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Interactive Storytelling Systems for Children: Using Technology to Explore Language and Identity

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More and more often there is embarrassment all around when the wish to hear a story is expressed. It is as if something that seemed inalienable to us, the securest among our possessions, were taken from us: the ability to exchange experiences.

The Storyteller, Walter Benjamin

Storytelling is a good medium for learning about identity and communication as it enables exploration of one's inner world and requires flexing one's language skills. This paper presents a new approach to interactive storytelling: *SAGE* (*Storytelling Agent Generation Environment*), an authoring environment for children to create their own wise storytellers to interact with by telling and listening to stories. In order to encourage children's emotional engagement in the *SAGE* environment, the storytellers are embodied in an interactive stuffed animal, also programmable by the children.

This paper presents technical aspects of *SAGE*'s design and implementation as well as results from pilot studies done with fourth and fifth graders. Results show that children had a tendency to share their personal stories with the soft interactive interface. Exploration of identity and communication happened in several ways: First, storytellers built by the children were projections of their fears, feelings, interests, and role models; they allowed them to explore their own identity

> as well as present themselves to others. Second, through designing and testing the conversational structures of their storytelling characters, children observed and repaired breakdowns in conversational interaction. This process engaged them in the exploration of communication and decentering, or taking the point of view of others.

In everyday life, conversational personal storytelling is a communicative experience in which story listening is as important as storytelling in order to construct a sense of identity. New technologies have the potential to encourage people to share their personal stories; however, there is a lack of computational environments explicitly designed to encourage exploration of identity. *SAGE* (*Storytelling Agent Generation Environment*) was designed with this explicit goal and uses storytelling to achieve its purpose.

Stories are one of the primary ways in which the self is presented to others and to us. When people communicate they often do it through telling stories about their experiences and by finding personal relevance in other people's stories. *SAGE* encourages, enables, and enhances this type of storytelling, as well as provides a framework for children to design and program their own interactive storytellers. The latter supports changes in the way children think about themselves and about storytelling as a communicative activity.

Thus, *SAGE* supports two modes of interaction. In the first—storytelling interaction—children are invited to share what is going on in their lives with an old sage, who "listens" and then offers a relevant traditional tale in response. In the second—storyteller authoring interaction—children are invited to add to the library of old sages by designing their own storyteller for themselves and other children to interact with. In order to support children as designers as well as users of the storytellers, we implemented a visual authoring language that allows children to program (a) the scripts that are told by the storyteller, (b) the conversational structure, or flow of the interaction between user and storyteller, (c) the body behaviors of the interactive stuffed animal—the storyteller's assistant, and (d) the database of stories that are offered as the storyteller's response.

In this paper we situate our work within a transdisciplinary theoretical background. Then we describe *SAGE*'s design and technical implementation. Next, we share results from empirical studies conducted with fourth and fifth graders using the system. Finally we present conclusions.

CONTEXT OF THE WORK

Although little research has been done on how technology can be used to encourage children to learn about identity and communication through storytelling, a fair amount of research exists in relevant fields that have an impact upon these issues. In what follows we present a theoretical framework, drawing from research in diverse areas such as narrative theory, psychology, artificial intelligence, education, and human-computer interaction. We are aware that a complete survey of these research areas is impossible, therefore we chose to focus on the particular aspects that guided our system design.

Telling and Listening to Stories

Narrative is the primary form through which we understand and give meaning to our experience (Polkinghorne, 1988). Our research focuses on a particular kind of narrative—conversational stories of personal experience—defined by Polanyi (1989) as highly structured linguistic productions found in the context of everyday talk, and by Miller, Potts, Fung, Hoogstra, and Mintz (1990) as face-to-face interactions in which self-expression is accomplished by the recounting of personal experience.

Narrative, including conversational stories of personal experience, serves at least three vital functions. These three functions of narrative were carefully analyzed in order to design the *SAGE* system.

1. Cognitive function: Personal stories are fundamental constituents of human memory, and new experiences are interpreted in terms of old stories and generalized story scripts (Bartlett, 1932; Schank & Abelson, 1995). Bruner (1986) describes narrative as a mode of cognitive functioning that provides a distinctive way of ordering and understanding experience.
2. Social function: The tales that one knows and can tell define the social group or culture to which one belongs (Turner, 1980). Myths, legends, and traditional tales provide a sense of continuity between generations as well as models for human behavior (Campbell, 1988). Conversational personal stories play an important role in the social construction of the self from early childhood (Miller et al., 1990). Adults tell and retell life stories according to certain conventions and in many different contexts as a way of establishing coherence in their lives (Linde, 1993).

3. Emotional function: Storytelling has been used in very different forms of psychotherapy (Wigren, 1994). In fact, one view of psychotherapy is that it leads us to be able to tell coherent life stories (Polkinghorne, 1988). The emotional value of tales has been explored by Erickson in hypnotherapy (Rosen, 1982) and in fairy tales by Bettelheim (1976). As Freud (1965), Erikson (1950), and others have shown, through the verbal-play experience of storytelling, children can find not only recreation but also self-cure.

From cognitive, social, and emotional standpoints, it is important for children and adults to have a place to tell their story. But it is also important to provide a space for them to explore what is narrative and how conversational storytelling works. *SAGE* was conceived to support both storytelling and story making. While storytelling helps children to "play out" what is happening in their lives, story making supports learning about narrative by interacting with and designing meaningful storytellers.

For example, in interaction mode, by playing the role of a wise, old person listening and responding to children's stories, *SAGE* explicitly encourages children to tell their personal stories. It enables them to explore their inner life, developing a better sense of who they are and a set of values for constructing their role in the world. In authoring mode, *SAGE* supports children in designing and programming their own meaningful storytellers. Taken together, these two modes allow users to construct and express their narrative voice (Cassell, in press) as well as their identity.

Storytelling Systems: Beyond Story Writing

To date, most of the research on computers and storytelling has focused on interactive games, mystery simulations, and interactive fiction (although see Don, 1990; Laurel, 1993). Interactive games and mystery simulations present a plot by way of short descriptions of characters and places, and they allow users to navigate through the spaces and find out more about the characters. Unlike narratives about the self, these are "forms of narrative that privilege space over characterization or plot development. [They are] part of an alternative tradition of 'spatial stories,' a different way of organizing narratives that must be examined and evaluated according to their own cultural logic" (Fuller & Jenkins, 1995).

Interactive fiction presents a short story or novel in a hypertext format, the branching nodes allowing users to read a different story each time by

choosing different links. Unlike personal narratives, this work concentrates on how to adapt the genre of fiction to the constraints and possibilities of the computer. Other work has used computation to assist production and viewing of narrative structure models for cinema. For example, "Agent Stories" (Brooks, 1996) is an environment for non-linear, cinematic story design and presentation that can be used by cinematic story writers.

In the entertainment domain, the design of storytelling systems for children has focused on interactive games and fiction of the type described above. In the educational domain, work has been done on supporting children's story writing process. Commercial software such as *Kid Works Deluxe* (Davidson & Associates, 1995) and the *Amazing Writing Machine* (Brøderbund, 1994) are augmented word processors that encourage children to tell stories by giving them a choice of first sentences, a set of characters as inspiration, and sample illustrations for their stories. Educational researchers have also devoted extensive effort in developing story writing software. For example, *TOPOI* (Burns, 1984) was originally designed to aid college essay writers in brainstorming and planning, while *Catch* (Daiute, 1985) was developed at Harvard University to improve young users' story-writing skills. At the MIT Media Laboratory, Montford (1998) designed *EddieEdit*, a conversational computer character to aid children in the process of writing stories, with special focus in planning and revision.

By contrast, the research presented in this paper is not aimed at improving story writing, rather *SAGE* seeks to support children's authoring of their own wise storytellers and story listeners through the design of an interactive character. The authoring process involves the design and implementation of conversational interactions between the user and the wise storyteller. This serves as a vehicle for the transformation of ways of thinking about narrative as a communication process deeply involved in identity construction.

SAGE employs the notion of a simple conversational system with a well-defined character, similar to Eliza (Weizenbaum, 1976), Parry (Colby, 1975), and Julia (Mauldin, 1994). These are described by Murray (1991) as parodic interactive character whose computational rigidities model recognizably human types. *SAGE* extends the domain to the world of narrative and allows storyteller construction as well as interaction. It has been suggested that the construction of emotionally believable characters with a limited field of interaction can maintain the suspension of disbelief of the user and thus allow successful human-computer interaction in the absence of deep artificial intelligence (AI) (Bates, Maes, & Hayes-Roth, 1995). This alternative to the deep AI approach focuses on believability over ability.

By ability we refer to the vision that computers should try to re-create the cognitive processes that people use to understand stories—as a step towards machine understanding with broad applicability. For example, there is extensive research on producing models of the world that contain particular knowledge organized around standard situations, scripts, or cases (Schank & Riesbeck, 1981). This story understanding research depends on a theory of narrative as primarily constituted by goals and actions in the context of plans. A different tradition within AI, drawing from anthropology and ethnomethodology instead of cognitive science, has proposed a theory of situated action as complementary to the traditional planning approach (Suchman, 1987). The emphasis is not on mental processes but on social relations produced through the actions people take in the world. The integration of social and cognitive approaches has been proposed by understanding how meaning involves a social as well as a mental dimension (Winograd & Flores, 1986). These theories are compatible with *SAGE*'s notion of stories as social as well as cognitive artifacts.

In *SAGE*, a strong sense of context and a shared assumption about the socio-cultural role of the storyteller allow the user (a) to believe in the abilities of the system, despite minimal natural language understanding; and (b) to find coherence between his/her personal stories and the response stories retrieved by the system. This is achieved by enabling children to design storytellers with strong stereotypical characteristics and well-defined domains that set up certain behavioral expectations.

Learning by Designing

The educational philosophy of constructionism (Papert, 1980) asserts that learners are likely to have access to different kinds of new ideas when they are building artifacts that they can reflect upon and share with others in their learning community. In the light of this approach, *SAGE* focuses on the building of stories and *SAGE* storytellers as "evocative objects" (Turkle, 1984, 1995) that invite reflection about identity and communication.

Extensive work has been done within constructionism on creating tools to help children think in different ways about the sciences and mathematics (Harel & Papert, 1993). For example, educational software such as *Logo* supports direct manipulation and creation of computational artifacts as well as reflection about the programming process. *Starlogo* is an extension of *Logo* that allows parallel processing and invites children to create and reflect on decentralized systems (Resnick, 1994). Environments such as *Boxer* use the spatial metaphor of objects on a screen to encourage people to interpret the organization of the computational system in terms of spatial relationships (diSessa & Abelson, 1986).

All of these tools leverage children's understanding of the world in order to help them to learn how to program. Conversely, they also use children's understanding of programming in order to change their understanding of the world. However, little work has yet been done, within a constructionist approach, on designing technological tools that help children learn about themselves or narrative language (although see Bruckman, 1994; & Hooper, 1993).

Computational construction kits are tools that support children's design and construction of their own projects within some domain (Resnick, Bruckman, & Martin, 1996). *SAGE* is a construction kit that supports two types of connections required by constructionism to bootstrap learning:

- Personal connections: children can program their interactive embodied storytellers according to their interests; and
- Epistemological connections: *SAGE* encourages new ways of thinking about storytelling as a communicative activity, and the self.

SAGE provides an authoring environment and programming language where children can create their own interactive storytellers. When children design storytellers and describe the underlying turn-taking rules and body movements of the storyteller's toy assistant, they behave as communication and narrative theorists as well as programmers. In the process of creating their own simulated characters they become explicitly aware of the structure of the conversation; for example, in order to allow turn-taking between user and system, they must understand the nature of conversational units. Programming in this case is a vehicle for the transformation of ways of thinking about the self and communication as well as for constructing knowledge about technology.

Computationally Augmented Soft Toys for Storytelling

SAGE embeds the sage storyteller's assistant in a programmable interactive stuffed animal—a soft interface (Figure 1). The stuffed animal is capable of some of the types of nonverbal behaviors that humans use to indicate engagement and that are commonly found in conversational narratives between people (Cassell, 1995). In interaction mode, children can watch the stuffed animal move and blink its eyes to indicate attentiveness as they converse with it. In design mode, children can decide on the toy's communicative behaviors as well as the different personalities and conversational styles that it might demonstrate.

Figure 1. Interactive programmable stuffed rabbit and Handy Board (microcontroller) (copyright ©1998 by ACM)

Stuffed animals are objects whose emotional affordances can be exploited in building computational interfaces for children (Druin, 1987; Glos, 1997; Umaschi, 1997a). For example, Microsoft has developed an interactive toy called Barney. The toy communicates with the PC wirelessly, reacts to CD-ROM games, and watches television with the child (Alexander & Strommen, 1998). The psychologist Winnicott (1971) introduced the term "transitional object" to refer to the first "not-me" infant's possession—often a stuffed animal. The favorite toy, as described by Winnicott, "must seem to the infant to give warmth, or to move, or to have texture, or to do something that seems to show it has vitality or reality of its own" (p. 5).

Research on human-computer interaction has taken on challenge to unite the digital with the physical world so as to integrate the power of computing seamlessly into toys. This area is moving from graphical user interfaces (GUI) to tangible user interfaces (TUI)—from a mouse and keyboard to ubiquitous computing and tangible media (Ishii & Ullmer, 1997). An example in the domain of technology for children is *Dr. LegoHead* (Borovoy, 1996). In this system physical Lego blocks have been augmented with digital information, allowing children to build creatures out of high-level Lego brick parts such as eyes and mouths, thus exploring ideas about the nature of metaphor and function. Following this line and in order to support emotional engagement, *SAGE* offers the possibility to embed the wise storyteller's assistant into a programmable stuffed animal with basic motor functions.

SAGE takes the challenge of designing tangible user interfaces and leverages from the fact that children establish intimate communicative relationships with their stuffed toys (Dyl & Wapner, 1996). On one hand, the natural tendency to communicate at a deep level with soft objects can be leveraged by adding computational abilities so toys can give feedback. On the other hand, children can program the toy's communicative behaviors, thus exploring powerful ideas about the nature of communication. The result is computationally augmented soft toys for storytelling.

SAGE: DESIGN AND IMPLEMENTATION

SAGE was designed to support the creation of wise storytellers who have a comforting story at hand in response to the user's experiences. Children can engage with *SAGE* in two modes: (a) by interacting with a *SAGE* storyteller chosen from a library of already existing characters, and (b) by creating their own *SAGE*s and types of storytelling interactions.

The LISP-based *SAGE* architecture has three main components as shown in Figure 2. These modules are described at length in the following subsections:

- *SAGE* computation module: in charge of parsing the user's story, expanding keywords through WordNet, and performing a match between the user's personal story and a story in the database.
- *SAGE* authoring language: used by children to design their own interactive characters, the conversational flow between user and storyteller and the database of stories offered by the system in response to the user's story.

- *SAGE* interface: the interactive toy and its motor behaviors, computer screen and sound (output), and the keyboard (input).

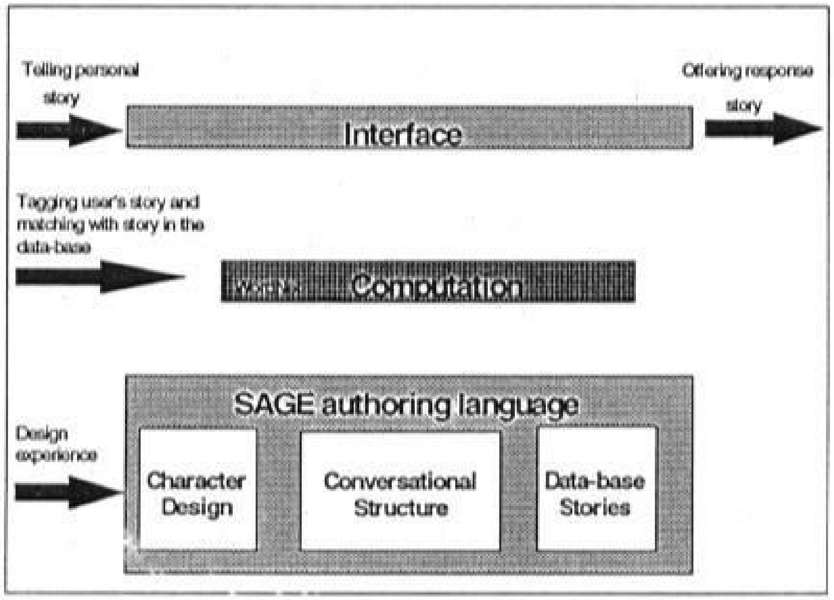

Figure 2. The three components of *SAGE*: interface, computation module, and authoring language

The Computation Module

The *SAGE* computation module is in charge of processing the user's story and retrieving a comforting story for the sage storyteller to give in reply. As represented in Figure 3, the process is as follows: The user's story is parsed. Nouns and verbs are extracted and submitted to WordNet, a hierarchical semantic lexical reference system in which nouns, verbs, and adjectives are organized into sets that represent concepts (Miller, Beckwith, Fellbaum, Gross, & Miller, 1993). WordNet returns a list of synonyms, hyponyms, and hypernyms of the original keywords. Different keywords that can be grouped under one single hypernym result in weighting that concept more highly than others. The final list of weighted nouns and verbs is a way of representing the user's story at a more abstract level. The weighted

nouns and verbs are matched against nouns and verbs indexing stories in the story database. The story that is most like the user's story—which deals with the same themes—is retrieved and told to the user. This computational module is not directly accessed by the user.

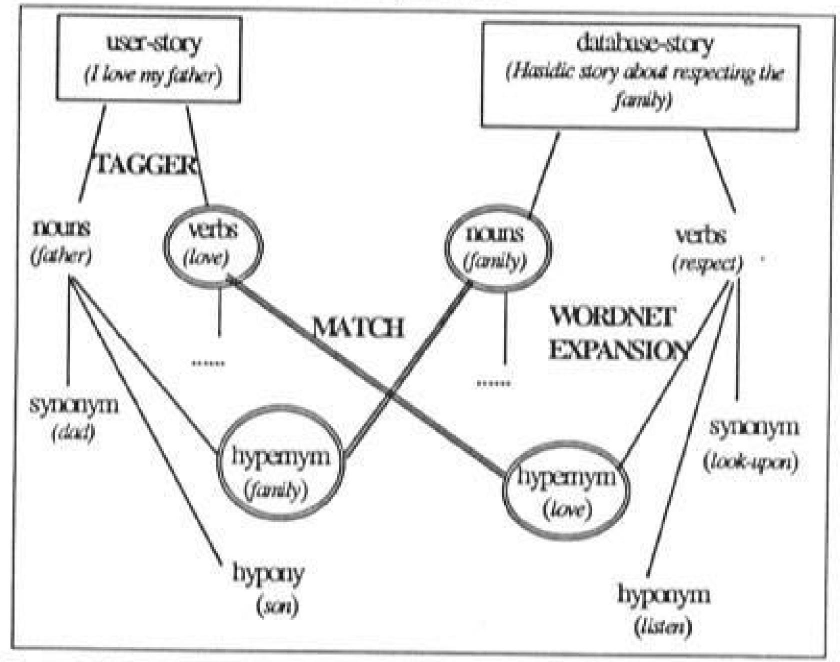

Figure 3. How the tagger, the WordNet expansions, and the matcher work

The Authoring Language Module

The *SAGE* authoring language has a graphical user interface that allows children both to design storytellers to interact with and also to model different types of storytelling situations. The environment supports children's creation of interactive storytellers by providing three design windows that can be chosen from a menu:

- Character's creation window: Children describe different facts about the lives of the sage storyteller and an optional storyteller's assistant—the interactive toy (Figure 4). These facts will determine how the storyteller (and assistant) interact with the user. This window is also used to load pictures of the storyteller who lives on the screen (scanned photos or sketches done in a drawing program).

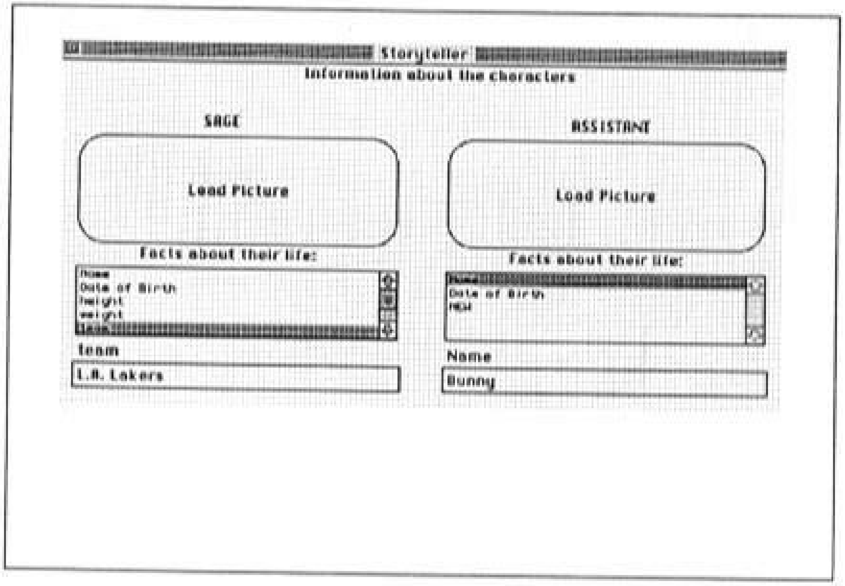

Figure 4. Window to design character's personality

- Conversational structure window: Children design the conversational flow between user and storyteller (or the storyteller's intermediary, the toy assistant) by selecting and arranging objects of three different types from a palette: turn-taking states, communicative actions, and parts of conversation. These objects are placed by the user in the conversational structure window in order to model the conversational storytelling interaction (Figure 5). Once these objects have been selected, the scripts that instantiate them can be written in the window that pops up when the object is double-clicked. In order to facilitate children's understanding of what these abstract conversational units mean, users always have the option of referring to—and/or copying/modifying—the conversational structure window of existent storytellers designed by previous users.

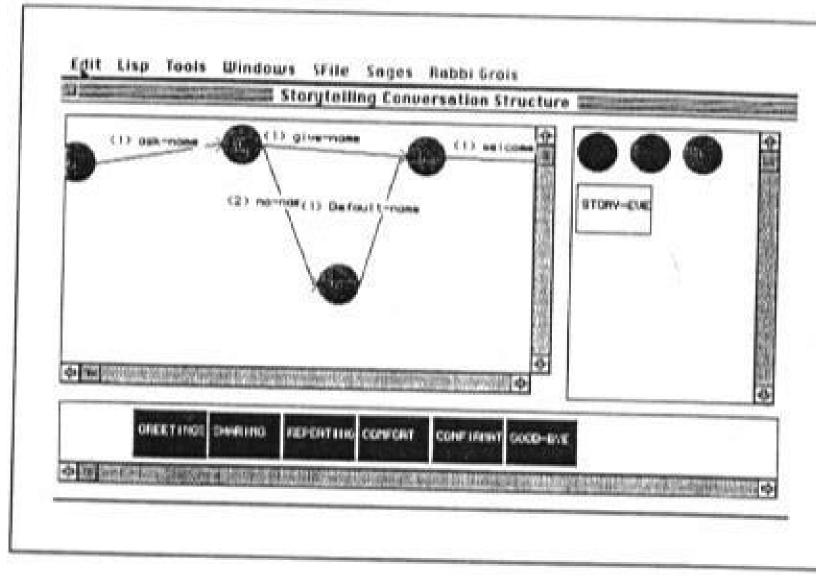

Figure 5. Objects manipulated to design the conversational flow. The screen is divided into three windows. On the right, the palette to select parts of conversation and turns: user (U), interactive toy assistant (A), and storyteller (S). On the left, the space to design the conversational flow and combine turns (circles) with communicative actions (arrows). On the lower end, the plot of parts of conversation.

- Database of stories: Users can write, record in their own voice, or scan in response stories—the comforting stories that will be offered by the sage. Children categorize or annotate the stories with story values and nouns and verbs that they consider good descriptors of the main story points (Figure 6). This information is used by the computational module to determine which response story best suits user's input story.

The *SAGE* authoring language has the following characteristics:

- Graphical user interface (GUI): This is a standard graphical representation for children to easily create, manipulate, and edit conversational flows by clicking and dragging objects such as story parts, turns, and communicative actions off a palette.

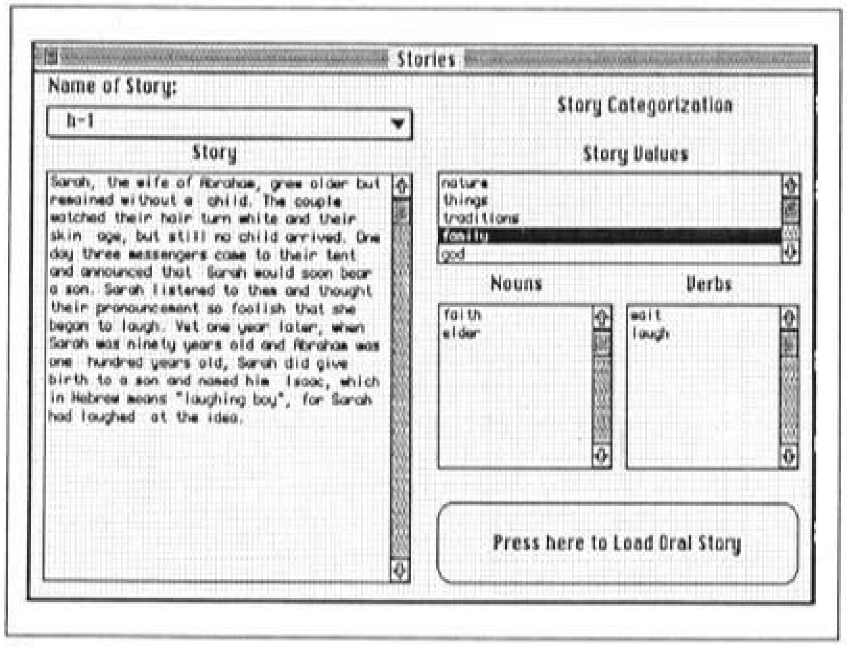

Figure 6. The database of stories and its descriptors

- Scaffolding: Novice users can quickly get started with their projects by using the supporting framework provided by *SAGE*. They can start by designing conversational flows that re-use already programmed variables to match user's input (such as age and name) and later, as they develop expertise with the software and the programming concepts, they can create their own variables. For example, one of the participants in the *SAGE* workshops, Pauline,[1] first learned how to use variables and then had her character add to the user-name the suffix "pa." She did that in order to give to Waloompa, her storyteller, a more alien-like personality. Even after becoming expert users, children were still challenged by developing complex narrative interactions. *SAGE* does not provide learner-adaptable scaffolding that changes automatically according to the user's needs. Instead, it has static mechanisms that can be utilized or ignored by the users.
- Availability of examples: Children can always look at other children's storytellers and re-use parts of their design by "cutting," "pasting," or modifying it. *SAGE* is an open environment in which code is always accessible by users. Everything is an example for others to use.

- Ease of use: The GUI allows children to create conversational flows in the same way that they engage in pretend role play games, by planning *who* is going to say *what*, and *when*, while arranging objects in the conversational structure window. For example Pauline, the author of Waloompa the alien, who worked out loud, used the turn-taking feature as follows: "First Waloompa says hi and asks user's name and then the user responds and then Waloompa asks the user how old he or she is, and the user responds and Waloompa says 'that is a nice age but how long does your species live?'..." This narration unfolded while Pauline placed the turns and communicational actions in the conversational structure window.
- Limited domain: The *SAGE* programming language only allows the user to create directed conversational storytelling situations. The nature of the conversational system is always machine-controlled (mixed-initiative is not readily an option), ensuring that the persona created is more likely to be believable and to interact successfully.

The Interface Module

The *SAGE* interface is the layer through which a user communicates with the system. The output device is composed of an interactive stuffed animal with programmable body behaviors and the computer screen with a graphical representation of a storyteller, his/her text balloon, and speech/sound output. The input device is the keyboard.

Since the technology is not yet available to create a stand-alone interactive toy (the main obstacle being the lack of adequate speech recognition systems for children's speech), we integrated the desktop computer with a physical toy. Output is multimodal, and input is typed text only. In order to explain the absence of symmetry in the interaction, in interaction mode the stuffed animal is presented as being the assistant of the sage storyteller that lives on the computer screen (Figure 7). This assistant character interacts with the user via synthesized speech. The assistant carries on the conversation and, at a certain point, calls on the sage storyteller to tell a traditional tale of wisdom. The body movements of the toy are very important to convey change of gaze. When the toy calls on the storyteller, it stops facing the child and turns to face the computer. The sage storyteller is presented as a character that lives in the computer. The storyteller is only in charge of telling the response stories from the database.

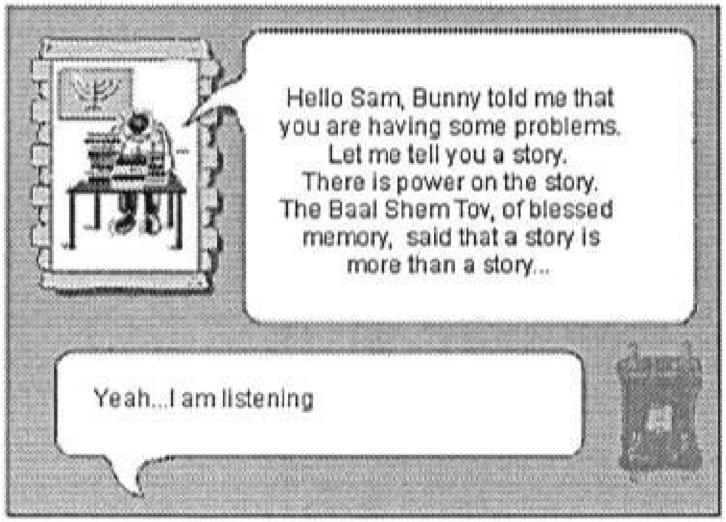

Figure 7. The sage storyteller, in this case a Hasidic Rabbi, lives in the screen and is in charge of telling the response stories

Children choose which sage storyteller they wish to interact with by placing different hats on the stuffed animal. The stuffed animal has a set of hats with small resistors whose unique value is read by the Handy Board (Martin, 1995). This microcontroller interfaces, via a serial connection, the physical stuffed animal with the *SAGE* software running on a Macintosh computer. It allows the system to know which character is loaded at any given moment, and it controls the movements of the interactive programmable stuffed animal.

INTERFACE USER STUDIES

A programmable stuffed animal was chosen as the interface for *SAGE* after conducting user studies to explore children's interface preferences. These studies tested three different conditions on 12 subjects between ages 10 and 13. Each of the subjects was tested with each of the three interfaces: a silent screen, a combined screen-toy, and an interactive toy. After interacting for approximately 30 minutes with the different interfaces with a storyteller that we had designed, they completed a questionnaire with a

Likert scale test. The questionnaire was intended to help the children express what interface they liked best and why. After completing the questionnaire, children were asked to orally share their overall experience in an extended personal interview. Conditions were counterbalanced. The following is a description of each of the conditions:

1. Silent screen: Children can input information only through the keyboard. The system responds through a silent, graphical cartoon-like representation of a storyteller on the screen.
2. Combined screen and toy: Children can input information only through the keyboard. The system responds with a text-to-speech synthesizer when the conversation happens with the storyteller's assistant (the interactive stuffed rabbit) and a recorded human voice when the cartoon-like character, the storyteller, offers a comforting story.
3. Interactive toy: There is no screen. The rabbit maintains the conversation and tells stories to the children. A hidden human "wizard"[2] simulates the speech recognition by typing what he/she hears into the system. The wizard also acknowledges the child's gaze and tactile information and accordingly controls the body movements of the rabbit.

Among a total of 12 children, 50% (6 children) preferred the combined interface, 33% the interactive stand-alone toy, and 17% the silent screen. This preference for the combined interface (Figure 8), as shown later, can be explained in terms of imperfection of speech synthesis and attractiveness of the toy. However, the number of tested subjects is too small to make generalizations.

Figure 8. The combined interface was preferred by children. A 10-year-old is interacting with the assistant of the storyteller rabbit. (copyright ©1997 by ACM)

The argument given by children who preferred the combined interface is well represented by Marie, a fifth grader:

> It is neat to use the computer and also hear the bunny talking and see him moving. If I didn't understand some of the words I could just look on the screen and read them. The rabbit was cute and it is better if it moves because it expresses itself a little more and sometimes it even makes it easier to understand.

Marie's statement suggests that technical problems, such as the bad quality of speech synthesis,[3] make the combined interface better than the stand-alone toy.

The presence of an interactive stuffed animal seems to foster children's engagement (Umaschi, 1997b). Results from the user studies testing children's interface preferences led us to the conclusion that in further research we would use the combined interface consisting of both the interactive toy, as the sage's assistant, and the computer screen.

EMPIRICAL RESEARCH

In the introduction we claimed that the *SAGE* storytelling system is an example of how technology can be used to encourage children to reflect on their inner life and to support their learning about narrative and communication. In this section we describe empirical research that supports these claims. We show that children's interactions with *SAGE* did indeed lead them to reflect on thoughts, feelings, and interpersonal communication, and also expanded their knowledge about personal storytelling as a communicative activity. In particular, we demonstrate that, by using *SAGE* in design mode, children's intuitive storytelling skills can be used to introduce them to the types of formalization that are required by computer programming. The following sections present the methodology used in the empirical research and then address these claims.

Description of Workshops

We conducted several pilot studies to examine children's interactions with the sage storytellers and their ability to build their own meaningful characters. Our earliest research showed that children were in fact quite ready to engage deeply with sages that we had designed (Umaschi, 1996). They opened up willingly to tell personal problems to the characters that we had designed, a Hasidic Rabbi and a Buddhist scholar. Before the studies were conducted we introduced the children to the counseling role of the sages. The nature of their engagement was no different whether they understood the workings of the implementation or believed that the computer system learned something deep about them. This result led us to believe that children would also be able to interact with sages of their own design. We envisioned that the iterative process of designing, interacting, and then improving the design of their own characters would result in an increased awareness of the nature of narrative communication and of computational systems.

In the study described here, we conducted research with fourth and fifth graders in order to test *SAGE*'s impact on storytelling awareness, self-reflection skills, and the interaction between these skills and technological fluency (Papert & Resnick, 1995). Children of this age are almost adult-like in their narrative productions (Karmiloff-Smith, 1985; Hickmann, 1987) but are still not capable of explicit meta-linguistic comments about the structure of narrative (Gombert, 1992). Likewise, American fifth graders are in general familiar with computer applications, but for the most part are not fluent programmers. The general claim here is that *SAGE* integrates programming and storytelling skills by supporting the design and modeling of abstract structures needed and used in both activities.

In order to understand children's design and creation of their own meaningful storytellers, we conducted two-day weekend workshops. Children were solicited for the workshops through local schools and personal connections. Children who participated in the workshops came from a range of backgrounds and were not particularly computer-competent. Individual extended interviews were carried out before and after the workshops to explore the children's ability to be self-reflective, their notions of storytelling, as well as their computer skills. Eight children (four boys and four girls) participated in the study reported here. Each workshop comprised one prestudy personal interview, two full days of design and programming, one poststudy personal interview, and one demonstration for parents given by the children. Each child worked on a separate computer to design and program a storyteller of his/her choice, and kept his/her own design notebook with ideas, problems, and so forth.

The methodology used for the study was based on an ethnographic approach, with natural observation of the children's interaction with the system as well as with each other, extended personal interviews, and an experimental task. (For a complete description of the methodology and the questionnaires used, please see the appendix in Umaschi [1997b].) In order to avoid "technocentric questions" (Papert, 1987), the methodology was centered on what children do with *SAGE* and not what *SAGE* does to children. The study included,

- the observation of children using *SAGE* in both the interacting and authoring modes;
- the observation of children's discussions with each other during the authoring process;
- the extended personal interviews. The interviews explored children's notions of identity and language use (in particular, turn-taking, parts of interaction, and sense of listener). They also explored children's theories of how human-computer dialogue systems work, in order to assess their technological fluency before and after the authoring process;
- an experimental task. Children were presented with pictures of people interacting with other people and with artifacts, and were asked to choose the picture showing the activity most similar to interacting with *SAGE*. This task was designed to reveal how children think about human-computer interaction. The same task was repeated in the post-study to explore differences and explicit references to *SAGE*;
- the analysis of system logs generated by interaction with storytellers;
- the analysis of children's personal designer notebooks. Children used their design notebooks to write and sketch ideas and problems before, during and after the authoring process; and
- post hoc analysis of videotaped workshops and interviews.

In the following sections we look at examples of sage storytellers created by children. Each example is a case study that illustrates a phenomenon also found more generally during the workshops.

The Presentation of the Self

When interacting with one of the sages that we had designed, children revealed aspects of their inner lives and the problems they face everyday. In building a sage, children designed that person to whom they wished they could turn with their problems. It is essential to note that the sages they designed were also aspects of the inner lives of the child designers. That is, since the children were creating their own characters and databases of stories, they were also playing with different notions of self and creating or imitating the narrative voices they wanted or needed to hear. One might claim that the children were simply imitating images of role models that they had perceived in their environment, but as Piaget (1962) wrote, "Imitation is always a continuation of understanding, but in the direction of differentiation with respect to new models." Children created storytellers as projections of fears, feelings, interests, and role models.

These projections allowed the presentation of the self to themselves as well as to others.

Out of a total of eight storytellers built during the workshops, three were based on humans or fictional media characters: Doug, a cartoon character; Tera Randof, based on a mixture of a real sports figure and family members of the author; and Shaquille O'Neil, a well-known basketball player. The other five characters were fictional, although two of them, Spot and the Big Orange Fox, clearly tell stories based on the authors' personal experiences.

Abi is a bilingual fourth grader whose parents come from Russia. When he grows up he wants to be a physicist because he likes computers, math, and science. Unlike all the other children who participated in the workshop, he said that he had never heard the word identity before, and after we explained its meaning he concluded: "It is what is inside me, like being Jewish and American and having my relatives in Russia."

During the workshop Abi created The Big Orange Fox that would explicitly ask the user if she or he has specific problems. If the user responded positively, The Big Orange Fox would tell an appropriate story indexed in the database under different types of problems. For example, below are two stories written by Abi and told by his character.

> There was a boy who was really rich who lived in the best house and got 3000 dollars per month for allowance but there was one thing he did not have and it was friends so he had a very bad life so one day he decided to live by himself getting his 3000 per month and living only a little better than normal people then he had a lot of friends but his friends did not understand how much money he wasted on necessary stuff so they thought he was spoiled and only played with him for money because he had to give 10 dollars per hour to whoever he played with and now he was sad because he had bad friends. (This story was indexed by Abi as a friendship problem.)

> There was once a boy who did not like his religion so he followed his family religion but when he was alone he secretly followed his religion but when his parents spotted him they cut off his finger and put him into a tiny dark box with spikes on all the sides but the bottom and left him there for 24 hours. (This story was indexed by Abi as a religion problem.)

Abi wrote 12 stories of this sort in his database. He is the child who created the most number of stories. This is extremely noteworthy considering that in the pre-interview Abi stated very clearly that he didn't like writing and he only liked to do it with a partner, not alone.

During the demonstration day, when Abi's parents came to play with The Big Orange Fox, they were surprised by the questions the character asked but even more by the stories it offered. While playing with other children's characters they noticed that Abi's was addressing in a direct way personal problems as well as telling stories, that although fictional, were obviously expressions of fears and feelings. During the post-interview, Abi said,

> First of all I learned how to put myself in another place and pretend I am someone else, and I learned how hard it is [...]. But really I talked to myself and I learned more about myself [...]. My stories are sad, but if you want to hear a funny story you can play with Waloompa the alien. When you have a problem it is sad and that is why my stories are sad. But my family didn't like my stories too much because of that, but they learned on what place I am now, and I am in the sad stories.

Abi used *SAGE* to create a fictional representation of himself, for himself, and for his parents. Through the creation of this character he was able to express feelings and fears that otherwise remained buried in everyday conversations. His parents also discovered, through The Big Orange Fox, a part of Abi's inner world.

In the same way that Abi used *SAGE* to play with his fears and feelings, Tracy, a 10-year-old girl with no previous programming experience, used it to represent herself in the future. During the workshops, Tracy created Tera Randof, a young female basketball player "who will become a sports figure" like the ones Tracy admires. In the post-interview, Tracy revealed that Tera's personality is a mixture of Tracy's mother and grandmother, and that the stories that Tera tells are Tracy's mother's childhood stories. Tracy created the character and the conversational structure and wrote all the stories in the database. By interacting with her own programmed storyteller over and over again, Tracy improved the program until it was able to respond to many different kinds of user's stories without crashing. In the process, Tracy also reflected on how people become good listeners. And, despite the fact that she was interacting with a storyteller of her own design, Tracy shared real personal problems and deeply engaged in reflection to make sense of the given advice. The following interaction between Tracy and her sage storyteller took place during the design process:

> SAGE: *I have a lot of problems like wondering if my team is going to win the big game or if I will mess it up for everyone. Please tell me a problem you have.*

> USER: I am sad because my parents told me that we can't take my dog on vacations with us, so I will miss him.

> SAGE: *Your problem reminded me of this story. Kerri is my best friend. Kerri knows everything about me and I know everything about her. Every Friday we sleep over each other [sic] houses. Switching houses each week. This week it was at my house. I got the usual snacks: popcorn, pizza, chips, soda, and candy. A few hours later Kerri came by with her sleeping bag. You could tell she was in a bad mood. I asked her to lighten up, and she snapped, "Fine." and left. I was stunned. What was her problem? I waited the few minutes that it took for her to walk home then called her. Her mom answered. I asked to talk to Kerri. Her mom said Kerri doesn't feel like talking to you right now. Kerri didn't talk to me in school for a month. Then I got the horrible news: my mom got a great job in L.A. so we were moving there! Kerri didn't even come over to say good-bye. I have never seen or talked to her since. Maybe she wasn't really my best friend. Did you like that story? Did you understand the moral of it? Please tell me what you think that story meant.*

> USER: You didn't see your friend ever again, but I will see my dog when we come back from vacation. I guess that is not that bad.

Tracy is only one of the many cases in which we observed, by analyzing the logs of the interactions, that a deep knowledge of how the system works doesn't affect emotional engagement and sharing of a personal problem. Both Abi's and Tracy's case studies show that *SAGE* was effectively used by children to explore identity, according to their personal needs at the time.

Opening the Black Box of the Design Process

Children who participated in the authoring experience learned how to open the "black box" of the *SAGE* software and the thinking skills needed in order to design their wise storytellers. They were able to understand the computational processes as well as to debug their programs and conversational structures. Tracy created a very coherent and developed personality for Tera Randof, thus making her into a believable character to maintain a conversation with. At the same time, Tracy's knowledge of how *SAGE* works allowed her to reflect on the nature of sharing problems in a deeper way and compare it with her intuitions about how people help one another:

> A person already knows how to react to a question, but the computer doesn't. You have to feed in information about what to say and that is like creating a mind and a personality [...]. When people communicate they take an experience they had or think of something that the other person might want to hear, a same sort of problem, something familiar or similar, and they just tell it.

Mischa created Mother Nature and designed a complex conversational structure that has two parallel branches, one for people who like to be in nature and one for people who do not. In the post-interview, reflecting on her authoring experience, Mischa said,

> The most fun part was working on the computer and programming kind of a game for people to use [...] it is a program for you to make another program. I liked creating what it might say and the questions and the structure and I learned that people can type anything and that you always have to be prepared because people might type not just "yes" or "no" but, for example "I guess so," so you have to use more branches.

Both Mischa's and Tracy's understanding of conversational storytelling bootstrapped their understanding of programming, leading them to realize that one has to be ready with an appropriate output for any input.

Communication and Computational Bugs

SAGE facilitates the exploration of notions of communication as children observe conversational breakdowns in their own and others' interactions with the created characters. The most frequently observed communication breakdown was due to children's difficulty in decentering and designing interactions in which other people, different from themselves, could participate. By decentering, we mean the ability to imagine a conversational interaction from the point of view of another interlocutor, that is, more generally, the moving out of the phase of egocentrism where one cannot differentiate somebody else's point of view from one's own.

During the post-interview, when children were asked to choose a picture most like the experience of building their own storytellers, Abi chose a picture with a boy pushing a huge rock.

> I pushed a rock and then I got better and I got used to do it so I could push a little further. The rock was the beginning of the Big Orange Fox

> and then it started to get easy for me. It is the first complicated program I ever made because you have to think about what the user is going to say, altogether. You start thinking that you are like a user and how would you like to use the program and then you do it. Thinking in the place of the user was hard and also not being nervous that it will have bugs that you have to fix.

The iterative design experience, which involved programming and immediate testing with a real audience—themselves, their parents, and other children—gave children the opportunity to decenter and debug their conversational structures after observing other people's interactions. Bernie's experience is a good example of the difficulty children had in decentering. Bernie built "Shaquille O'Neil" and brought to the workshop pictures of and books written by the famous basketball player. He adapted six of Shaquille's stories from a book and recorded them with his own voice. He indexed them by typing not just keywords but values, such as "Good things can happen if you wait" and "If you have a plan then things are better than they seem."

At the time, Bernie was taking programming classes with *Logo* in an after-school program. This knowledge allowed him to understand faster than other children concepts such as variables and branching. He was able to quickly create a basic conversational structure. However, the first time he tried to run "Shaquille," he discovered that it didn't work as he expected. The problem was that Bernie had not created any pattern to match and recognize users' inputs.

While debugging, Bernie found the problem and he created the missing input matching structures and copied the most complex ones, such as digit matching for recognizing the user's age, from another *SAGE* character. Confident that the problem was a computational one, and that he had resolved it, Bernie called over one of the adults to show off his new working version. In effect, when Bernie interacted with "Shaq," the new version of the program responded well. However, when the adult tried it, the first thing that happened was that Shaq called her "Bernie," although when the system asked her name she had responded, "Marina." Bernie realized that he had hard-coded his name in all the system responses. The problem was not a computational bug, which he had earlier resolved, but a communication bug. Bernie had not decentered, that is, he had not created an experience for users different from himself.

A week later, when his parents came for a demonstration, Bernie had already fixed "the name problem," as he called it. However, when Shaq asked Bernie's dad, "I guess you are around 11, am I right?" and the response was, "No, I am 45," Shaq crashed. This time Bernie saw the problem immediately. He hadn't provided a branching node to allow the possibility of a "no." He quickly went back to the authoring mode and added the branching to the conversational structure.

Bernie's experience was common to most of the children, who observed similar problems when their parents interacted with their characters. In general, the conversational structures designed were very linear, without branches to take into account different kinds of user input. Only after observing others' interactions with their sages did the children realize that they had to contemplate the possibility of responses other than their own. This discovery was facilitated by the iterative design process, meaning the loop of working on the computer and immediately debugging or trying results in the real world in an iterative process. Iterative design implies a reality check with real users.

The power of iterative design is that it not only occurs while children are in front of the computer, but it also extends into their everyday communicational experiences. For example, Pauline, the author of Waloompa the alien, had the habit of never saying "good-bye" to the person who was videotaping the workshops, although she knew him and engaged in many conversations with him. When this was pointed out to Pauline, she responded: "You know what? Waloompa doesn't say 'bye' either ? And 'bye' is like "good-bye;' I should include it in the macros of my program." At the next meeting she created a new storytelling part called "bye" with two turns: one in which the alien says "good-bye" to the user and another in which the user can respond farewell to the character.

To create a representation or model of the structure of a conversation is not an easy task. With *SAGE*, it involves working with different levels of abstraction, such as what is actually said (scripts), when it is said (turn-taking), and why it is said (part of conversation). The part of conversation is the highest level of abstraction as it requires thinking about the goal of a particular chunk of an interaction that might include several turns. Parts of conversation implemented by children included introducing oneself, asking for personal information about the user, comforting, and so forth. Most of the children who participated in the workshop had trouble understanding the idea of conversational part, or meta-level structure. Among other research on metalinguistic ability (Hickmann, 1987; Gombert, 1992), the current suggests that switching between levels of abstractions is hard for children in storytelling as it is in learning how to program.

Struggling With Knowledge Representation

While creating storytelling structures and turn-taking machines, children explored concepts such as branching and abstract structures; while indexing the stories in the database they learned about the notion of knowledge representation. Abi's experience is one of the most noteworthy in this sense. Most of the children decided to index their stories either with keywords or with morals. However, Abi chose categories that he called "problems." After some hard work he came up with the following categories: "religion problems," "school problems," "learning problems," "relative problems," "subject problems," and "teasing problems." Abi's sage, the Big Orange Fox, asks, one by one, about each of the problems in the following way: "Do you have any religion problem?", "Do you have any learning problem?", and so on. Abi's idea was to have the Big Orange Fox tell a story relevant to the problem to which the user responded "yes."

In the first debugging session, when Seth was interacting with the fox, Abi found a major problem in his knowledge representation structure. Seth had teasing problems but also school problems. Abi realized that some of his categories were "inside the others." For example, teasing happened in school, as did learning problems and subject problems. He was very proud of his category-based story indexing and he wanted to keep it. After a lot of thought, Abi found an interesting solution to this meta-representation problem. After interviewing the user about all of the possible problems, the Big Orange Fox asks, "Take all the problems you said yes to, out of the ones I asked you. And please put them into the category you have most problems with. Do only one category." From the point of view of the user and the interaction, the question posed by the character is very confusing. However, for Abi it was a good solution, one that allowed him to start thinking about powerful computational ideas such as "knowledge representation" and powerful communication ideas such as meta-problems.

To create conversational structures and to categorize stories obliges children to reflect and work with levels of representation and abstractions. It introduces children to thinking in a different and more abstract way, all the while depending on concepts they are familiar with, such as who says what to whom and when. The kind of experience that *SAGE*'s authoring mode supports is a gateway to the world of abstraction, preplanning, and structured thinking, skills that are used in the hard sciences and programming as well as in storytelling.

CONCLUSIONS

In this paper we discussed the importance of technological tools specifically designed to encourage children's exploration of identity and communication. We proposed personal storytelling as a way to access the inner world as well as to explore notions of communication. Constructionism informed the philosophy of our work.

We presented the design and implementation of such a technological tool: *SAGE*, an authoring environment for creating embodied interactive storytellers with whom one can converse. We described children's interactions with the *SAGE* tool, concentrating on case studies.

The themes that emerged from the analysis of learning experiences form the central contributions of this research:

- The continuum between the interacting and the authoring mode in *SAGE*: From the self-reflection perspective, both experiences were successful. However, the authoring mode seemed to support deeper explorations of identity and communication as well as a bigger sense of empowerment and control over the learning experience.
- The creation of storytellers as projections of fears, feelings, interests, and role models: These projections allow the presentation of the self to ourselves as well as to others.
- The exploration of notions of communication while observing breakdowns: The iterative design experience supported this type of exploration by providing children with the opportunity to decenter and debug their system's conversational structures after observing other people's interactions with them.
- The use of children's knowledge about storytelling to leverage their technological fluency: Through the process of building their own storytellers, children developed modeling skills, abstract and structured thinking that are fundamental requirements for storytelling as well as for programming.

This work provides a conceptual and technological framework for designing and implementing tools for reflecting on the inner world as well as exploring communication issues. Both activities can also be done without technology, through mentoring with a good counselor or teacher. However, the use of computers enables a different exploratory depth as well as supports children's experiential learning while they are modeling and designing abstract, conversational storytelling structures. The endeavor is just beginning, and further research must be done in order to explore in depth each of the themes that has emerged from this work.

For the moment we have examined the interaction between technological and storytelling fluency across single-weekend workshops. In the future we hope to look at the effects of interaction with *SAGE* over a longer period of time. We have also begun to look at other types of functions that interaction with a sage storyteller can sustain. Some children are particularly in need of telling the stories of their lives—for example those children whose stories are complex and emotionally wrenching, such as chronically ill children (Bers et al., 1998).

SAGE also has the characteristics of a gender-neutral technology which should support girls to become familiar with the world of technology and boys to become more comfortable with storytelling. However, gender-based empirical research needs to be done in order to test this hypothesis. An appropriate methodology should be defined to conduct gender-based studies.

However, for all children the importance of technological and storytelling fluency should be clear. We live surrounded by stories and by technology, sometimes in combination. We live among stories that we tell and stories that we listen to. Some stories emerge from everyday experience, others are provided by the media, with putative entertainment and information goals. We don't always need to understand the structure of a story to enjoy it; however, we do need to be able to recognize something about the structure in order to become critical readers of our reality.

Our hope is that by supporting children's creation of their own storytelling structures, children will become more aware of the metacommunication cues that signal the goals or agenda with which certain stories are told or written. We also live among technology, and, increasingly, technological fluency is demanded of us in all aspects of our daily lives. Our hope is that by supporting children's creation of a technology to their own specifications, children will become more educated consumers and creators, and there will be fewer adults scared of what technology represents. We believe that technological tools for reflecting on the inner world do not only improve children's sense of themselves, but that children's sense of themselves will improve the technology around us.

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Notes

1. Names of children and other identifying details have been changed.
2. A "Wizard of Oz" experiment is a simulation technique used to develop and test dialogue models prior to implementation. In each session, a human "wizard" simulates the interaction strictly following an algorithm.
3. Macintalk was the speech synthesis used.

Author Notes

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Interactive Storytelling Systems for Children: Using Technology to Explore Language and Identity

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More and more often there is embarrassment all around when the wish to hear a story is expressed. It is as if something that seemed inalienable to us, the securest among our possessions, were taken from us: the ability to exchange experiences.

The Storyteller, Walter Benjamin

Storytelling is a good medium for learning about identity and communication as it enables exploration of one's inner world and requires flexing one's language skills. This paper presents a new approach to interactive storytelling: *SAGE* (*Storytelling Agent Generation Environment*), an authoring environment for children to create their own wise storytellers to interact with by telling and listening to stories. In order to encourage children's emotional engagement in the *SAGE* environment, the storytellers are embodied in an interactive stuffed animal, also programmable by the children.

This paper presents technical aspects of *SAGE*'s design and implementation as well as results from pilot studies done with fourth and fifth graders. Results show that children had a tendency to share their personal stories with the soft interactive interface. Exploration of identity and communication happened in several ways: First, storytellers built by the children were projections of their fears, feelings, interests, and role models; they allowed them to explore their own identity

> as well as present themselves to others. Second, through designing and testing the conversational structures of their storytelling characters, children observed and repaired breakdowns in conversational interaction. This process engaged them in the exploration of communication and decentering, or taking the point of view of others.

In everyday life, conversational personal storytelling is a communicative experience in which story listening is as important as storytelling in order to construct a sense of identity. New technologies have the potential to encourage people to share their personal stories; however, there is a lack of computational environments explicitly designed to encourage exploration of identity. *SAGE* (*Storytelling Agent Generation Environment*) was designed with this explicit goal and uses storytelling to achieve its purpose.

Stories are one of the primary ways in which the self is presented to others and to us. When people communicate they often do it through telling stories about their experiences and by finding personal relevance in other people's stories. *SAGE* encourages, enables, and enhances this type of storytelling, as well as provides a framework for children to design and program their own interactive storytellers. The latter supports changes in the way children think about themselves and about storytelling as a communicative activity.

Thus, *SAGE* supports two modes of interaction. In the first—storytelling interaction—children are invited to share what is going on in their lives with an old sage, who "listens" and then offers a relevant traditional tale in response. In the second—storyteller authoring interaction—children are invited to add to the library of old sages by designing their own storyteller for themselves and other children to interact with. In order to support children as designers as well as users of the storytellers, we implemented a visual authoring language that allows children to program (a) the scripts that are told by the storyteller, (b) the conversational structure, or flow of the interaction between user and storyteller, (c) the body behaviors of the interactive stuffed animal—the storyteller's assistant, and (d) the database of stories that are offered as the storyteller's response.

In this paper we situate our work within a transdisciplinary theoretical background. Then we describe *SAGE*'s design and technical implementation. Next, we share results from empirical studies conducted with fourth and fifth graders using the system. Finally we present conclusions.

CONTEXT OF THE WORK

Although little research has been done on how technology can be used to encourage children to learn about identity and communication through storytelling, a fair amount of research exists in relevant fields that have an impact upon these issues. In what follows we present a theoretical framework, drawing from research in diverse areas such as narrative theory, psychology, artificial intelligence, education, and human-computer interaction. We are aware that a complete survey of these research areas is impossible, therefore we chose to focus on the particular aspects that guided our system design.

Telling and Listening to Stories

Narrative is the primary form through which we understand and give meaning to our experience (Polkinghorne, 1988). Our research focuses on a particular kind of narrative—conversational stories of personal experience—defined by Polanyi (1989) as highly structured linguistic productions found in the context of everyday talk, and by Miller, Potts, Fung, Hoogstra, and Mintz (1990) as face-to-face interactions in which self-expression is accomplished by the recounting of personal experience.

Narrative, including conversational stories of personal experience, serves at least three vital functions. These three functions of narrative were carefully analyzed in order to design the *SAGE* system.

1. Cognitive function: Personal stories are fundamental constituents of human memory, and new experiences are interpreted in terms of old stories and generalized story scripts (Bartlett, 1932; Schank & Abelson, 1995). Bruner (1986) describes narrative as a mode of cognitive functioning that provides a distinctive way of ordering and understanding experience.
2. Social function: The tales that one knows and can tell define the social group or culture to which one belongs (Turner, 1980). Myths, legends, and traditional tales provide a sense of continuity between generations as well as models for human behavior (Campbell, 1988). Conversational personal stories play an important role in the social construction of the self from early childhood (Miller et al., 1990). Adults tell and retell life stories according to certain conventions and in many different contexts as a way of establishing coherence in their lives (Linde, 1993).

3. Emotional function: Storytelling has been used in very different forms of psychotherapy (Wigren, 1994). In fact, one view of psychotherapy is that it leads us to be able to tell coherent life stories (Polkinghorne, 1988). The emotional value of tales has been explored by Erickson in hypnotherapy (Rosen, 1982) and in fairy tales by Bettelheim (1976). As Freud (1965), Erikson (1950), and others have shown, through the verbal-play experience of storytelling, children can find not only recreation but also self-cure.

From cognitive, social, and emotional standpoints, it is important for children and adults to have a place to tell their story. But it is also important to provide a space for them to explore what is narrative and how conversational storytelling works. *SAGE* was conceived to support both storytelling and story making. While storytelling helps children to "play out" what is happening in their lives, story making supports learning about narrative by interacting with and designing meaningful storytellers.

For example, in interaction mode, by playing the role of a wise, old person listening and responding to children's stories, *SAGE* explicitly encourages children to tell their personal stories. It enables them to explore their inner life, developing a better sense of who they are and a set of values for constructing their role in the world. In authoring mode, *SAGE* supports children in designing and programming their own meaningful storytellers. Taken together, these two modes allow users to construct and express their narrative voice (Cassell, in press) as well as their identity.

Storytelling Systems: Beyond Story Writing

To date, most of the research on computers and storytelling has focused on interactive games, mystery simulations, and interactive fiction (although see Don, 1990; Laurel, 1993). Interactive games and mystery simulations present a plot by way of short descriptions of characters and places, and they allow users to navigate through the spaces and find out more about the characters. Unlike narratives about the self, these are "forms of narrative that privilege space over characterization or plot development. [They are] part of an alternative tradition of 'spatial stories,' a different way of organizing narratives that must be examined and evaluated according to their own cultural logic" (Fuller & Jenkins, 1995).

Interactive fiction presents a short story or novel in a hypertext format, the branching nodes allowing users to read a different story each time by

choosing different links. Unlike personal narratives, this work concentrates on how to adapt the genre of fiction to the constraints and possibilities of the computer. Other work has used computation to assist production and viewing of narrative structure models for cinema. For example, "Agent Stories" (Brooks, 1996) is an environment for non-linear, cinematic story design and presentation that can be used by cinematic story writers.

In the entertainment domain, the design of storytelling systems for children has focused on interactive games and fiction of the type described above. In the educational domain, work has been done on supporting children's story writing process. Commercial software such as *Kid Works Deluxe* (Davidson & Associates, 1995) and the *Amazing Writing Machine* (Brøderbund, 1994) are augmented word processors that encourage children to tell stories by giving them a choice of first sentences, a set of characters as inspiration, and sample illustrations for their stories. Educational researchers have also devoted extensive effort in developing story writing software. For example, *TOPOI* (Burns, 1984) was originally designed to aid college essay writers in brainstorming and planning, while *Catch* (Daiute, 1985) was developed at Harvard University to improve young users' story-writing skills. At the MIT Media Laboratory, Montford (1998) designed *EddieEdit*, a conversational computer character to aid children in the process of writing stories, with special focus in planning and revision.

By contrast, the research presented in this paper is not aimed at improving story writing, rather *SAGE* seeks to support children's authoring of their own wise storytellers and story listeners through the design of an interactive character. The authoring process involves the design and implementation of conversational interactions between the user and the wise storyteller. This serves as a vehicle for the transformation of ways of thinking about narrative as a communication process deeply involved in identity construction.

SAGE employs the notion of a simple conversational system with a well-defined character, similar to Eliza (Weizenbaum, 1976), Parry (Colby, 1975), and Julia (Mauldin, 1994). These are described by Murray (1991) as parodic interactive character whose computational rigidities model recognizably human types. *SAGE* extends the domain to the world of narrative and allows storyteller construction as well as interaction. It has been suggested that the construction of emotionally believable characters with a limited field of interaction can maintain the suspension of disbelief of the user and thus allow successful human-computer interaction in the absence of deep artificial intelligence (AI) (Bates, Maes, & Hayes-Roth, 1995). This alternative to the deep AI approach focuses on believability over ability.

By ability we refer to the vision that computers should try to re-create the cognitive processes that people use to understand stories—as a step towards machine understanding with broad applicability. For example, there is extensive research on producing models of the world that contain particular knowledge organized around standard situations, scripts, or cases (Schank & Riesbeck, 1981). This story understanding research depends on a theory of narrative as primarily constituted by goals and actions in the context of plans. A different tradition within AI, drawing from anthropology and ethnomethodology instead of cognitive science, has proposed a theory of situated action as complementary to the traditional planning approach (Suchman, 1987). The emphasis is not on mental processes but on social relations produced through the actions people take in the world. The integration of social and cognitive approaches has been proposed by understanding how meaning involves a social as well as a mental dimension (Winograd & Flores, 1986). These theories are compatible with *SAGE*'s notion of stories as social as well as cognitive artifacts.

In *SAGE*, a strong sense of context and a shared assumption about the socio-cultural role of the storyteller allow the user (a) to believe in the abilities of the system, despite minimal natural language understanding; and (b) to find coherence between his/her personal stories and the response stories retrieved by the system. This is achieved by enabling children to design storytellers with strong stereotypical characteristics and well-defined domains that set up certain behavioral expectations.

Learning by Designing

The educational philosophy of constructionism (Papert, 1980) asserts that learners are likely to have access to different kinds of new ideas when they are building artifacts that they can reflect upon and share with others in their learning community. In the light of this approach, *SAGE* focuses on the building of stories and *SAGE* storytellers as "evocative objects" (Turkle, 1984, 1995) that invite reflection about identity and communication.

Extensive work has been done within constructionism on creating tools to help children think in different ways about the sciences and mathematics (Harel & Papert, 1993). For example, educational software such as *Logo* supports direct manipulation and creation of computational artifacts as well as reflection about the programming process. *Starlogo* is an extension of *Logo* that allows parallel processing and invites children to create and reflect on decentralized systems (Resnick, 1994). Environments such as *Boxer* use the spatial metaphor of objects on a screen to encourage people to interpret the organization of the computational system in terms of spatial relationships (diSessa & Abelson, 1986).

All of these tools leverage children's understanding of the world in order to help them to learn how to program. Conversely, they also use children's understanding of programming in order to change their understanding of the world. However, little work has yet been done, within a constructionist approach, on designing technological tools that help children learn about themselves or narrative language (although see Bruckman, 1994; & Hooper, 1993).

Computational construction kits are tools that support children's design and construction of their own projects within some domain (Resnick, Bruckman, & Martin, 1996). *SAGE* is a construction kit that supports two types of connections required by constructionism to bootstrap learning:

- Personal connections: children can program their interactive embodied storytellers according to their interests; and
- Epistemological connections: *SAGE* encourages new ways of thinking about storytelling as a communicative activity, and the self.

SAGE provides an authoring environment and programming language where children can create their own interactive storytellers. When children design storytellers and describe the underlying turn-taking rules and body movements of the storyteller's toy assistant, they behave as communication and narrative theorists as well as programmers. In the process of creating their own simulated characters they become explicitly aware of the structure of the conversation; for example, in order to allow turn-taking between user and system, they must understand the nature of conversational units. Programming in this case is a vehicle for the transformation of ways of thinking about the self and communication as well as for constructing knowledge about technology.

Computationally Augmented Soft Toys for Storytelling

SAGE embeds the sage storyteller's assistant in a programmable interactive stuffed animal—a soft interface (Figure 1). The stuffed animal is capable of some of the types of nonverbal behaviors that humans use to indicate engagement and that are commonly found in conversational narratives between people (Cassell, 1995). In interaction mode, children can watch the stuffed animal move and blink its eyes to indicate attentiveness as they converse with it. In design mode, children can decide on the toy's communicative behaviors as well as the different personalities and conversational styles that it might demonstrate.

Figure 1. Interactive programmable stuffed rabbit and Handy Board (microcontroller) (copyright ©1998 by ACM)

Stuffed animals are objects whose emotional affordances can be exploited in building computational interfaces for children (Druin, 1987; Glos, 1997; Umaschi, 1997a). For example, Microsoft has developed an interactive toy called Barney. The toy communicates with the PC wirelessly, reacts to CD-ROM games, and watches television with the child (Alexander & Strommen, 1998). The psychologist Winnicott (1971) introduced the term "transitional object" to refer to the first "not-me" infant's possession—often a stuffed animal. The favorite toy, as described by Winnicott, "must seem to the infant to give warmth, or to move, or to have texture, or to do something that seems to show it has vitality or reality of its own" (p. 5).

Research on human-computer interaction has taken on challenge to unite the digital with the physical world so as to integrate the power of computing seamlessly into toys. This area is moving from graphical user interfaces (GUI) to tangible user interfaces (TUI)—from a mouse and keyboard to ubiquitous computing and tangible media (Ishii & Ullmer, 1997). An example in the domain of technology for children is *Dr. LegoHead* (Borovoy, 1996). In this system physical Lego blocks have been augmented with digital information, allowing children to build creatures out of high-level Lego brick parts such as eyes and mouths, thus exploring ideas about the nature of metaphor and function. Following this line and in order to support emotional engagement, *SAGE* offers the possibility to embed the wise storyteller's assistant into a programmable stuffed animal with basic motor functions.

SAGE takes the challenge of designing tangible user interfaces and leverages from the fact that children establish intimate communicative relationships with their stuffed toys (Dyl & Wapner, 1996). On one hand, the natural tendency to communicate at a deep level with soft objects can be leveraged by adding computational abilities so toys can give feedback. On the other hand, children can program the toy's communicative behaviors, thus exploring powerful ideas about the nature of communication. The result is computationally augmented soft toys for storytelling.

SAGE: DESIGN AND IMPLEMENTATION

SAGE was designed to support the creation of wise storytellers who have a comforting story at hand in response to the user's experiences. Children can engage with *SAGE* in two modes: (a) by interacting with a *SAGE* storyteller chosen from a library of already existing characters, and (b) by creating their own *SAGE*s and types of storytelling interactions.

The LISP-based *SAGE* architecture has three main components as shown in Figure 2. These modules are described at length in the following subsections:

- *SAGE* computation module: in charge of parsing the user's story, expanding keywords through WordNet, and performing a match between the user's personal story and a story in the database.
- *SAGE* authoring language: used by children to design their own interactive characters, the conversational flow between user and storyteller and the database of stories offered by the system in response to the user's story.

- *SAGE* interface: the interactive toy and its motor behaviors, computer screen and sound (output), and the keyboard (input).

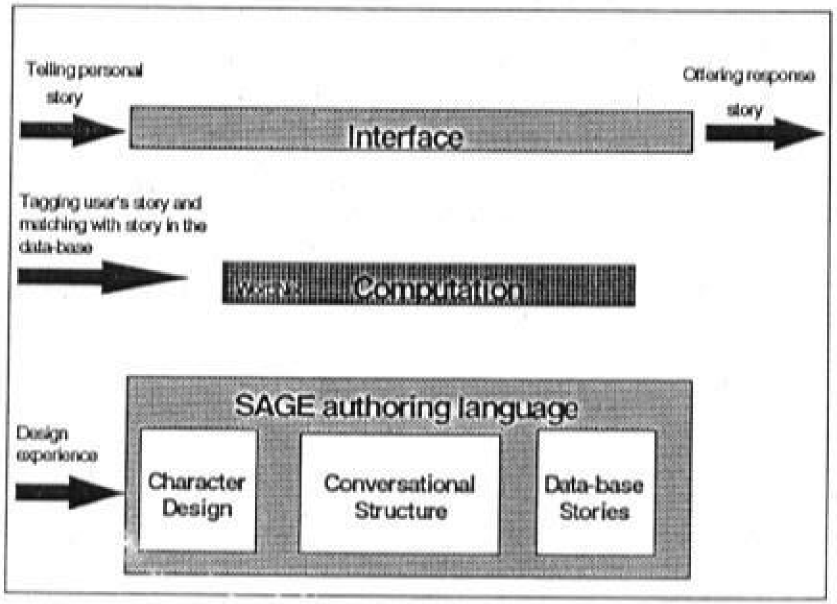

Figure 2. The three components of *SAGE*: interface, computation module, and authoring language

The Computation Module

The *SAGE* computation module is in charge of processing the user's story and retrieving a comforting story for the sage storyteller to give in reply. As represented in Figure 3, the process is as follows: The user's story is parsed. Nouns and verbs are extracted and submitted to WordNet, a hierarchical semantic lexical reference system in which nouns, verbs, and adjectives are organized into sets that represent concepts (Miller, Beckwith, Fellbaum, Gross, & Miller, 1993). WordNet returns a list of synonyms, hyponyms, and hypernyms of the original keywords. Different keywords that can be grouped under one single hypernym result in weighting that concept more highly than others. The final list of weighted nouns and verbs is a way of representing the user's story at a more abstract level. The weighted

nouns and verbs are matched against nouns and verbs indexing stories in the story database. The story that is most like the user's story—which deals with the same themes—is retrieved and told to the user. This computational module is not directly accessed by the user.

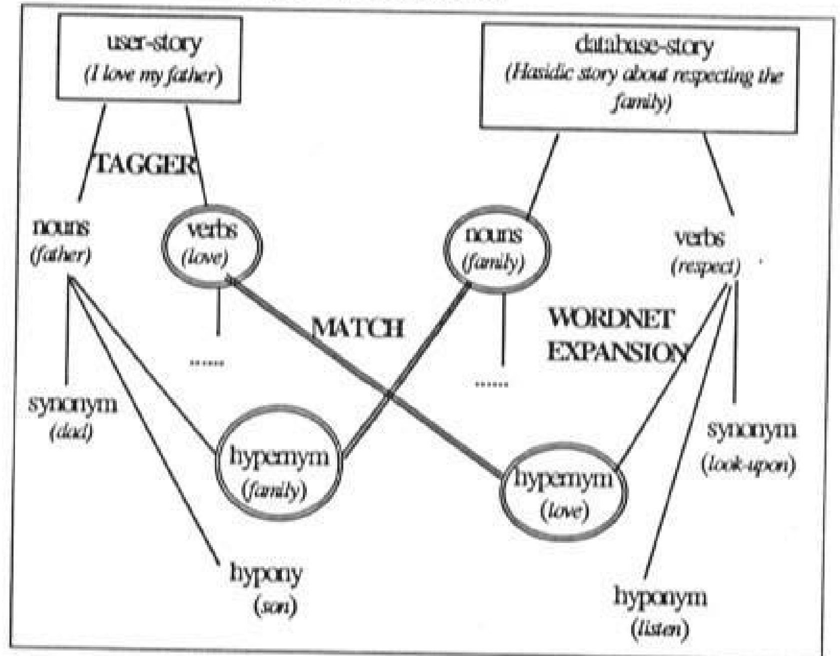

Figure 3. How the tagger, the WordNet expansions, and the matcher work

The Authoring Language Module

The *SAGE* authoring language has a graphical user interface that allows children both to design storytellers to interact with and also to model different types of storytelling situations. The environment supports children's creation of interactive storytellers by providing three design windows that can be chosen from a menu:

- Character's creation window: Children describe different facts about the lives of the sage storyteller and an optional storyteller's assistant—the interactive toy (Figure 4). These facts will determine how the storyteller (and assistant) interact with the user. This window is also used to load pictures of the storyteller who lives on the screen (scanned photos or sketches done in a drawing program).

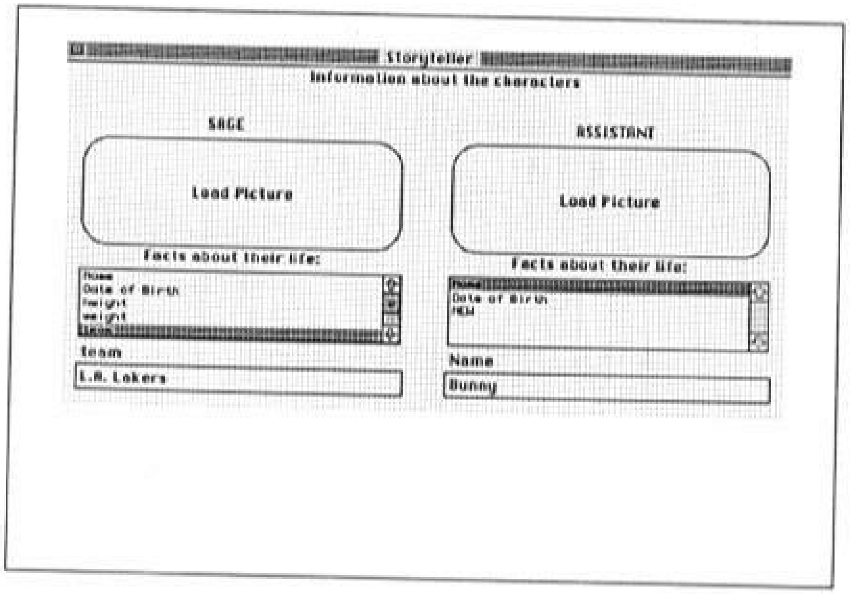

Figure 4. Window to design character's personality

- Conversational structure window: Children design the conversational flow between user and storyteller (or the storyteller's intermediary, the toy assistant) by selecting and arranging objects of three different types from a palette: turn-taking states, communicative actions, and parts of conversation. These objects are placed by the user in the conversational structure window in order to model the conversational storytelling interaction (Figure 5). Once these objects have been selected, the scripts that instantiate them can be written in the window that pops up when the object is double-clicked. In order to facilitate children's understanding of what these abstract conversational units mean, users always have the option of referring to—and/or copying/modifying—the conversational structure window of existent storytellers designed by previous users.

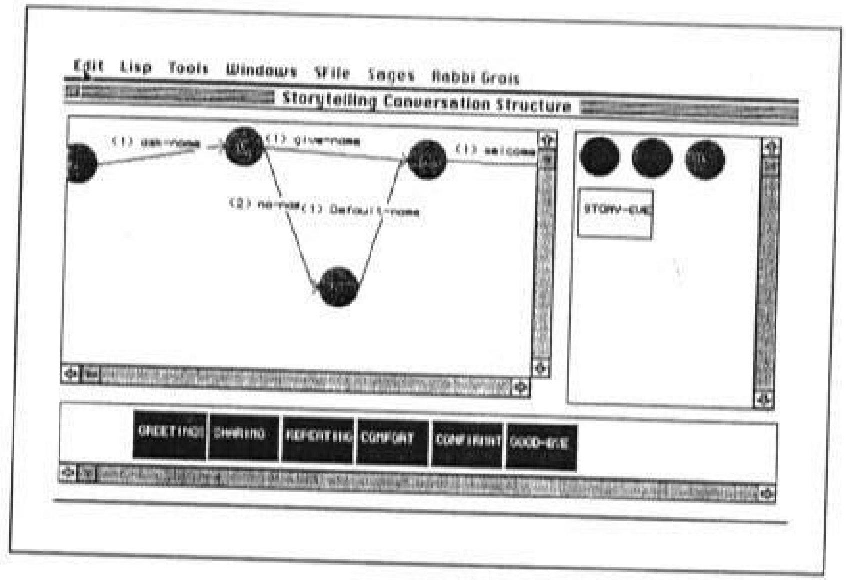

Figure 5. Objects manipulated to design the conversational flow. The screen is divided into three windows. On the right, the palette to select parts of conversation and turns: user (U), interactive toy assistant (A), and storyteller (S). On the left, the space to design the conversational flow and combine turns (circles) with communicative actions (arrows). On the lower end, the plot of parts of conversation.

- Database of stories: Users can write, record in their own voice, or scan in response stories—the comforting stories that will be offered by the sage. Children categorize or annotate the stories with story values and nouns and verbs that they consider good descriptors of the main story points (Figure 6). This information is used by the computational module to determine which response story best suits user's input story.

The *SAGE* authoring language has the following characteristics:

- Graphical user interface (GUI): This is a standard graphical representation for children to easily create, manipulate, and edit conversational flows by clicking and dragging objects such as story parts, turns, and communicative actions off a palette.

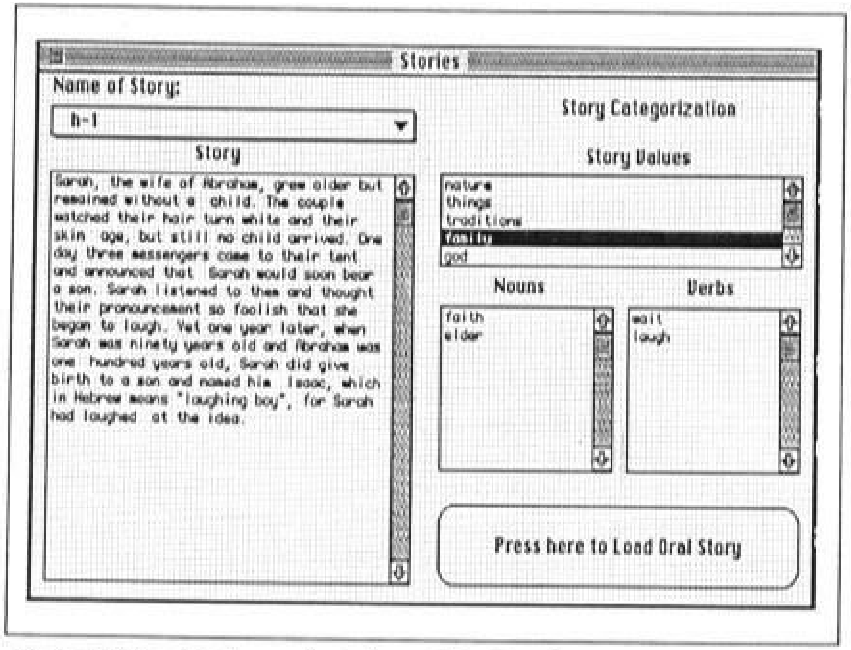

Figure 6. The database of stories and its descriptors

- Scaffolding: Novice users can quickly get started with their projects by using the supporting framework provided by *SAGE*. They can start by designing conversational flows that re-use already programmed variables to match user's input (such as age and name) and later, as they develop expertise with the software and the programming concepts, they can create their own variables. For example, one of the participants in the *SAGE* workshops, Pauline,[1] first learned how to use variables and then had her character add to the user-name the suffix "pa." She did that in order to give to Waloompa, her storyteller, a more alien-like personality. Even after becoming expert users, children were still challenged by developing complex narrative interactions. *SAGE* does not provide learner-adaptable scaffolding that changes automatically according to the user's needs. Instead, it has static mechanisms that can be utilized or ignored by the users.
- Availability of examples: Children can always look at other children's storytellers and re-use parts of their design by "cutting," "pasting," or modifying it. *SAGE* is an open environment in which code is always accessible by users. Everything is an example for others to use.

- Ease of use: The GUI allows children to create conversational flows in the same way that they engage in pretend role play games, by planning *who* is going to say *what*, and *when*, while arranging objects in the conversational structure window. For example Pauline, the author of Waloompa the alien, who worked out loud, used the turn-taking feature as follows: "First Waloompa says hi and asks user's name and then the user responds and then Waloompa asks the user how old he or she is, and the user responds and Waloompa says 'that is a nice age but how long does your species live?'..." This narration unfolded while Pauline placed the turns and communicational actions in the conversational structure window.
- Limited domain: The *SAGE* programming language only allows the user to create directed conversational storytelling situations. The nature of the conversational system is always machine-controlled (mixed-initiative is not readily an option), ensuring that the persona created is more likely to be believable and to interact successfully.

The Interface Module

The *SAGE* interface is the layer through which a user communicates with the system. The output device is composed of an interactive stuffed animal with programmable body behaviors and the computer screen with a graphical representation of a storyteller, his/her text balloon, and speech/sound output. The input device is the keyboard.

Since the technology is not yet available to create a stand-alone interactive toy (the main obstacle being the lack of adequate speech recognition systems for children's speech), we integrated the desktop computer with a physical toy. Output is multimodal, and input is typed text only. In order to explain the absence of symmetry in the interaction, in interaction mode the stuffed animal is presented as being the assistant of the sage storyteller that lives on the computer screen (Figure 7). This assistant character interacts with the user via synthesized speech. The assistant carries on the conversation and, at a certain point, calls on the sage storyteller to tell a traditional tale of wisdom. The body movements of the toy are very important to convey change of gaze. When the toy calls on the storyteller, it stops facing the child and turns to face the computer. The sage storyteller is presented as a character that lives in the computer. The storyteller is only in charge of telling the response stories from the database.

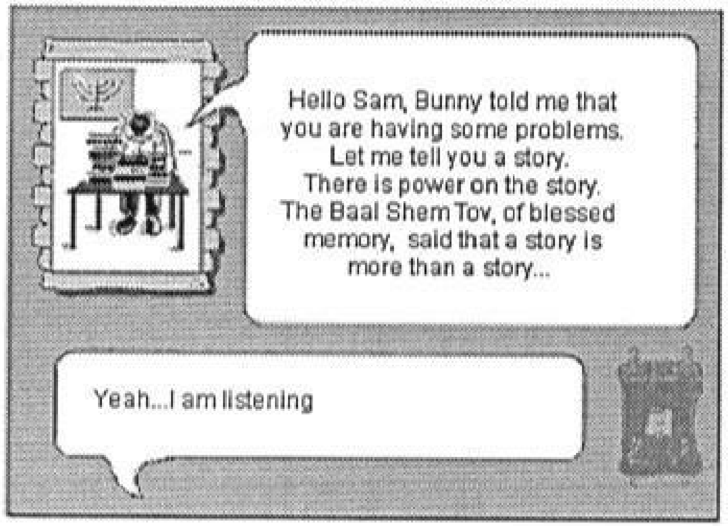

Figure 7. The sage storyteller, in this case a Hasidic Rabbi, lives in the screen and is in charge of telling the response stories

Children choose which sage storyteller they wish to interact with by placing different hats on the stuffed animal. The stuffed animal has a set of hats with small resistors whose unique value is read by the Handy Board (Martin, 1995). This microcontroller interfaces, via a serial connection, the physical stuffed animal with the *SAGE* software running on a Macintosh computer. It allows the system to know which character is loaded at any given moment, and it controls the movements of the interactive programmable stuffed animal.

INTERFACE USER STUDIES

A programmable stuffed animal was chosen as the interface for *SAGE* after conducting user studies to explore children's interface preferences. These studies tested three different conditions on 12 subjects between ages 10 and 13. Each of the subjects was tested with each of the three interfaces: a silent screen, a combined screen-toy, and an interactive toy. After interacting for approximately 30 minutes with the different interfaces with a storyteller that we had designed, they completed a questionnaire with a

Likert scale test. The questionnaire was intended to help the children express what interface they liked best and why. After completing the questionnaire, children were asked to orally share their overall experience in an extended personal interview. Conditions were counterbalanced. The following is a description of each of the conditions:

1. Silent screen: Children can input information only through the keyboard. The system responds through a silent, graphical cartoon-like representation of a storyteller on the screen.
2. Combined screen and toy: Children can input information only through the keyboard. The system responds with a text-to-speech synthesizer when the conversation happens with the storyteller's assistant (the interactive stuffed rabbit) and a recorded human voice when the cartoon-like character, the storyteller, offers a comforting story.
3. Interactive toy: There is no screen. The rabbit maintains the conversation and tells stories to the children. A hidden human "wizard"[2] simulates the speech recognition by typing what he/she hears into the system. The wizard also acknowledges the child's gaze and tactile information and accordingly controls the body movements of the rabbit.

Among a total of 12 children, 50% (6 children) preferred the combined interface, 33% the interactive stand-alone toy, and 17% the silent screen. This preference for the combined interface (Figure 8), as shown later, can be explained in terms of imperfection of speech synthesis and attractiveness of the toy. However, the number of tested subjects is too small to make generalizations.

Figure 8. The combined interface was preferred by children. A 10-year-old is interacting with the assistant of the storyteller rabbit. (copyright ©1997 by ACM)

The argument given by children who preferred the combined interface is well represented by Marie, a fifth grader:

> It is neat to use the computer and also hear the bunny talking and see him moving. If I didn't understand some of the words I could just look on the screen and read them. The rabbit was cute and it is better if it moves because it expresses itself a little more and sometimes it even makes it easier to understand.

Marie's statement suggests that technical problems, such as the bad quality of speech synthesis,[3] make the combined interface better than the stand-alone toy.

The presence of an interactive stuffed animal seems to foster children's engagement (Umaschi, 1997b). Results from the user studies testing children's interface preferences led us to the conclusion that in further research we would use the combined interface consisting of both the interactive toy, as the sage's assistant, and the computer screen.

EMPIRICAL RESEARCH

In the introduction we claimed that the *SAGE* storytelling system is an example of how technology can be used to encourage children to reflect on their inner life and to support their learning about narrative and communication. In this section we describe empirical research that supports these claims. We show that children's interactions with *SAGE* did indeed lead them to reflect on thoughts, feelings, and interpersonal communication, and also expanded their knowledge about personal storytelling as a communicative activity. In particular, we demonstrate that, by using *SAGE* in design mode, children's intuitive storytelling skills can be used to introduce them to the types of formalization that are required by computer programming. The following sections present the methodology used in the empirical research and then address these claims.

Description of Workshops

We conducted several pilot studies to examine children's interactions with the sage storytellers and their ability to build their own meaningful characters. Our earliest research showed that children were in fact quite ready to engage deeply with sages that we had designed (Umaschi, 1996). They opened up willingly to tell personal problems to the characters that we had designed, a Hasidic Rabbi and a Buddhist scholar. Before the studies were conducted we introduced the children to the counseling role of the sages. The nature of their engagement was no different whether they understood the workings of the implementation or believed that the computer system learned something deep about them. This result led us to believe that children would also be able to interact with sages of their own design. We envisioned that the iterative process of designing, interacting, and then improving the design of their own characters would result in an increased awareness of the nature of narrative communication and of computational systems.

In the study described here, we conducted research with fourth and fifth graders in order to test *SAGE*'s impact on storytelling awareness, self-reflection skills, and the interaction between these skills and technological fluency (Papert & Resnick, 1995). Children of this age are almost adult-like in their narrative productions (Karmiloff-Smith, 1985; Hickmann, 1987) but are still not capable of explicit meta-linguistic comments about the structure of narrative (Gombert, 1992). Likewise, American fifth graders are in general familiar with computer applications, but for the most part are not fluent programmers. The general claim here is that *SAGE* integrates programming and storytelling skills by supporting the design and modeling of abstract structures needed and used in both activities.

In order to understand children's design and creation of their own meaningful storytellers, we conducted two-day weekend workshops. Children were solicited for the workshops through local schools and personal connections. Children who participated in the workshops came from a range of backgrounds and were not particularly computer-competent. Individual extended interviews were carried out before and after the workshops to explore the children's ability to be self-reflective, their notions of storytelling, as well as their computer skills. Eight children (four boys and four girls) participated in the study reported here. Each workshop comprised one prestudy personal interview, two full days of design and programming, one poststudy personal interview, and one demonstration for parents given by the children. Each child worked on a separate computer to design and program a storyteller of his/her choice, and kept his/her own design notebook with ideas, problems, and so forth.

The methodology used for the study was based on an ethnographic approach, with natural observation of the children's interaction with the system as well as with each other, extended personal interviews, and an experimental task. (For a complete description of the methodology and the questionnaires used, please see the appendix in Umaschi [1997b].) In order to avoid "technocentric questions" (Papert, 1987), the methodology was centered on what children do with *SAGE* and not what *SAGE* does to children. The study included,

- the observation of children using *SAGE* in both the interacting and authoring modes;
- the observation of children's discussions with each other during the authoring process;
- the extended personal interviews. The interviews explored children's notions of identity and language use (in particular, turn-taking, parts of interaction, and sense of listener). They also explored children's theories of how human-computer dialogue systems work, in order to assess their technological fluency before and after the authoring process;
- an experimental task. Children were presented with pictures of people interacting with other people and with artifacts, and were asked to choose the picture showing the activity most similar to interacting with *SAGE*. This task was designed to reveal how children think about human-computer interaction. The same task was repeated in the post-study to explore differences and explicit references to *SAGE*;
- the analysis of system logs generated by interaction with storytellers;
- the analysis of children's personal designer notebooks. Children used their design notebooks to write and sketch ideas and problems before, during and after the authoring process; and
- post hoc analysis of videotaped workshops and interviews.

In the following sections we look at examples of sage storytellers created by children. Each example is a case study that illustrates a phenomenon also found more generally during the workshops.

The Presentation of the Self

When interacting with one of the sages that we had designed, children revealed aspects of their inner lives and the problems they face everyday. In building a sage, children designed that person to whom they wished they could turn with their problems. It is essential to note that the sages they designed were also aspects of the inner lives of the child designers. That is, since the children were creating their own characters and databases of stories, they were also playing with different notions of self and creating or imitating the narrative voices they wanted or needed to hear. One might claim that the children were simply imitating images of role models that they had perceived in their environment, but as Piaget (1962) wrote, "Imitation is always a continuation of understanding, but in the direction of differentiation with respect to new models." Children created storytellers as projections of fears, feelings, interests, and role models.

These projections allowed the presentation of the self to themselves as well as to others.

Out of a total of eight storytellers built during the workshops, three were based on humans or fictional media characters: Doug, a cartoon character; Tera Randof, based on a mixture of a real sports figure and family members of the author; and Shaquille O'Neil, a well-known basketball player. The other five characters were fictional, although two of them, Spot and the Big Orange Fox, clearly tell stories based on the authors' personal experiences.

Abi is a bilingual fourth grader whose parents come from Russia. When he grows up he wants to be a physicist because he likes computers, math, and science. Unlike all the other children who participated in the workshop, he said that he had never heard the word identity before, and after we explained its meaning he concluded: "It is what is inside me, like being Jewish and American and having my relatives in Russia."

During the workshop Abi created The Big Orange Fox that would explicitly ask the user if she or he has specific problems. If the user responded positively, The Big Orange Fox would tell an appropriate story indexed in the database under different types of problems. For example, below are two stories written by Abi and told by his character.

> There was a boy who was really rich who lived in the best house and got 3000 dollars per month for allowance but there was one thing he did not have and it was friends so he had a very bad life so one day he decided to live by himself getting his 3000 per month and living only a little better than normal people then he had a lot of friends but his friends did not understand how much money he wasted on necessary stuff so they thought he was spoiled and only played with him for money because he had to give 10 dollars per hour to whoever he played with and now he was sad because he had bad friends. (This story was indexed by Abi as a friendship problem.)

> There was once a boy who did not like his religion so he followed his family religion but when he was alone he secretly followed his religion but when his parents spotted him they cut off his finger and put him into a tiny dark box with spikes on all the sides but the bottom and left him there for 24 hours. (This story was indexed by Abi as a religion problem.)

Abi wrote 12 stories of this sort in his database. He is the child who created the most number of stories. This is extremely noteworthy considering that in the pre-interview Abi stated very clearly that he didn't like writing and he only liked to do it with a partner, not alone.

During the demonstration day, when Abi's parents came to play with The Big Orange Fox, they were surprised by the questions the character asked but even more by the stories it offered. While playing with other children's characters they noticed that Abi's was addressing in a direct way personal problems as well as telling stories, that although fictional, were obviously expressions of fears and feelings. During the post-interview, Abi said,

> First of all I learned how to put myself in another place and pretend I am someone else, and I learned how hard it is [...]. But really I talked to myself and I learned more about myself [...]. My stories are sad, but if you want to hear a funny story you can play with Waloompa the alien. When you have a problem it is sad and that is why my stories are sad. But my family didn't like my stories too much because of that, but they learned on what place I am now, and I am in the sad stories.

Abi used *SAGE* to create a fictional representation of himself, for himself, and for his parents. Through the creation of this character he was able to express feelings and fears that otherwise remained buried in everyday conversations. His parents also discovered, through The Big Orange Fox, a part of Abi's inner world.

In the same way that Abi used *SAGE* to play with his fears and feelings, Tracy, a 10-year-old girl with no previous programming experience, used it to represent herself in the future. During the workshops, Tracy created Tera Randof, a young female basketball player "who will become a sports figure" like the ones Tracy admires. In the post-interview, Tracy revealed that Tera's personality is a mixture of Tracy's mother and grandmother, and that the stories that Tera tells are Tracy's mother's childhood stories. Tracy created the character and the conversational structure and wrote all the stories in the database. By interacting with her own programmed storyteller over and over again, Tracy improved the program until it was able to respond to many different kinds of user's stories without crashing. In the process, Tracy also reflected on how people become good listeners. And, despite the fact that she was interacting with a storyteller of her own design, Tracy shared real personal problems and deeply engaged in reflection to make sense of the given advice. The following interaction between Tracy and her sage storyteller took place during the design process:

> SAGE: *I have a lot of problems like wondering if my team is going to win the big game or if I will mess it up for everyone. Please tell me a problem you have.*

> USER: I am sad because my parents told me that we can't take my dog on vacations with us, so I will miss him.

> SAGE: *Your problem reminded me of this story. Kerri is my best friend. Kerri knows everything about me and I know everything about her. Every Friday we sleep over each other [sic] houses. Switching houses each week. This week it was at my house. I got the usual snacks: popcorn, pizza, chips, soda, and candy. A few hours later Kerri came by with her sleeping bag. You could tell she was in a bad mood. I asked her to lighten up, and she snapped, "Fine." and left. I was stunned. What was her problem? I waited the few minutes that it took for her to walk home then called her. Her mom answered. I asked to talk to Kerri. Her mom said Kerri doesn't feel like talking to you right now. Kerri didn't talk to me in school for a month. Then I got the horrible news: my mom got a great job in L.A. so we were moving there! Kerri didn't even come over to say good-bye. I have never seen or talked to her since. Maybe she wasn't really my best friend. Did you like that story? Did you understand the moral of it? Please tell me what you think that story meant.*

> USER: You didn't see your friend ever again, but I will see my dog when we come back from vacation. I guess that is not that bad.

Tracy is only one of the many cases in which we observed, by analyzing the logs of the interactions, that a deep knowledge of how the system works doesn't affect emotional engagement and sharing of a personal problem. Both Abi's and Tracy's case studies show that *SAGE* was effectively used by children to explore identity, according to their personal needs at the time.

Opening the Black Box of the Design Process

Children who participated in the authoring experience learned how to open the "black box" of the *SAGE* software and the thinking skills needed in order to design their wise storytellers. They were able to understand the computational processes as well as to debug their programs and conversational structures. Tracy created a very coherent and developed personality for Tera Randof, thus making her into a believable character to maintain a conversation with. At the same time, Tracy's knowledge of how *SAGE* works allowed her to reflect on the nature of sharing problems in a deeper way and compare it with her intuitions about how people help one another:

> A person already knows how to react to a question, but the computer doesn't. You have to feed in information about what to say and that is like creating a mind and a personality [...]. When people communicate they take an experience they had or think of something that the other person might want to hear, a same sort of problem, something familiar or similar, and they just tell it.

Mischa created Mother Nature and designed a complex conversational structure that has two parallel branches, one for people who like to be in nature and one for people who do not. In the post-interview, reflecting on her authoring experience, Mischa said,

> The most fun part was working on the computer and programming kind of a game for people to use [...] it is a program for you to make another program. I liked creating what it might say and the questions and the structure and I learned that people can type anything and that you always have to be prepared because people might type not just "yes" or "no" but, for example "I guess so," so you have to use more branches.

Both Mischa's and Tracy's understanding of conversational storytelling bootstrapped their understanding of programming, leading them to realize that one has to be ready with an appropriate output for any input.

Communication and Computational Bugs

SAGE facilitates the exploration of notions of communication as children observe conversational breakdowns in their own and others' interactions with the created characters. The most frequently observed communication breakdown was due to children's difficulty in decentering and designing interactions in which other people, different from themselves, could participate. By decentering, we mean the ability to imagine a conversational interaction from the point of view of another interlocutor, that is, more generally, the moving out of the phase of egocentrism where one cannot differentiate somebody else's point of view from one's own.

During the post-interview, when children were asked to choose a picture most like the experience of building their own storytellers, Abi chose a picture with a boy pushing a huge rock.

> I pushed a rock and then I got better and I got used to do it so I could push a little further. The rock was the beginning of the Big Orange Fox and then it started to get easy for me. It is the first complicated program I ever made because you have to think about what the user is going to say, altogether. You start thinking that you are like a user and how would you like to use the program and then you do it. Thinking in the place of the user was hard and also not being nervous that it will have bugs that you have to fix.

The iterative design experience, which involved programming and immediate testing with a real audience—themselves, their parents, and other children—gave children the opportunity to decenter and debug their conversational structures after observing other people's interactions. Bernie's experience is a good example of the difficulty children had in decentering. Bernie built "Shaquille O'Neil" and brought to the workshop pictures of and books written by the famous basketball player. He adapted six of Shaquille's stories from a book and recorded them with his own voice. He indexed them by typing not just keywords but values, such as "Good things can happen if you wait" and "If you have a plan then things are better than they seem."

At the time, Bernie was taking programming classes with *Logo* in an after-school program. This knowledge allowed him to understand faster than other children concepts such as variables and branching. He was able to quickly create a basic conversational structure. However, the first time he tried to run "Shaquille," he discovered that it didn't work as he expected. The problem was that Bernie had not created any pattern to match and recognize users' inputs.

While debugging, Bernie found the problem and he created the missing input matching structures and copied the most complex ones, such as digit matching for recognizing the user's age, from another *SAGE* character. Confident that the problem was a computational one, and that he had resolved it, Bernie called over one of the adults to show off his new working version. In effect, when Bernie interacted with "Shaq," the new version of the program responded well. However, when the adult tried it, the first thing that happened was that Shaq called her "Bernie," although when the system asked her name she had responded, "Marina." Bernie realized that he had hard-coded his name in all the system responses. The problem was not a computational bug, which he had earlier resolved, but a communication bug. Bernie had not decentered, that is, he had not created an experience for users different from himself.

A week later, when his parents came for a demonstration, Bernie had already fixed "the name problem," as he called it. However, when Shaq asked Bernie's dad, "I guess you are around 11, am I right?" and the response was, "No, I am 45," Shaq crashed. This time Bernie saw the problem immediately. He hadn't provided a branching node to allow the possibility of a "no." He quickly went back to the authoring mode and added the branching to the conversational structure.

Bernie's experience was common to most of the children, who observed similar problems when their parents interacted with their characters. In general, the conversational structures designed were very linear, without branches to take into account different kinds of user input. Only after observing others' interactions with their sages did the children realize that they had to contemplate the possibility of responses other than their own. This discovery was facilitated by the iterative design process, meaning the loop of working on the computer and immediately debugging or trying results in the real world in an iterative process. Iterative design implies a reality check with real users.

The power of iterative design is that it not only occurs while children are in front of the computer, but it also extends into their everyday communicational experiences. For example, Pauline, the author of Waloompa the alien, had the habit of never saying "good-bye" to the person who was videotaping the workshops, although she knew him and engaged in many conversations with him. When this was pointed out to Pauline, she responded: "You know what? Waloompa doesn't say 'bye' either ? And 'bye' is like "good-bye;' I should include it in the macros of my program." At the next meeting she created a new storytelling part called "bye" with two turns: one in which the alien says "good-bye" to the user and another in which the user can respond farewell to the character.

To create a representation or model of the structure of a conversation is not an easy task. With *SAGE*, it involves working with different levels of abstraction, such as what is actually said (scripts), when it is said (turn-taking), and why it is said (part of conversation). The part of conversation is the highest level of abstraction as it requires thinking about the goal of a particular chunk of an interaction that might include several turns. Parts of conversation implemented by children included introducing oneself, asking for personal information about the user, comforting, and so forth. Most of the children who participated in the workshop had trouble understanding the idea of conversational part, or meta-level structure. Among other research on metalinguistic ability (Hickmann, 1987; Gombert, 1992), the current suggests that switching between levels of abstractions is hard for children in storytelling as it is in learning how to program.

Struggling With Knowledge Representation

While creating storytelling structures and turn-taking machines, children explored concepts such as branching and abstract structures; while indexing the stories in the database they learned about the notion of knowledge representation. Abi's experience is one of the most noteworthy in this sense. Most of the children decided to index their stories either with keywords or with morals. However, Abi chose categories that he called "problems." After some hard work he came up with the following categories: "religion problems," "school problems," "learning problems," "relative problems," "subject problems," and "teasing problems." Abi's sage, the Big Orange Fox, asks, one by one, about each of the problems in the following way: "Do you have any religion problem?", "Do you have any learning problem?", and so on. Abi's idea was to have the Big Orange Fox tell a story relevant to the problem to which the user responded "yes."

In the first debugging session, when Seth was interacting with the fox, Abi found a major problem in his knowledge representation structure. Seth had teasing problems but also school problems. Abi realized that some of his categories were "inside the others." For example, teasing happened in school, as did learning problems and subject problems. He was very proud of his category-based story indexing and he wanted to keep it. After a lot of thought, Abi found an interesting solution to this meta-representation problem. After interviewing the user about all of the possible problems, the Big Orange Fox asks, "Take all the problems you said yes to, out of the ones I asked you. And please put them into the category you have most problems with. Do only one category." From the point of view of the user and the interaction, the question posed by the character is very confusing. However, for Abi it was a good solution, one that allowed him to start thinking about powerful computational ideas such as "knowledge representation" and powerful communication ideas such as meta-problems.

To create conversational structures and to categorize stories obliges children to reflect and work with levels of representation and abstractions. It introduces children to thinking in a different and more abstract way, all the while depending on concepts they are familiar with, such as who says what to whom and when. The kind of experience that *SAGE*'s authoring mode supports is a gateway to the world of abstraction, preplanning, and structured thinking, skills that are used in the hard sciences and programming as well as in storytelling.

CONCLUSIONS

In this paper we discussed the importance of technological tools specifically designed to encourage children's exploration of identity and communication. We proposed personal storytelling as a way to access the inner world as well as to explore notions of communication. Constructionism informed the philosophy of our work.

We presented the design and implementation of such a technological tool: *SAGE*, an authoring environment for creating embodied interactive storytellers with whom one can converse. We described children's interactions with the *SAGE* tool, concentrating on case studies.

The themes that emerged from the analysis of learning experiences form the central contributions of this research:

- The continuum between the interacting and the authoring mode in *SAGE*: From the self-reflection perspective, both experiences were successful. However, the authoring mode seemed to support deeper explorations of identity and communication as well as a bigger sense of empowerment and control over the learning experience.
- The creation of storytellers as projections of fears, feelings, interests, and role models: These projections allow the presentation of the self to ourselves as well as to others.
- The exploration of notions of communication while observing breakdowns: The iterative design experience supported this type of exploration by providing children with the opportunity to decenter and debug their system's conversational structures after observing other people's interactions with them.
- The use of children's knowledge about storytelling to leverage their technological fluency: Through the process of building their own storytellers, children developed modeling skills, abstract and structured thinking that are fundamental requirements for storytelling as well as for programming.

This work provides a conceptual and technological framework for designing and implementing tools for reflecting on the inner world as well as exploring communication issues. Both activities can also be done without technology, through mentoring with a good counselor or teacher. However, the use of computers enables a different exploratory depth as well as supports children's experiential learning while they are modeling and designing abstract, conversational storytelling structures. The endeavor is just beginning, and further research must be done in order to explore in depth each of the themes that has emerged from this work.

For the moment we have examined the interaction between technological and storytelling fluency across single-weekend workshops. In the future we hope to look at the effects of interaction with *SAGE* over a longer period of time. We have also begun to look at other types of functions that interaction with a sage storyteller can sustain. Some children are particularly in need of telling the stories of their lives—for example those children whose stories are complex and emotionally wrenching, such as chronically ill children (Bers et al., 1998).

SAGE also has the characteristics of a gender-neutral technology which should support girls to become familiar with the world of technology and boys to become more comfortable with storytelling. However, gender-based empirical research needs to be done in order to test this hypothesis. An appropriate methodology should be defined to conduct gender-based studies.

However, for all children the importance of technological and storytelling fluency should be clear. We live surrounded by stories and by technology, sometimes in combination. We live among stories that we tell and stories that we listen to. Some stories emerge from everyday experience, others are provided by the media, with putative entertainment and information goals. We don't always need to understand the structure of a story to enjoy it; however, we do need to be able to recognize something about the structure in order to become critical readers of our reality.

Our hope is that by supporting children's creation of their own storytelling structures, children will become more aware of the metacommunication cues that signal the goals or agenda with which certain stories are told or written. We also live among technology, and, increasingly, technological fluency is demanded of us in all aspects of our daily lives. Our hope is that by supporting children's creation of a technology to their own specifications, children will become more educated consumers and creators, and there will be fewer adults scared of what technology represents. We believe that technological tools for reflecting on the inner world do not only improve children's sense of themselves, but that children's sense of themselves will improve the technology around us.

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Notes

1. Names of children and other identifying details have been changed.
2. A "Wizard of Oz" experiment is a simulation technique used to develop and test dialogue models prior to implementation. In each session, a human "wizard" simulates the interaction strictly following an algorithm.
3. Macintalk was the speech synthesis used.

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