A Theoretical Model of Children's Storytelling using Physically-Oriented Technologies (SPOT)

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Abstract

This paper develops a model of children's storytelling using Physically-Oriented Technology (SPOT). The SPOT model draws upon literature regarding current physical storytelling technologies and was developed using a grounded theory approach to qualitative research. This empirical work focused on the experiences of 18 children, ages 5-6, who worked with an existing multimedia physical storytelling technology in order to tell stories. Pairs of children worked over five weeks to tell stories using *StoryRooms,* a physical storytelling technology developed at the University of Maryland's Human-Computer Interaction Lab (HCIL). The SPOT model suggests that the each unique *child* and *context* together determine the best *degree of control over the technology*, *the degree of control over story content,* and the *physical activity* for each situation. Together, these characteristics of technology, story content, and physical activity produce a unique *storytelling experience.* The SPOT theoretical model provides a basis to propose technology design guidelines that will support the creation of new multimedia physical storytelling technologies.

1.0 Introduction

Storytelling is beneficial for children in many ways, including as a means of expression and communication (Engle, 1999; Paley, 1990). Many technological advances for supporting storytelling are currently being developed. As much as storytelling has always been a part of children's lives, technology is becoming a critical and pervasive part of children's lives today-- from the necessity of using a cell phone to call home to the need for keyboarding skills in classrooms. Druin and Solomon (1996) believe that many technologies, including multimedia authoring tools used for storytelling, can be beneficial to children. In addition to the traditional mouse, monitor, and keyboard computer often found in classrooms and homes, technology is often embedded in items that children interact with on an everyday basis (Montemayor et al., 2004), including in stuffed animals (Druin et al., 1999; Maddocks 2000, Strommen 1998, Umaschi 1997), Lego blocks (Martin et al., 2000), musical instruments (Lamb & Buckley 1984; Roh & Wilcox, 1995) and even toilets (Druin, 2002). From this ubiquity of technology, a critical question arises for designers of technology: What is the best way for technology to support storytelling for children?

Storytelling technologies, especially those created specifically for young children, can include components to support children's physical exploration of the world. Young children's early cognitive development is enhanced by interactions with the physical world (Brosterman, 1997; Bruner, 1966; Papert, 1980). By creating storytelling technologies that encourage young children to explore their physical world, storytelling technologies can be enhanced. Given recent technological advances in wireless and embedded technologies, the capability now exists to enable children to explore their

physical world using technologies that do not constrain children to a keyboard and screen. This type of physical exploration was suggested by Cassell (2004) and Druin and Solomon (1996) as a positive direction for multimedia storytelling technologies. Physical interaction with multimedia technology such as a child running around, sitting in, and squeezing the ears of a giant computerized stuffed animal named Noobie (Druin and Solomon, 1996) is now being applied to storytelling technologies in exciting ways.

This paper begins with an examination of existing physical storytelling technologies to set a context for the theoretical work described in this paper. The research methods and the SPOT theoretical model will then be presented. This paper concludes with a discussion of the implications of this research and theory as it relates to designing future multimedia physical storytelling technologies.

2.0 Defining the Constructs

During the course of this paper, the phrase "physical storytelling technology" is used often. It is important to examine each of these terms individually and how they function together as a construct.

"Physical", for the purposes of this paper, refers to an object that young children can interact with using gross motor skills (using large muscles, such as those in the arms) as opposed to a fine motor function (using small muscles, such as those in the fingers). The physical development of young children progresses from large to small muscle groups (Allen & Marotz, 1994). Although many young children will already have well-developed fine motor control, using gross motor skills may produce more successful interactions between children and technology. Researchers such as Montemayor et al. (2004) and Pinhanez et al. (2000) discuss physicality as it relates to designing children's

technology. Defining "physical" as requiring gross motor activity helps to maintain a developmentally appropriate orientation in working with young children.

Determining a working definition for "storytelling" is difficult. Common themes among researchers' varying definitions of storytelling include the concepts of a sequence of events involving the passage of time and the conveying of meaning, and that a story is communicated intentionally (Labov, 1972; Engle, 1999; Peterson & McCabe, 1991, Well, 1986). There is also debate about whether storytelling is an exclusively oral activity (Peterson & McCabe, 1991), or a written account (Engle, 1999). For the purpose of this theory, "storytelling" is any effort by a child or children to intentionally communicate using a narrative. A sequence of events and the passage of time are not included in this definition due to the young age of the children. In addition, all of the stories collected in the current study were orally told; however, this was again due to the young nature of the participants and is not meant to imply that stories cannot be written.

"Technology" today is no longer necessarily defined only by a traditional conception of a computer. Weiser (1991) foresaw a future where technology "disappeared" and became essentially an extension of people and their environment, which is referred to as ubiquitous computing. Likewise, some researchers have noted a trend in Human-Computer Interaction research towards "tangible and mobile interfaces" (Joiner et al., 2003, p. 145). It is this kind of ubiquitous, tangible, and mobile computing that defines "technology" in this paper.

Therefore, for this discussion, a "physical technology" is a ubiquitous computing technology that requires a child to interact in a gross motor manner. While traditional conceptions of "multimedia" may not have included a physical component, a key

component of multimedia environments was that they were interactive (Druin & Solomon, 1996). As multimedia moves into the 21st century, this interaction might also include the manipulation of computationally enhanced physical objects that are embedded in the user's environment (Druin & Solomon, 1996). These "physical technologies" have been referred to elsewhere as "tangible non-screen-and-keyboard based technology" (Cassell, 2004) and "tangible technology" (Stanton et al., 2002). A "physical storytelling technology" refers to any physical technology that is designed specifically as a tool for children to use when storytelling. Some researchers (Cassell, 2004; Alborzi et al., 2000) have discussed the potential importance of a physical component in storytelling technologies.

3.0 Prior Research and Conceptual Framework

There are many different types of storytelling technologies currently available for children. One category of storytelling technologies is virtual storytelling environments, such as the *Hayes-Roth Improvisational Puppet System* which allows children to manipulate puppet-like characters on a screen (Hayes-Roth, 1995). Other virtual environments use the internet as a tool to allow children who are geographically distant from one another to collaborate in storytelling. Huffaker (2004) explored the use of message boards, webblogs, and instant messaging in storytelling. Other internet-based storytelling technologies include *MOOSE Crossing*, a virtual environment in which children can construct and interact using a programming language designed specifically for children (Bruckman, 1997); *StoryBuilder*, an on-line storytelling tool which allows children to add to stories written by children in a comic-book style (Antle, 2003); and *Renga*, a system that allows children to contribute sentences to a story in a round-robin

manner (Cassell, 2004; Cassell & Ryokai, 2001). While these virtual storytelling technologies support children as storytellers, adding a physical component may offer children, especially young children, enhanced storytelling experiences.

Physical technologies designed to support children's efforts in storytelling do exist, and many include discrete concrete objects, such as stuffed animals, robots, and toys that children use to aid in storytelling. In addition to physical interactions, these multimedia technologies often also include auditory and visual interfaces. Computationally enhanced stuffed animals that promote storytelling include *Rosebud* (Glos & Cassell, 1997; Cassell, 2004), *Actimates Barney* (Strommen, 1998), and *SAGE* (Umaschi, 1997). One technology that integrates stuffed animals with video storytelling is *Swamped!* (Johnson, 1999; Pinhanez et al., 2000). *PETS*, the "Personal Electronic Teller of Stories" (Druin, 1999; Montemayor, 2000), uses a robot to tell stories with children. *Telltale* (Annany, 2001; Cassell, 2004) uses a physical worm whose individual body segments are used to store audio sections of a story that can then be physically combined to tell a story. Technologies that go beyond stuffed animals and into other familiar objects can also be found. For example, *Sam the Castlemate* (Ryokai, 2003; Cassell, 2004) encourages children to use a toy castle and castle props to tell a story, both in a physical world as well as a virtual world with a virtual peer. All of these technologies, whether with a robot, stuffed animal or toy, support children as storytellers by allowing interaction with discrete physical object(s) that can be used in storytelling, often using multimedia feedback.

Storytelling technology does not have to be limited to individual objects such as stuffed animals or robots. There are currently a few physical storytelling technologies

that move beyond discrete physical objects to take advantage of the child's environment. *KidsRoom* is a child's "bedroom," where computer vision is used to track children's movements in the room in order to guide their progress through a story (Pinhanez, 2000; Bobick, 1999). *Storymat* (Cassell & Ryokai, 2001, Cassell 2004) is a large quilt and small stuffed animals that enable children to construct and retell stories, through interactions with the toys and the quilt. *POGO* (DeCortis 2002; Fusai, 2003) is a mixed physical and virtual environment, created to support children in storytelling by offering multimedia tools that can capture and incorporate video and audio clips into stories, as well as tools for manipulating story elements through gross motor movements. These examples embed multimedia technology in children's environments.

4.0 Methods

Qualitative methods were used in this research, specifically grounded theory as described by Strauss and Corbin (1990), to understand the storytelling experiences of young children using a physical storytelling technology, *StoryRooms*. The sections that follow present a discussion of materials used in the study including a description of the specific technology, followed by a description of participants, procedures, and analysis activities.

4.1 Materials Used

The best way to understand *StoryRooms* technology is through an example. In this study, one story used was the "Irene Story", a story about a young girl who is lost in the woods and asks various animals for help in finding her house. In order to tell stories using *StoryRooms*, props are built or found (see Figure 1). Simple props such as these

made from basic art supplies or found in the environment are integral to *StoryRooms* as they help the children connect the story to their environment.

Physical icons are another integral part of *StoryRooms*. The icons are large, foamy, and not intended to be subtle to the user (see Figure One). These icons include sensors, which are pushed or otherwise stimulated, and actuators, which react when a sensor is pushed. In order to use *StoryRooms* to tell a story, the icons are intended to be placed with the props (see Figure 1 for Irene *StoryRoom* setup).

Figure 1: Setup for the Irene Story. The props include the cottage, the mouse, the koala bear, and the snake inside the cave. The foot icon is a sensor programmed to trigger the blinking arrow by the mouse. The hand icon, also a sensor, was programmed to trigger the sun icon (light) and the wind icon (fan).

In order to establish connections between icons, a child "wizard" wears a wizard's hat and uses a magic wand to program the technology. An example of this is connecting a hand and sun icon so that when the hand is pressed the light turns on. The wizard presses the "new-spell button" (a small button located on the middle of the magic wand) and waves the magic wand over the sets of icons she wants to connect (Figure 2). For more on this novel "physical programming" approach, see Montemayor (2003).

Figure 2: A child authoring a StoryRoom and creating interaction rules. By wearing the wizard's hat, she knows that she can create "magic". The magic wand gives her the power to create "invisible" wires to connect different icons. Here, she is waving the wand over a physical hand icon.

The final Irene *StoryRoom* is as follows. A narrator (child or adult) begins near the cottage, next to which is the foot icon. The narrator begins, "*This story is about Irene, a little girl who is lost in the woods and cannot find her house. Irene asks the people in the cottage if they know where her house is, but they do not. Irene sees a strange foot and pushes on it*." Pushing on the foot activates the blinking purple arrow light next to a stuffed mouse, which directs attention to the mouse. The narrator continues, "*Irene asks Mr. Mouse if he knows where her house is. Mr. Mouse says no, but that she should ask Mr. Koala*." The children run to Mr. Koala, who has the hand icon near him. The narrator says, "*Irene then asks Mr. Koala if he knows where her house is. Mr. Koala says no, but that she should ask Mr. Snake in the cave*." The children press on the hand icon, which activates the fan and light placed near a snake prop in a cave. The children run over to the cave and the narrator ends the story, "*Irene asks Mr. Snake if he knows where her house is. Mr. Snake says yes, just turn around and go ten feet and there it is*."

4.2 Participants

Eighteen children, eight girls and ten boys, ages 5-6, participated in this study. Of the 18 children, 7 were Caucasian, 3 African American, 3 Chinese American, 2 Korean American and 3 were bi-racial. The family income ranged from approximately $30,000 to $200,000 annually. All of the children were in the kindergarten program at the Center for Young Children (CYC), an early childhood center located on the campus of the University of Maryland. All children in the kindergarten class were invited to participate in the research study through a letter to parents, and eighteen of the nineteen children in the class were given permission to participate. Throughout the study, the children demonstrated a wide variety in their academic ability. Children worked in a large open space at the CYC in peer pairs with a team of five adults for sessions that lasted approximately 20 minutes each. Children were placed in nine pairs that remained the same throughout the study. The pairs were created to ensure diversity in gender, race, and ethnicity within and across pairs.

4.3 Procedures Used

4.3.1 Session Activities

The children were asked to participate in three activities in which they interacted with *StoryRooms*. All children were given the opportunity to be involved in the first two activities. For the first activity, to learn if children could participate in an already created *StoryRoom*, the children heard an unfamiliar story, the Irene Story. The story was first told to the children by an adult narrator, after which the children assumed the role of narrator and retold the story. They were assessed for their ability to recall the content of the story and to use the *StoryRoom* icons. The children also briefly used the *StoryRoom*

to tell their own story. During the second activity, the children were engaged in physical programming by first watching a demonstration of how to program using the magic wand and then using the wand to program.

The third activity utilized a case study method to learn if children could create an original story using the *StoryRoom* technology. The purpose of this activity was to determine if the children were able to go beyond repeating the words of others to creating their own ideas and giving voice to them utilizing the *StoryRoom* technology. Two pairs of children participated in this case study in a very in-depth manner. The first pair, Bobby and Dennis (not their real names), were two Caucasian boys who were selected to represent the high end of the spectrum of competence with *StoryRooms* as they had scored the highest on the retelling activity based on coding of videotape from that activity. The second pair, Mary and Shelly (not their real names), were chosen to represent the lower end of the spectrum of competence with *StoryRooms* as they were one of two pairs that had scored the lowest on the retelling section. Mary is Chinese-American and speaks Chinese at home. Shelly was born in Korea and moved to the U.S. one month before the school year began, and was in the process of learning English. Choosing children at the extremes of competence with *StoryRooms* allowed for a determination of boundaries for how most children would likely perform when asked to create a story using *StoryRooms*.

4.3.2 Analysis Activities

The analytic process was grounded in coding, sorting, and comparisons that characterize the grounded theory approach (Strauss & Corbin, 1990). The process of analysis was designed to uncover the components of a young child's storytelling

experience including physically interactive technology. Sorting, comparing and contrasting was as Strauss (1987) suggests, done until "saturated," or no new codes or categories emerged with analysis. Once a coding system was devised, analysis was carried out of video and participant observation notes. All of the video was watched by one or two researchers who were present throughout the actual sessions with the children.

5.0 Results

Figure 3 presents a grounded theory model of children's storytelling experience using physical storytelling technologies (SPOT). SPOT asserts that the unique *child* and *context* determine the most appropriate *degree of control over the technology tool, degree of control over story content,* and *physical activity of the child,* all of which together produce a unique *storytelling experience.* In the sections that follow each part of this theoretical model will be described in detail. A phrase often used during this discussion is "positive storytelling experience". For a positive storytelling experience to occur, the child was both able to adequately complete the tasks required to tell the story (i.e., recall parts of a story, properly manipulate the technology, properly program the technology) and also demonstrated enjoyment while doing so It is also important to note that the defined levels in *degree of control over the technology tool, degree of control over story content,* and *physical activity* actually constitute a continuum. For ease of discussion, technologies are classified as the category to which they are closest along the continuum.

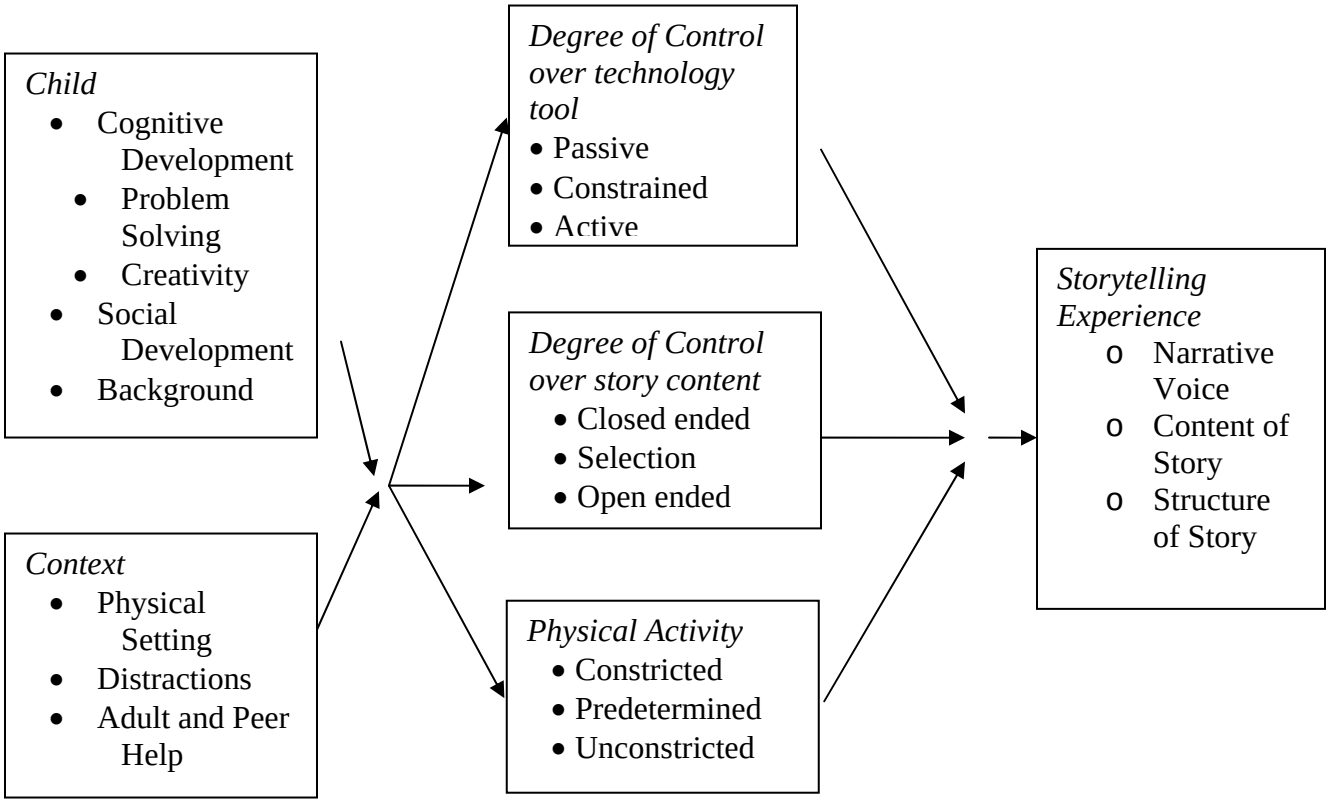

Figure 3: A model of children's storytelling using physically-oriented technology (SPOT). The unique child and context determine the best degree of control over the technology interface, degree of control over story content, and physical activity, and together produce a storytelling experience.

5.1 Child

No one child is quite like another (Hohmann & Weikart, 1995), and therefore when technology is designed, developers need to take into consideration the individuality of each child (Wyeth & Purchase, 2003). The unique characteristics of each individual child user will necessarily alter the use of the technology as envisioned by the creator of that technology. This means that every child will have a unique storytelling experience, regardless of the storytelling technology. In the current study, the children differed in many ways, including their *cognitive development* (including *problem solving* and *creativity), social development,* and *background.*

Cognitive development plays a large role in the type of storytelling experience that will result from interaction with a multimedia physical storytelling technology. During the case study, Bobby and Dennis demonstrated higher level thinking including problem solving in order to perform the subtasks necessary in order to use *StoryRooms* technology. Mary and Shelly were less able in this area. The *creativity* expressed by Bobby and Dennis led to an original story, while Mary and Shelly's relative lack of creativity led to a retelling of a previously heard story. *Problem solving* skills, a part of cognitive development (Allen & Marotz, 1994), also figure in to the eventual storytelling experience. For example, when Mary and Shelly encountered problems in programming the interface for their story (they repeatedly programmed all of the icons together in one continuous string instead of separate commands), they were unable to develop a solution to this problem on their own, showing a relative lack of problem solving skills. The research team intervened by bringing out Bobby and Dennis to assist Mary and Shelly in programming, however, left to their own devices, it is doubtful that Mary and Shelly would have overcome this problem and therefore would have had a much less positive storytelling experience.

The storytelling experience is also impacted by a child's level of *social development*, which can vary greatly at this age (National Research Council, 2001). The children exhibited many different types of social interaction during this study, including pairs where one child was obviously dominant, pairs where the dominance role switched, pairs in which one child was excessively shy, and pairs with turn-taking ability. All of these types of social interactions were able to produce a storytelling experience, but they affected this experience.

Finally, the *background* of each child will affect the storytelling experience. For example, Shelly has limited English proficiency. This obviously impacted her ability to tell a story in English. The background of a child can range from the family situation the child comes from to how he or she is feeling on any given day.

5.2 Context

Many scholars, including noted psychologists Jean Piaget and Lev Vygotsky, assert that the context in which a child works is important (National Research Council, 2001). The work for this study pointed to three variables related to context that affected the storytelling experience. The first was the actual *physical setting* in which the children worked. For this experience, the children worked in the "Great Room", a large two-story space which seemed to engender in the children a sense of freedom due to its large and open nature, and possibly made the children more likely to explore the technology. A smaller, more enclosed space might have constricted the children's ability to use this multimedia technology.

A second issue in dealing with context is *distractions.* The space in which this work took place was central to the school, which meant that there were oftentimes distractions. For example, when another teacher walked through the Great Room, Shelly looked up and called to her, spent time waving at this teacher, and then had to be redirected to the storytelling task at hand. While this interruption was not catastrophic for her storytelling experience, it disrupted the flow of the experience.

Finally in the area of context is the idea of *adult and peer help.* While there is often interaction between children and adults during storytelling, the amount of interaction changes the complexion of the storytelling experience. This type of

interaction can range, as it did in this study, from help building props to scaffolding a story to settling minor disputes.

5.3 Degree of Control over the Technology Tool

There are three basic levels of control over the interface that children can be given when using a physical storytelling technology. The first is a *passive* interaction, in which the child has no control over how the technology tool functions, that is, the manner in which the tool functions has been pre-determined, either by another child, an adult, or the programmer. The second level is a *constrained* level of control, in which the child is given some degree of control over how the technology tool functions, but not complete autonomy. The third and final level of degree of control over the technology tool is *active,* in which children are free to define the interaction of the technology tool in any way they see fit. During the course of this study, all three levels of interaction occurred.

During the portion of the study in which the children were told the Irene story and asked to retell it, their degree of control over the technology tool was *passive* — the technology had been pre-programmed. Most children were able, with varying degrees of adult guidance, to retell the story of Irene. Children who had successful experiences in retelling were able to do so with mainly generic guiding prompts from adults, such as "*Tell the story with me*" and "*How did the story start?*". While their interaction with the technology interface was *passive,* many children were able to remember both the plot of the Irene story and the proper times at which to activate the technology, and therefore have a positive storytelling experience.

When the children had an *active* degree of control over the technology tool, some of them unintentionally indicated that they needed to be at more of a *constrained* level of

control over the interface. Most children were able to actively program the *StoryRoom*, but individual children needed varying degrees of adult guidance in order to do so. Some children could program the multimedia sensors and actuators using the magic wand with nearly no adult help, while others needed a tremendous amount of adult support in order to do so. For example, one child needed specific and leading prompts from an adult while programming that included such leading questions as *"What do you want the blue foot to turn on? Press the new spell button. What are you going to connect that to?"* This child was not able to handle a completely *active* degree of control and was looking for one that was more *constrained.* Children were still able to have a beneficial experience at this *constrained* level of control.

The intent of programming with *StoryRooms* is that it is an entirely *active* process – the children are allowed to program the icons in any combination that they wish. Because adult guidance may not always be optimal in children's storytelling, the case study section was created in part to explore this degree of control of the technology tool. Some children, like Bobby and Dennis, were able to actively program the technology of the *StoryRoom* with virtually no assistance in programming from the adults present, and were therefore able to have a more seamless storytelling experience.

5.4 Degree of Control over Story Content

Three levels of degree of control over story content emerged from the data, the video and the participant observation notes. There is a *closed-ended* story choice, in which the children must use a pre-determined story; a *selection* level, in which children are allowed to make a selection from a pre-determined pot of stories to tell, or in which

the technology itself directs children towards the type of story to tell; and an *open-ended* level of story to tell, in which children can make up or retell any story.

An example of the *closed-ended* option was when children retold the Irene Story. For this activity there was only one story outcome. There was variation in the abilities of the children – some were able to retell the story using the icons with no troubles, while others did not do as thorough a retelling. However, all of the children were able to reiterate at least some of the Irene Story. Thus, it appears that a *closed-ended* option of story to tell will lead most children to a successful storytelling experience, as evidenced by the fact that most of the children were able to retell, with some degree of accuracy, the Irene Story.

After the children heard and retold the Irene Story using *StoryRooms*, they used the *StoryRoom* to tell a story. This increased the possible story outcomes, and illuminated more of a range in abilities. Two pairs simply retold the Irene story, while five pairs retold the Irene Story with some changes (e.g., changing a character). All of these pairs used the icons in their story. These children would probably need a *selection* of story outcomes – they were able to use the *StoryRooms*, but using a story that had already been supplied, even though they were allowed to tell any story. Two pairs told an original story without using the icons, two pairs told an original story using the icons, and one pair told a story about the icons. Although all of these pairs did not necessarily use the *StoryRoom* technology in the manner intended, they showed the ability to generate their own story. These children would most likely fare well when the choices of story to tell were *open-ended.* There were twelve stories told by only nine pairs because some of the pairs spontaneously told more than one story.

To understand the range of possibilities in dealing with choices of story to tell, children on both ends of the ability spectrum participated in the case study to develop a *StoryRoom* of their own. It seemed that having *open-ended* story choices was appropriate for Bobby and Dennis. They were able to create an original story and use the *StoryRooms* technology to express this story. Adults scaffolded this story by asking questions to help Bobby and Dennis tell their story. This, however, does not affect the idea that they began with *open-ended* possibilities for the story to tell. Their original story, edited here for brevity sake, is:

Once upon a time there was a little girl. She was combing her hair, and the sink went on all by itself. She didn't know why it did, but she thought her dog, Rocket, could help her. Rocket couldn't help her. There was a ghost in the sink. He was a bad ghost. The little girl scared him away with a mask and he went to a cave.

On the other hand, Mary and Shelly, who had more difficulty using the StoryRooms technology, had trouble with the fact that there were no limits to the story they could tell. Although Mary and Shelly were encouraged numerous times to create an original story to tell, they chose a story already created by others. Their story, again edited for brevity, went as follows:

Max and Emmy moved to a new house and found a special wish in a drawer. They made the special wish, "I wish, I wish, with all my heart, to fly with dragons in a land apart" and went to Dragonland. They met lots of dragons, Zach, Wheezy, Ord, and Cassie. They went to Dragon School[1]. It is possible that a technology that offered a

[1] DragonTales is trademarked and copyrighted by Sesame Workshop/Columbia Tristar Television Distribution.

selection of stories for Mary and Shelly could have been more appropriate given their ability level.

5.5 Physical Activity

During this work with children and *StoryRooms*, there were many different levels of physical activity. One level not used in this study was the level of *constricted* activity, in which children are not allowed to move about a space while interacting with a physical storytelling technology, and are only able to interact with the technology using fine motor skills. The children did work at the *predetermined* level of physical activity, in which the physical activity of the children is directed or constrained in some manner by the technology during the Irene story. While the children were able to determine their own means of moving around the story, the general direction in which they moved was predetermined by the manner in which the *StoryRoom* was laid out. During this activity, the children used many modes of getting around, including walking, crawling, and walking on their knees. The children also worked in an *unconstricted* physical activity mode, in which no limits were put on their choice of physical activity within their environment. During our case studies, children used many types of physical activity, including sitting, crawling, and walking.

5.6 Storytelling Experience

The end result of any physical storytelling technology is a storytelling experience including the components of *narrative voice*, *content of story*, and *structure of story*.

Narrative voice refers to the originality and confidence of how a story is told (Druin, 2003). A wide range of narrative voices were heard, from Bobby and Dennis's entirely original story to Mary and Shelly's nearly verbatim retelling of a tale from

television. During the initial activity in which children were prompted to tell a story using the StoryRoom, many children simply briefly retold the Irene story, sometimes with changes. On the other hand, one pair of children told a story for longer than six minutes about a boy named Alex who had many adventures including going to a "very cold cave", getting burned by touching the sun, and meeting a snake who was eating "onion, of course"! These stories demonstrate a variety of narrative voices. There was also a large variation in the *content* of stories – from fiction to fantasy. Children also included a wide range of characters in their stories, from Goldilocks to little girls who did not have names to the boy named Alex. Plots of original stories also ranged widely, from the little girl who had a ghost in her sink to Alex's adventures as described above.

Finally in this category is the *structure* of the story, which refers to its having characters, plot, setting, problem, and solution. As we mentioned in the section on definitions, there was no requirement that all stories had all of these components in order to be considered stories. As young children are beginning storytellers, any attempt at telling a story was considered to be a valid story structure.

6.0 Discussion

Developing this theory of children's storytelling experiences with physical storytelling technologies led to many conclusions which can be seen as guidelines for the design of future multimedia physical storytelling technologies. Note that these suggestions are based on the second column of the SPOT theoretical model. Makers of children's technology do not have control over the unique *children* who are using the technology or the *context* in which they do so. Therefore, these suggestions concentrate

on the future direction of the *degree of control over the technology tool, the degree of control over story content,* and *physical activity*.

6.1 Degree of Control over the Technology Tool

When designing any multimedia physical technology for children, one decision to consider is the *degree of control over the technology tool* that will be given to the child. Technologies already exist at various levels of control through the interface. For instance, a technology such as Actimates Barney (Strommen, 1998) has a *passive* and pre-determined degree of control over the technology tool. A *constrained* degree of control is allowed by Telltale (Annany, 2001; Cassell, 2004), as the child has some degree of control over the technology interface (by choosing the number of segments and the order in which they are put together), but not complete autonomy. An example of a technology allowing children an *active* degree of control over the interface would be POGO (DeCortis & Rizzo, 2002; Fusai et al., 2003), where children can use the tools given to them in any manner they see fit.

Based on the results of the above study, there is an apparent need for multimedia physical storytelling technologies that provide all levels of control over the technology tool. Children seem to benefit from interaction at all of these levels, with individual children best suited to certain levels. Not only do individual children vary from one another in their need for differing levels of control over the technology tool, but a single child's need for a different level of control would likely change over time as she grew. Varying degrees of control over the technology tool will be necessary to properly support all children over time, interacting with physical storytelling technologies. Even in the

small sample that participated in this study, children needed varying degrees of control over the technology tool in order to have positive storytelling experiences.

How can designers incorporate these seemingly competing degrees of control in multimedia physical storytelling technologies? One way may be to create entirely separate technologies; however, this may be impractical as it would mean designing many different types of multimedia physical storytelling technologies. In addition, consumers would need to obtain a number of physical storytelling technologies to support many children or one growing child. Another possibility would be to create technologies that can change modes – to allow a great degree of child control in one mode and yet to switch to modes that provide scaffolding or a preprogrammed set of interactions if necessary to support the child in her storytelling experience. Finally, innovative ideas for ways to support children's degree of control over the tool such as "help" mode buttons would be appropriate.

6.2 Degree of Control over Story Content

Degree of control over story content refers to the possible stories that can be told using the physical storytelling technology. Many physical storytelling technologies, such as KidsRoom (Pinhanez, 2000) are somewhat *closed* in degree of control the child has over the story content: that is, the story to be told is predetermined. It seems that there are times when story choice can and should be limited, but also that allowing a range of story choice can have many benefits. Many technologies exist at a *selection* level, where children have some freedom to choose the story they will tell but are in some way guided to their story choice by the technology, such as StoryBuilder (Antle, 2003) in which children's stories are based on pre-drawn and characters and settings. Finally, PETS

(Montemayor, 2000) allows for an *open-ended* choice of story to tell as any story can be told using the robot that the children build.

Similar issues arise in choice of story to tell as do with degree of control over the technology tool. By leaving the possibilities for story outcomes open-ended, children are encouraged to develop problem solving skills and paths to creativity. On the other hand, children who are given unlimited story outcomes and who are unable to choose among them may feel inadequate in their ability to use the storytelling technology, therefore, they may have a less positive storytelling experience.

The options for tackling the problem of degree of control over choice of story are similar to that of the degrees of control over technology tool. One option is to design completely separate technologies, some that include predetermined story outcomes and some that allow children to define their own story outcomes. Another idea is to create multimedia physical storytelling technologies that can be switched from mode to mode in order to provide story outcomes for those children who need support or to allow children the freedom to create their own story outcomes if they are able. Again, innovative ways of supporting children with story outcomes should be considered, such as "idea cards" for use with *StoryRooms* which provide simple story starter ideas for children having difficulty coming up with their own stories. This is a low-tech way in which to make a physical storytelling technology support many different levels of storytellers.

6.3 Physical Activity

It appears that there are many benefits of physical activity, especially gross motor activity, for young children. Therefore, while there are benefits to virtual storytelling technologies that are *constricted*, these would likely be more beneficial for older children.

Physical storytelling technologies designed for young children should either have a *predetermined* physical component or be *unconstricted* in the amount of physical activity they allow. An example of a currently existing technology at the *predetermined* level of physical activity is StoryMat (Cassell, 2003; Cassell & Ryokai, 2001), which allows children freedom of movement around a large floor mat, but which does require that the children be tethered to that mat for the storytelling experience. An *unconstricted* technology would be one such as Rosebud (Glos & Cassell, 1997; Cassell, 2003) or SAGE (Umaschi, 1997) in their final iteration, when the only object to which a child is linked is a stuffed animal, which can then be taken anywhere to tell a story.

The benefits of a *predetermined* physical component would be for children who are unable to regulate themselves and might get carried away with physicality, therefore losing the storytelling experience. *Unconstricted* physical activity will be beneficial to children who are able to self-regulate, therefore offering them more opportunities for creativity. Again, the creation of innovative multimedia physical storytelling technologies that would allow for both *predetermined* and *unconstricted* physical activity opportunities will be beneficial. *StoryRooms* offers this option as the children can either set up their own story or interact with a preset story that predetermines the physicality involved.

6.5 Conclusions

The future of designing multimedia physical storytelling technologies for children is limitlessness. These technologies can be incredibly powerful, especially if they support the child's exploration of the physical world. The guidelines offered here can help the designers of multimedia physical storytelling technologies to create beneficial

tools that support children's development. These technologies should be designed to support children with a variety of needs by allowing for various degrees of control of the technology tool, degrees of control over story content, and physical activity, while bearing in mind the needs of the children for whom they are being designed and the contexts in which they will be used.

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