareTable. Finally, we were interested in exposing participants to our system to gain insight to potential activities they may want the system to support and interview them to guide future design.

5.1 Participants & Setting

Seven parent-child pairs participated in the study. The set of parents, four males and three females, varied in age from 30 to 44 (average 37.3, median 38). Their occupations ranged from attorney to professor to student, but all had a high degree of education. The children, three females and four males, were between 7 and 10 years old (average 8.4, median 9). Overall, three father-daughter, one father-son, and three mother-son pairs participated. We recruited these participants through word-of-mouth and flyers posted around campus. We advertized that we were looking for individuals interested in technology for families who spend significant time apart. One of the seven parent-child pairs represented a divorced family. The other six pairs represented families in which one or both of the parents were often away from the child for work reasons.

We deployed the system at Georgia Tech's Aware Home residential laboratory, an off-campus house simulating a domestic residence [15]. The parent's ShareTable was located in the home office of the residence, while the child's version was located in the adjacent playroom, allowing us to simulate the parent and child being apart.

5.2 Procedure

We familiarized participants with the residential lab and introduced the project. We gave them time to play and experiment with the ShareTable in an unstructured manner. They were encouraged to think about how they would possibly use such a system while apart and to actively try out some of those activities. When the participants were ready to continue, we asked them to perform three separate tasks and fill out a brief questionnaire.

The first two tasks involved completing a worksheet together. The worksheet given to the child consisted of a political map of Africa without any labels, with instructions to color in all countries that began with a certain letter ("M" in the first task, "A" or "Z" in the second). The parent was given an answer sheet—a colored map of Africa that contained the names of the countries and their capitals—and instructed to assist the child in any manner they thought appropriate. For one of these tasks, the parent-child pair was asked to use videoconferencing, while the other task allowed them to use the ShareTable. Each parent-child pair completed both tasks, representing a within-participant design, counter-balanced for order effects. We were interested in comparing the strategies that parents and children used with the addition of the extra video channel.

In the third task, the parent and the child were asked to play a board game together using the ShareTable system. This represents a task that is currently impossible to carry out using a videoconference system alone, so there was no videoconferencing condition. We provided a simple game, based on the idea of "Ludo" or "Sorry!" (see Figure 2b). Only the parent's side had the physical game board, but each side had physical token pieces and a die. Thus, the child had to place his or her pieces on the projected surface of the board. We were interested in whether the child would be able to manage turn-taking and access in this unusual space which interweaves physical and projected artifacts.

After completing all three tasks, we returned to the questionnaire to understand why participants answered a certain way. For example, if a child moderately agreed that using the ShareTable was fun, we probed him or her deeper to explore how the child understood the idea of "fun" and what aspects of the interaction corresponded with or went against that idea. We also asked the participants open-ended questions about their experiences with the system, including what they found confusing about using it, which aspects they liked or disliked, and how they might use a system like this at home. We asked each parent-child pair to commit one hour to this study; however, they were also given the option of continuing to play with the system in whatever way they chose at the end of that time. Throughout the study, two investigators observed each participant and took independent notes, which were later combined for analysis.

6. RESULTS

Our goals were evaluating whether the ShareTable provided any benefit over a plain videoconferencing connection, understanding whether children as young as seven were capable of managing play mediated by this system, and generating ideas for tasks that families may want to do with the system. To get at these issues, we looked at the following specific questions in our exploratory evaluation:

1. How do the pairs complete a task using the ShareTable system as compared to using videoconferencing alone?
2. How do parents and children coordinate turn-taking and access to artifacts with the ShareTable?
3. What activities do the children and parents choose to do when allowed unstructured time to use the system?

6.1 Comparing to Videoconferencing

We began by observing how parents and children completed two worksheet tasks—one with the ShareTable system and the other with plain videoconferencing. After completing each task, we asked them to answer a few questions about their experience.

We asked each parent and child how difficult it was to do the worksheet with each communication medium and how much they liked using each system on a 5-point Likert scale (see Figure 3). We hypothesized that the ShareTable would be rated as both easier and better liked than plain videoconferencing. We analyzed the results using a Fisher's Exact Test, which is appropriate for categorical data (*i.e.,* a Likert scale) with a small sample size [16]. We found that participants enjoyed doing the worksheet task better with the ShareTable than with videoconferencing. This difference was statistically significant ($p = 0.012$), meaning it was unlikely to have occurred by accident. Participants also reported that the

worksheet task using the ShareTable was easier to do than using videoconferencing (p = 0.001). While this shows that the ShareTable was experienced quite differently than videoconferencing, we were interested in better qualifying this difference. For this, we turn to observation data.

In the videoconference condition, children and parents used the following strategy: the parent would verbally explain where the country is (e.g., "the little one to the left of the big one that looks like a heart"), the child would point to the country and hold up the worksheet to the webcam, the parent would confirm or reject the selection, and the child would color in the country if it was confirmed. The main breakdown in the process occurred as the child tried to identify and confirm the country. Several children seemed to assume that the parent could see where they were pointing without holding up the paper (even though it was explained that the parent could not). Several children had trouble understanding how the worksheet would look to the parent when held up to the camera—holding it too close, too far, or even upside down.

In the ShareTable condition, the child would keep the worksheet flat on the table. The parents described the correct countries verbally, by pointing to it with their finger, or by circling it with a marker. Children would verbally confirm if they had the right country or would touch the country with the tip of the marker and look up at the video screen for confirmation. Interestingly, parents did not seem to be concerned with the *efficiency* of completing the worksheet. None of the parents simply put the sheet with the answers on the table. In one family, the mother explicitly acknowledged that if she showed the answers, she would feel like she was cheating and that her son would probably learn more if they worked through the worksheet together. Another common behavior was taking verbal tangents from the task to tie the worksheet to other experiences in the child's life. For example, a father pointed to an African country to tell the daughter a story about her aunt who currently lives there. Additionally, every parent made a remark about the country Madagascar and the children's animated movie by the same name.

It has previously been demonstrated that gestures over video streams can support quicker completion of remote tasks. When one user assists another for work, measures like time to completion make a lot of sense. However, when the users are parents and children, completing the task takes a back seat to engaging with each other. In the ShareTable condition, we noticed a greater level of engagement between the parent and the child. They spent more time looking at each other and less time looking at the task. They also spent more time laughing and talking about peripherally related information. Parents supported their child's learning not by making sure that the worksheet was completed quickly, but rather by tying the activity to other aspects of the child's life, such as familiar children's media. By making the logistics of the task easier, we conjecture that the ShareTable freed the parent and child to focus on these other aspects of communication.

6.2 Access to Artifacts and Turn-Taking

To see how parents and children coordinated turn-taking and interaction with the artifacts while using the ShareTable, we asked them to participate in a simple board game task, similar to "Ludo" (see Figure 2b). Since the ShareTable just projects a video stream, each participant can only physically manipulate the artifacts on his or her side of the table. We wanted to see how participants would manage the interaction of "bumping" each other's pieces back to start. While all but one parent-child pair explicitly verbally

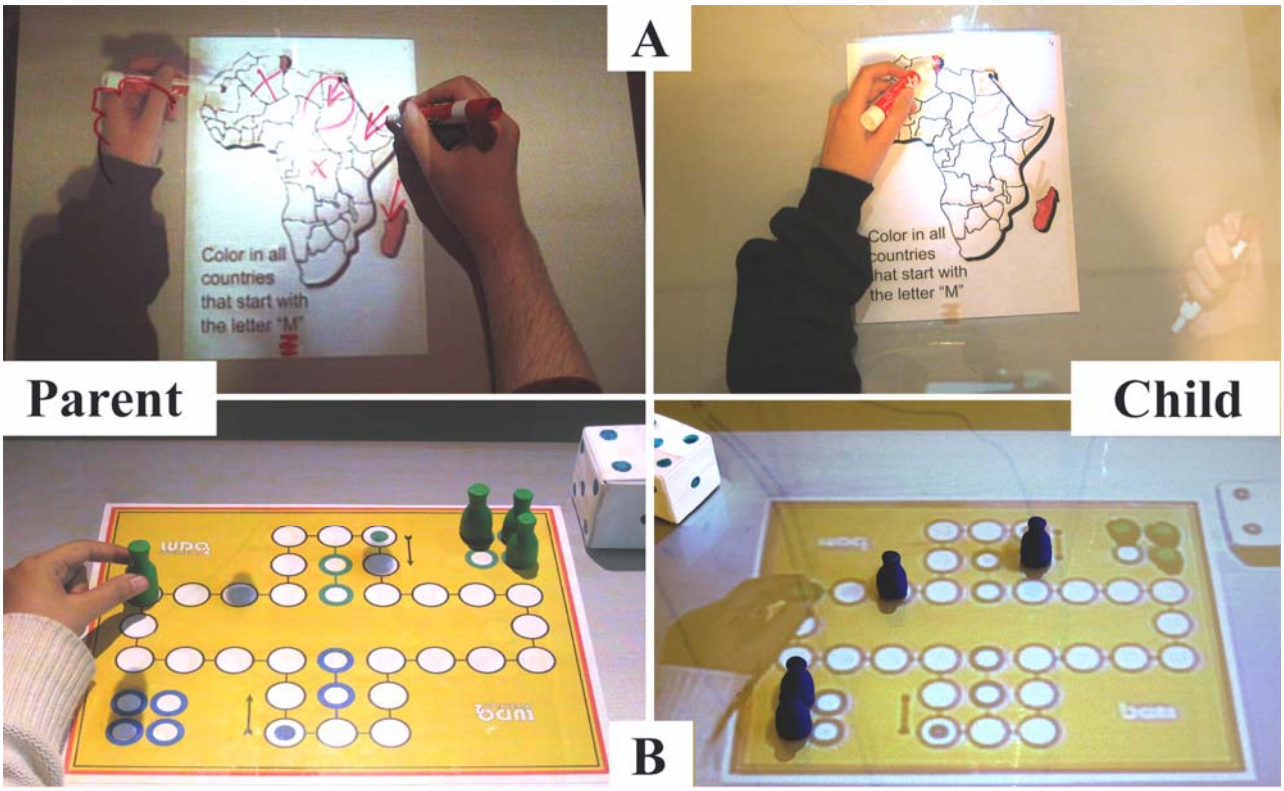

Figure 2. From the perspectives of the parent and child, a) the worksheet and b) the board game tasks being performed using the ShareTable system.

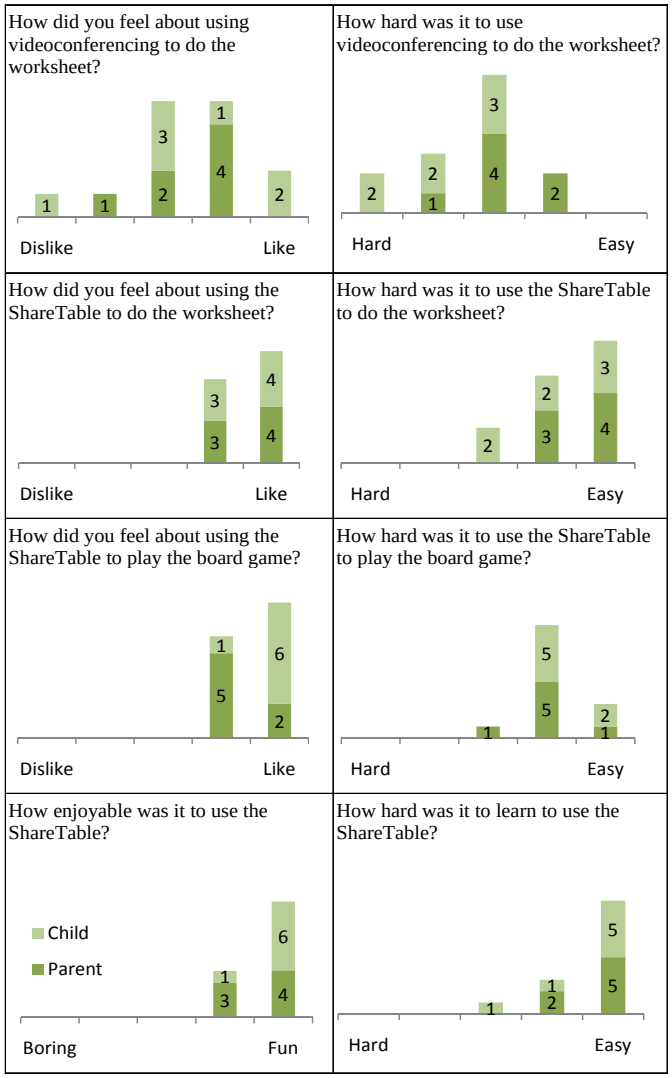

Figure 3. Responses to 5-point Likert-scale questions. Darker color represents parents, lighter color represents children in each histogram.

acknowledged the possibility of refusing to move their piece when bumped, but quickly dismissed it as it would "ruin the game" or make the game "no fun." In fact, there was a great deal of physical behavior surrounding the bumping of a piece despite the fact that the participants could not physically replace the opponent's piece back to the start. A common behavior was manipulating the game token in a "dancing" motion on top of the projection of the opponents' piece after bumping an opponent.

Unlike an online board game, the ShareTable leaves the management of turns and rules up to the users. While the user was taking his or her turn, they would usually focus on the table surface; however, during their opponents turn, they focused on the face-to-face video. Looking up at the screen at the end of one's turn seemed to signal to the other person that it was his or her move. One interesting facet we observed was that parents tried to bend the rules of the game to the advantage of the child—children won six out of the seven games played. Parents would do this by giving the child strategy advice and by letting them re-do moves or take extra turns. If we had built explicit games and rules into the infrastructure of the ShareTable, this interaction may have been lost.

In post-task interviews, two of the parents explicitly mentioned that, despite the lack of access to the opponent's pieces, playing the board game using the ShareTable felt much more similar to playing a board game in-person than using any other computer-mediated channel. Another parent mentioned that after the first ten minutes of using the ShareTable, he felt that he could focus entirely on interacting with his daughter, rather than "using the system." All of the children we interviewed cited trying more board games as activities that they would want to do with the ShareTable. Two of them explicitly requested the chance to play again at a later time. In conclusion, parents and children were successful at managing access to artifacts and turn-taking without specific system support—they mutually acknowledged the rules and possibilities of the interface and acted to manage them in a way similar to in-person interaction.

6.3 Observing Unstructured Activity

We observed the way users interacted with the ShareTable when given an opportunity for free play before and after the tasks. We sought to identify the features of the ShareTable that supported or hindered the activities that the parents and children chose. Several parent-child pairs participated in "collaborative drawing" in which the child or the parent would initiate a drawing while the other added elements to it (e.g., child draws butterfly and the parent adds patterns on the butterfly's wings). One of the parents mentioned that this task was actually easier with the ShareTable than in-person because she and her son could occupy the central physical location at the table without getting in each other's way.

We observed a variety of other playful activities. One parent-child pair participated in what we termed "competitive drawing"—the parent would draw something, then the child would cross it out and respond with a different drawing. One family used the surface of the table to "chat" in the way one would use an instant messenger—the child would write a statement, the parent responds to it below, and the child responds in turn. One parent-child pair participated in a "tracing" activity—the father put his hand on the table and the child carefully traced it. In one family, the child played a game of "tag" by trying to catch the projected version of her dad's hand with her own. One family really wanted to try doing their own task—playing a game of chess with their own board and pieces. We noted that because the ShareTable places the two users on the same side of the table, the father was put in the awkward position of having to play his pieces from the opponent's side of the board.

In post-task interviews, we asked the parents and children how they would use the system in their own home and if they had any suggestions for modifying the ShareTable. One parent said she wanted her son to be able to leave a short note on the table when he gets home from school. She wanted to be able to access a message left on the table from her mobile phone to quickly get feedback that her son safely arrived at home. Two children mentioned that they would want to use the ShareTable not just to interact with parents, but also to play with their friends. The children that participated in collaborative drawing during unstructured time were particularly excited about the potential of this activity. One child suggested that her father could put printed pictures on his side of the table so that she could trace them. Another child mentioned that he would have liked to be able to share the drawings he and his mother created by giving them to his father to take to work or hanging them on the refrigerator. Both

parents and children said that they would use the ShareTable for both play and homework if they had one in their home. Several parents mentioned wanting to be able to read with the child, but three expressed a concern that the resolution of the ShareTable surface would not be high enough to allow comfortably reading most books. However, the most commonly cited concern with the system was the periodic presence of audio echo in our setup, which reduced the clarity of audio transmission.

7. DISCUSSION

One goal of our exploratory evaluation was to serve as a proof-of-concept for the ShareTable system. It also served an equally important role in informing future design and research directions of our work. In this section, we describe the changes to the prototype that were informed by our deployment and revisit our initial research questions to identify potential opportunities for future investigations.

7.1 Emerging Design Directions

Encouraged by the positive response to our system in the exploratory evaluation, we have constructed two stand-alone versions of the next iteration ShareTable system for future deployment outside of the controlled setting of our residential lab (see Figure 4). Guided by the results of our evaluation, we made a number of modifications to the prototype.

7.1.1 Improving Audio and Surface Fidelity

When we asked the participants what they disliked or found difficult about using the ShareTable system, they focused on the fidelity of the connection and the presence of audio echo as deficiencies of the system. The microphone used in the prototype transmitted the speaker output back to the sender, sometimes resulting in an unnerving echo. We have removed audio echo in the current version of the system through use of a unidirectional microphone and software filtering. While audio was important to the fidelity of the interaction, the tabletop resolution determined what tasks were possible. Three parents mentioned that the resolution of the table surface was fine for the large-text worksheet but probably too low to read standard-sized text. In the current system prototype, we have upgraded to a high-definition camera that allows print to be clearly visible and still records a reasonably large surface area. To manage the additional demand that this change introduces on the bandwidth, we process the resulting surface image as 64 separate parts and transmit only those segments where some threshold of motion has occurred since last transmission. In the current system, we can adaptively change the threshold for detecting motion and the frame rate of the surface transmission to tolerate bandwidth limitations without reducing readability. Despite the occasional jerkiness of the face-to-face video, none of the children or parents seemed to be bothered by this, suggesting that we can probably manipulate frame rate to some extent before it becomes troublesome to the user.

7.1.2 Leveraging Embodied Interaction

One of the things that parents and children reported liking about the ShareTable was the fact that it did not have a traditional interface, but was instead rather similar to non-computer-mediated interaction. To continue building on this theme, we incorporated automatic calibration of the camera-projector system and kiosk-like activation into the current iteration of the system. To attempt to contact the parent or to answer an incoming call, the child must simply open the doors of the cabinet. To end a call, either party can simply close these doors. As an added benefit, the open doors create a cubby-like area for the interaction, which engenders a sense of privacy.

7.1.3 Supporting Semi-Synchronous Interaction

The term "semi-synchronous interaction" was coined by Dourish & Bellotti [7] to describe systems that support both synchronous and asynchronous modes of work. In a semi-synchronous system, the users can not only work together but also see representations of past activities by others. One of the parents pointed us towards this idea when she suggested that her son should be able to leave messages on the table surface for her. In the context of the ShareTable, the following is a semi-synchronous interaction scenario:

> *A son attempts to contact his mother using the ShareTable, but she is not available. He sits at the table for an hour doing homework, before leaving to play. He is still outside when his mother attempts to contact him through the ShareTable sometime later. While she can't get in contact with him directly, she is able to see his homework strewn across the surface of the table. From this representation of her son's past activity, she is able to determine that he had safely returned home from school and that he may need help with a math worksheet later. She draws a heart on the table and writes "I can help you with this after dinner" by the worksheet.*

The above scenario assumes that both ShareTable systems are continually activated. This may not be practical in the home setting for privacy reasons. To address this, we implemented a protocol for semi-synchronous exchanges that does not require an always-on system. When the mother places a call, the shared surface takes a still snapshot of the paired table and projects it onto her surface until her son responds to her call or she chooses to terminate it. Thus, she is able to see a message written on the surface or a note dropped on top of the table without unnecessarily invading the audio and video space of her son's room.

7.1.4 Expanding Functionality

We look to incorporate a number of other suggestions that came out of the exploratory evaluation. In the order that they will likely be developed, these include:

- Saving and printing current surface image
- Option to flip the surface orientation for games usually played across the table (e.g., checkers, chess)
- Leaving and viewing video messages
- Checking for new notes with a mobile phone by requesting an MMS snapshot of the current surface
- Enabling a secure way for the parent to potentially add new connections (e.g., grandparent, school friend) and for the child to select whom to call

The challenge for us as designers is to incorporate these in ways that continue to work with the physical metaphor of interaction and do not needlessly complicate the interface for the child.

7.2 Emerging Research Directions

In addition to informing the modifications to the prototype, we gained insight from the initial evaluation to help generate research questions and hypotheses to drive our future work.

7.2.1 Evaluating the Benefits of the ShareTable

We wondered whether the ShareTable workspace actually provides any benefit over standard videoconferencing. To address this, we observed parents and children complete a worksheet with and without the shared tabletop and we asked them about their

Figure 4. The current ShareTable prototype

experience. Participants preferred and found it easier to do the task with the ShareTable than videoconferencing. The shared surface let them focus on each other rather than the logistics of the worksheet task. One of the observed benefits was that children seemed to be more engaged in the interaction during the ShareTable condition. Keeping the child engaged longer was reported as a challenge for parents using existing technologies [28]. This suggests a hypothesis for a future investigation: session lengths will be longer with the ShareTable than with other technologies the family uses to stay in touch (e.g., telephone, videoconferencing). We plan to compare logs of pre-deployment remote communication and ShareTable-mediated communication in an in-home deployment to test this hypothesis.

We can claim with a degree of confidence that at least for *some* tasks, the ShareTable provides a clear benefit over videoconferencing. We want to continue investigating the tradeoff between the additional cost of providing the shared surface and any potential benefits it may provide. We have expanded the logging capability of the system to track the amount of motion that occurs over the surface of the each table. In future deployments, we will use this data to estimate whether the shared workspace feature is being used during a particular conversation session. We hypothesize that the ShareTable work surface will be actively used during the majority of sessions. We are interested in uncovering more precise statistics about its use and richer qualitative feedback about the tradeoffs involved.

7.2.2 Variety of Activities

We were interested in seeing what kinds of ShareTable-mediated activities seemed potentially compelling to children and parents. We found that even in the short timeframe of the study, families used the technology in ways we did not anticipate (e.g., to trace each other). One of the signs of a quality parent–child relationship is participating in a variety of contexts together [13]. Thus, it was exciting to see that parents and children identified a variety of potential remote activities that could be supported by the ShareTable. For a future deployment, we hypothesize that comparing participant diaries of pre-deployment remote interactions and ShareTable-mediated interactions will show the latter to incorporate a greater variety of topics and activities.

We are also interested in a data-driven analysis of diaries and interviews from an in-home deployment of this system to see what ShareTable-mediated activities actually emerge as the most compelling ones, as the novelty factor wears off and the family begins to appropriate the system. To what extent will the parents and children use the system to support existing passions and activities (as with the family that brought their chess board)? To what extent will families come up with entirely new activities simply because they are well suited to the affordances of the ShareTable (as with tracing and collaborative drawing)?

8. CONCLUSION

The ShareTable explored remote synchronous interaction between parents and children. It was well received by the parent-child pairs who participated in our study. Interaction mediated by the ShareTable was qualitatively different from interaction through videoconferencing alone. Children as young as seven years old understood and used the system without co-located help. Families saw opportunities for using the ShareTable for both new and familiar activities. Perhaps most telling of all, several families asked how soon a version of the ShareTable would be available for use in private homes.

Deploying the prototype in a controlled environment was helpful to the process of developing the ShareTable. It provided early answers to important feasibility questions and helped generate and prioritize directions for design. As it was meant to do, the exploratory evaluation raised many potential questions for future investigations. A clear next step is conducting a deployment of this system in the households of a parent and child who live apart. Though we cannot directly measure if the ShareTable brings two family members closer, we can triangulate self-reported relationship satisfaction with measures of two aspects related to quality parent–child relationships: the amount of interaction and the variety of contexts/topics involved. Besides more accurately quantifying the affect of the ShareTable, a longer in-home deployment can allow for explorations unavailable in the lab setting, such as observing which new practices are introduced and which existing ones are altered or reinforced as the family appropriates the ShareTable.

9. ACKNOWLEDGMENTS

Thank you to Hina Shah and Brian Di Rito who were instrumental in generating ideas for designs and helping with the logistics of running the evaluation. We also acknowledge John Stasko and James Eagan for their early guidance of this work. Most importantly, thank you to our participants for their time and feedback.

10. REFERENCES

[1] Bly, S.A., Harrison, S.R., and Irwin, S. Media spaces: bringing people together in a video, audio, and computing environment. *Communications of the ACM* 36, 1 ACM (1993), 28-46.

[2] Brush, A.J., Inkpen, K.M., and Tee, K. SPARCS: exploring sharing suggestions to enhance family connectedness. *Proc. of CSCW*, Springer (2008), 629-638.

[3] U.S. Census Bureau. *Children Under 18 Years Old By Presence Of Parents: 1980, 1990, 1995, 2000 And 2004 [By Race And Marital Status]*. Published 2005.

[4] Dalsgaard, T., Skov, M.B., Stougaard, M., and Thomassen, B. Mediated intimacy in families: understanding the relation between children and parents. *Proc. of IDC*, ACM (2006), 145-152.

[5] Dalsgaard, T., Skov, M.B., and Thomassen, B.R. eKiss: Sharing Experiences in Families Through a Picture Blog. *Proc. of British HCI*, (2007), 67-75.

[6] Davis, H., Skov, M.B., Stougaard, M., and Vetere, F. Virtual box: supporting mediated family intimacy through virtual and physical play. *Proc. of OZCHI*, ACM (2007), 151-159.

[7] Dourish, P. and Bellotti, V. Awareness and coordination in shared workspaces. *Proc. of CSCW*, Springer (1992), 107 - 114.

[8] Flango, C.R. *Virtual Visitation — Is This A New Option for Divorcing Parents?* The National Center for State Courts, 2003.

[9] Gray, M.R. and Steinberg, L. Unpacking Authoritative Parenting: Reassessing a Multidimensional Construct. *Marriage and the Family* 61, 3 (1999), 574-587.

[10] Hofferth, S.L. and Sandberg, J.F. How American Children Spend Their Time. *Marriage and Family* 63, 2 (121), 295-308.

[11] Hutchinson, H., Mackay, W., Westerlund, B., et al. Technology probes: inspiring design for and with families. *Proc. of CHI*, ACM (2003), 17-24.

[12] Ishii, H. TeamWorkStation: towards a seamless shared workspace. *Proc. of CSCW*, Springer (1990), 13-26.

[13] Kelly, J.B. and Lamb, M.E. Using Child Development Research to Make Appropriate Custody and Access Decisions for Young Children. *Family Court Review* 38, 3 (2000), 297-311.

[14] Kennedy, T.L.M., Smith, A., Wells, A.T., and Wellman, B. "Networked Families." *Pew Internet & American Life Project Report*. Washington, D.C., 2008.

[15] Kientz, J.A., Patel, S.N., Jones, B., Price, E., Mynatt, E.D., and Abowd, G.D. The Georgia Tech aware home. *Ext. Abst. of CHI*, ACM (2008), 3675-3680.

[16] Lowry, R. The Fisher Exact Probability Test. In *Concepts and Applications of Inferential Statistics*. Vassar College, Poughkeepsie, NY, 2008.

[17] Modlitba, P.L. *Globetoddler: Enhancing the experience of remote interaction for preschool children and their traveling parents.* Masters Thesis. Media Laboratory. MIT. 2008.

[18] Mynatt, E., Rowan, J., Jacobs, A., and Craighill, S. Digital family portraits: supporting peace of mind for extended family members. *Proc. of CHI*, ACM (2001), 333 - 340 .

[19] Nardi, B. and Harris, J. Strangers and friends: collaborative play in world of warcraft. *Proc. of CSCW*, Springer (2006), 149-158.

[20] Plaisant, C., Clamage, A., Hutchinson, H.B., Bederson, B.B., and Druin, A. Shared family calendars: Promoting symmetry and accessibility. *ACM Transactions on CHI* 13, 3 ACM (2006), 313-346.

[21] Romero, N., Markopoulos, P., van Baren, J., de Ruyter, B., IJsselsteijn, W., and Farshchian, B. Connecting the family with awareness systems. *Personal and Ubiquitous Computing* 11, 4 Springer (2007), 299-312.

[22] Saslis-Lagoudakis, G., Cheverst, K., Dix, A., Fitton, D., and Rouncefield, M. Hermes@Home: supporting awareness and intimacy between distant family members. *Proc. of OZCHI*, ACM (2006), 23 - 30.

[23] Siio, I., Rowan, J., and Mynatt, E. Peek-a-drawer: communication by furniture. *Ext. Abst. of CHI*, ACM (2002), 582-583.

[24] Stafford, M. Communication Competencies and Sociocultural Priorities of Middle Childhood. In *Handbook of Family Communication.* Lawrence Erlbaum Associates, Mahwah, NJ, 2004, 311-332.

[25] Tang, J.C. and Minneman, S.L. Videodraw: a video interface for collaborative drawing. *ACM Transactions on Information Systems* 9, 2 ACM (1991), 170-184.

[26] Vetere, F., Davis, H., Gibbs, M., and Howard, S. The Magic Box and Collage: Responding to the challenge of distributed intergenerational play. *International Journal of Human-Computer Studies* 67, 2 Elsevier (2009), 165-178.

[27] Wilson, A.D. and Robbins, D.C. PlayTogether: Playing Games across Multiple Interactive Tabletops. (2007), 53-56.

[28] Yarosh, S., Chew, Y.C., and Abowd, G.D. Supporting Parent-Child Communication in Divorced Families. *International Journal of Human Computer Studies* 67, 2 Elsevier (2009), 192-203.

[29] Zuckerman, O. and Maes, P. Awareness system for children in distributed families. *Ext. Abst. of IDC*, ACM (2004).