StoryBeads: a wearable for story construction and trade

Barbara Barry, Glorianna Davenport, Dan McGuire

Room E15-435 Media Laboratory
Massachusetts Institute of Technology

{barbara, gid, dmcguire} @media.mit.edu

Abstract

Stories take hundreds of different forms and serve many functions. They can be as energetic as an entire life story or as simple as directions to a favorite beach. Technological developments challenge and change storytelling processes. The invention of writing changed the story from an orally recounted form, mediated by the storyteller, to a recorded version which was technologically reproducible. The fleeting experience of a storyteller's woven tale became an immutable object. In cinema stories are told with a sequence of juxtaposed still images moving at a speed fast enough to fool the eye into seeing a continuously changing image instead of one image after another. The invention of the computer with its capacity for storage and manipulation of information let authors design stories and present them to different viewing audiences in different ways. Mobile computing, like the technological developments that came before it, will demand its own storytelling processes and story forms.

This paper introduces a tool for mobile, digital storytelling called StoryBeads. StoryBeads are necklaces made of small computer "beads" capable of storing, transmitting, or displaying images. They are wearable computers used for constructing stories by allowing users to sequence and trade story pieces combining image and text. The beads communicate by infrared light, allowing the trading of digital images from bead to bead. The network consists of a chain of beads connected wirelessly, where individual beads communicate with their two nearest neighbors. Each necklace is a database of images distributed across a network of communicating beads. Inter-necklace communication allows a community of users to share stories digitally by beaming them from necklace to necklace or by exchanging physical beads between necklaces. As images travel between users, new image descriptions are added, providing historical context. Theories of play styles, narrative accrual, and image-based storytelling informed the design. StoryBeads encourage messaging among a group of story participants, demonstrating that mobile and portable devices can create new possibilities for participation in distributed and networked story experiences.

1 Introduction

Stories are fluid. Their structure, content and meaning change over time as they are retold and passed from person to person. Stories reflect the characteristics of their containers: Oral stories, films and photographs each inspire unique methods for building stories. As new containers for stories are invented, the activity of story construction evolves as users find creative ways to express themselves using that container.

We developed the StoryBeads as system to examine how the storytelling process evolves when pictures and text can be traded and sequenced by multiple users. The basis for this study was the StoryBeads, wearable computer necklaces that can be used for building and trading stories. Digital images are stored on small computer "beads" which can stand alone as storage devices or can be strung together creating a network for transmission of images by infrared light. By pressing buttons on the beads, users can navigate through their database of images viewing images one at a time of a special bead, which has an LCD monitor. They can also trade digital pictures from necklace to necklace to share images, their interactions driving the co-construction of stories.

The activity of story construction can be seen as an artistic endeavor, a learning experience or a play activity. Using StoryBeads users create their stories by messaging, collecting and building stories as they walk through the world. Stories gain a presence as objects that can be physically manipulated as building blocks. This paper considers StoryBeads as new tool for storytelling in a time when stories and the activity of making stories is becoming more distributed, networked and mediated by technology. In particular we will examine how the activity of storytelling influenced the design of StoryBeads. We will also discuss the technical implementation and our observations of how they were used by our first test group.

2 Context

2.1 Story

Webster' s Dictionary defines story as "the telling of a happening or connected series of happenings, whether true or fictitious; an account; a narration." Story is a shape or pattern onto which events or series of events can be organized and understood (Livo, Rietz, 1986). Stories are sequences that live in and are influenced by their container, the medium of their telling. Containers give a story persistence, committing it to memory. Containers are manifestations of story that can be experienced by a viewer or listener. The choice of container influences the telling of the story. For example, a film editor takes scenes and strings them together to create a cinematic story, while a poet chooses words to evoke images in the readers mind. The scenes recorded on film or the words arranged on the page are the building blocks of the story. StoryBeads allow users to string together images and text in a pictorial sequence. These sequences in turn can invoke the sharing of oral stories.

Storytelling is essentially the sequencing of granules of expression. Whether the granules are images or words or sounds the storyteller glues these pieces together to transport the listener into a story world, a space where the audience knows that anything can happen. The listener has entrusted her attention and expectations for the story to the storyteller. The storyteller reveals one piece of the story at a time bringing the listeners or viewers to experience the story the teller sees in her mind. The storyteller constructs a story much like one would build a bridge out of Lego bricks. First the foundation is laid: “Once upon a time”, then the structure comes into focus as the characters reveal their struggles, triumphs and sometimes-mischievous tricks. The teller knows which story pieces must remain for the bridge to stand strong and which ones can be swapped and forgotten during a given telling. StoryBeads are a physical container for granules of expression and allow the telling to be integrated with a physical building activity.

2.2 Constructionism

In this paper, construction is defined as the epistemological term "constructionism." Constructionism is a concept developed by Seymour Papert of M.I.T. It extends Constructivist theory, which states that all children construct their own knowledge. Constructionism expands on this concept by claiming that children have many of their best learning experiences when they are actively engaged in making a product or artifact, which is meaningful to themselves or others (Papert, 1991). In the constructionist experience, the environment responds to the builder, giving her feedback during the process of learning. An example of constructionist learning is a child building a scale out of Lego bricks to learn about weight, balance and gravity -- building a flexible object to learn about a concept or idea. Constructionism refers to the creation of all types of artifacts, not only physical objects but also images and stories. Manipulating reusable and redescribable images as story fragments, learners investigate different story structures, and different ways of expressing their fictional, documentary or autobiographical narratives. By trading sequences of images, or single images, they learn how other storytellers describe images and build stories.

2.3 Nature of Play

D.W. Winnicott, a psychoanalytic theorist, sees play as a tool for self-discovery. The objects used in play are containers to fill with meaning. For example, a young child, as a way to individuate, might choose a specific toy plane or story character and mark it as more important than the parent. The symbol serves as training wheels for the child to internally ride away from the parent to autonomy. Each play object has a story. As life changes, the meaning attached to the object changes.

Winnicott investigates play activities and their consequences for ego development. Self-discovery is the result of a process. First, relaxation allows the mind to move into a chaotic and nonsensical state or space. Stories generated in this nonsensical space contain a grain of truth about the self. Then, when the truth is spoken and mirrored to another person, in Winnicott’s world the parent or psychiatrist, it becomes integrated into the personality. In Winnicott’s view, play is self-explanation.

2.4 Play and Learning Styles

In their work on epistemological pluralism, Sherry Turkle and Seymour Papert of M.I.T. make a connection between play styles in learning and gender. They argue that the basic elements of computation should be expanded to include the two styles of learning they described as "hard" and "soft." "Hard" describes a logical approach to problem solving using abstract thought and systematic planning typical of computation design. "Soft" describes a non-linear, bricolage approach to problem solving using manipulation of ideas and objects to find an emergent solution. Turkle and Papert found that, although individuals possess the ability to use both learning styles, girls are inclined to favor the "soft" approach. Girls are discouraged from participation in computation culture which places more value on the "hard" style. Story Beads was developed as a tool that allows the user to shift between "hard" and "soft" styles. The "hard" style can be viewed as rule-based play, the "soft" style as improvisation. An example of a game that incorporates both styles is hopscotch. There is a rule for physical movement on the hopscotch grid: get from one end to the other. The players often make up improvisational rhymes as they jump from square to square the rhyme echoing the rhythm of the player's feet hitting each square. In StoryBeads, there are not rules, but there is an interaction design. Images are copied from bead to bead when traded. Individual beads cannot hold more than eight images. These constraints influence the story construction activity. The beads are "soft" in that they allow spaces for improvisational oral storytelling during the trade of images. They also encourage the bricolage style as images can be sequenced and resequenced by stringing beads together.

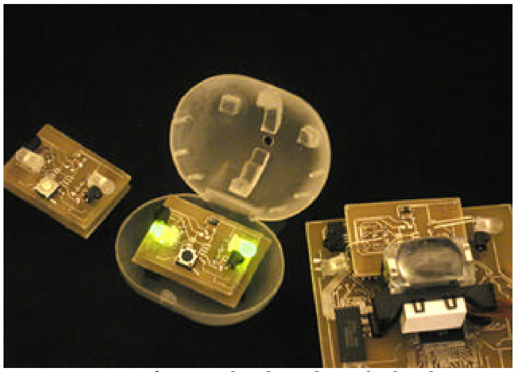
3 Related Work

3.1 Tradable Bits

StoryBeads is directly related to a body of work called "Digital Manipulatives" that is being researched by the Epistemology and Learning Group at the MIT Media Lab (Resnick, 1998). The work is Constructionist in that it expands the range of things that children can design and build using mathematical and computational concepts. Physical objects like badges, blocks, tiles and beads are imbued with computation giving them behavior and the ability to communicate with each other, usually by infrared light. Some of the physical objects can be programmed by the children, while others are used as fixed construction blocks. Their research also looks at play as a way to learn about systems. For example, a set of tiles that communicate by infrared light allow children to arrange the tiles in different ways to create patterns or experiment by adding new program behaviors to the blinking lights that jump from tile to tile (Kramer, 1998). StoryBeads use emergent patterns in story and allow people to share images and experiences. They are more of a construction set for collecting and building, than for observing and hypothesizing. Their focus is on trade between users as a network, where tiles trade code between objects. Closer to the interaction design of StoryBeads a recent project by Rick Borovoy of the Epistemology and Learning group called "i-balls," uses handheld devices to allow the trade of icons to create games of community interaction (Borovoy et al., 1998). This work also relates to much of the work in the Interactive Cinema Group of the MIT Media Lab where systems help users sequence short media elements. Some examples of these systems are Dexter, Contour, Agent Stories and most recently work in very distributed movies, where distributed communities collaborate in the co-construction of video-clip based stories (Davenport & Murtaugh, 1997; Davenport et.al. 2000).

4 StoryBeads System Overview

The Story Beads necklace consists of one or more storage beads and a single amulet bead.



String of storage beads and amulet bead.

The storage beads act as networkable, nonvolatile storage devices. Each bead can store up two eight color image on an internal EEPROM. The amulet bead acts as an access terminal. Users can call up images from any bead and display them on the amulet's small color LCD display.

4.1 Bead Hardware

Each storage bead measures 1.5 x 1 x 1 inches and weighs .9 ounces. Each bead is also equipped with:

o up to four 32 Kb serial EEPROMs,
o a pair of infrared transceivers for inter-bead communication,
o an embedded version of the Motorola 68000 microprocessor,
o simple power management circuitry.

The microprocessor controls inter-bead communication and manages the bead's image catalog. The storage bead also allows users to associate each image with up to three pieces of metadata, such as descriptive strings, and to associate the bead itself with a piece of metadata such as a thematic description of the images on it.

The amulet measures approximately 2.5 x 2.5 x 1 inches and weights 1.1 ounces. It is equipped with a small color LCD display that can display 320x240 images in eight-bit color. The amulet is also equipped with a third IR transceiver that allows it to send images to and receive them from other beads or other necklaces.

4.2 UI Overview

The user accesses the images stored on a bead by pressing a pushbutton switch on the bead's surface. That bead then transfers an image from its on-board non-volatile memory to the amulet, where it is displayed on the amulet's LCD screen. If the bead contains more than one image, pressing the button a second time sends another image to the amulet for display. Pressing the button multiple times allows the user to cycle through all of the images on the amulet.

The user interface on the amulet allows the user to alter the way that images are stored on the necklace and also allows the user to trade images with other users. The amulet's interface supports four basic functions:

o delete an image,
o view the keywords associated with an image,
o transfer an image to another necklace,
o and direct an image received from another user to the proper bead.

All of these functions are activated using pushbuttons on the surface of the amulet.

4.3 Communication

Typical ad-hoc networks support multiple routes between nodes. However, our decision to create a necklace as a network imposes a particular approach to packet transmission. On this linear network, each bead on the necklace can only communicate with its neighbors on each side. Thus, for a message to travel the length of the necklace, intervening beads must be able to accept a message, detect its destination, and then pass it along.

It thus looks very much like a flat ad hoc RF network (Johnson, 1994). Each element acts as a simple router and must maintain some representation of the network and its resources. However, the network topology supports only one meaningful route between nodes. An additional issue is that the computational resources of each node are very limited, imposing limits on the complexity of the routing algorithms that can be implemented efficiently.

Despite this, the necklace must maintain support for dynamic reconfiguration. Early play tests with children, who are the intended audience for this iteration of the beads, made it clear that the users expect to be able to add, remove, and rearrange the beads on the necklace.

To enable this flexibility, we divided the network into two layers. The first is the physical layer, which has the following responsibilities:

o transmit data to neighboring beads
o error detection
o discover routes between beads and propagate that routing information to all beads

The second is a data link layer, which is designed to transmit lengthy packet streams across those routes. It has the following functions:

o allow one bead to direct packets to any other bead on the necklace
o retransmit data when errors are detected
o break up and reassemble packet streams

We implemented route discovery using a hybrid of the two approaches currently used on ad hoc networks: source-initiated on-demand routing and table-based routing (Royer & Toh, 1999). When a bead needs to establish a connection with another bead, it initiates a route discovery process that we call "necklace reconfiguration." The beads cooperate to determine the length and configuration of the necklace. Once this process is complete, a routing table is propagated to all of the beads.

This routing table is maintained for as long as there is constant activity on the network. If the network is silent for more than fifteen seconds -- the amount of time that a child would need to remove the necklace, reconfigure it, and put it back on – then the next transmission will be preceded by a necklace reconfiguration.

4.4 Route discovery

The ultimate goal of the necklace reconfiguration process is to create a name space for the necklace by assigning each bead on the chain a unique Bead ID, which functions as that node's address.

In assigning Bead IDs, we assume that the necklace forms a linear network. We give the right-most bead on the network a Bead ID of "0". The bead to its left is given a Bead ID of "1", and so on. Each bead has a Bead ID one higher than the bead to its right.

The process of assigning Bead IDs begins with an attempt to find the right-most bead on the necklace. Each bead, on its own, is capable of accepting a packet from one side and sending it out the other. We exploit this to send a Force Reconfiguration packet as far down the necklace as we can. When the packet reaches the right-most bead on the network, attempts to transmit it further will time out. The bead will detect these timeouts and begin the next phase of the route discovery process.

The right-most bead assigns itself a Bead ID of 0, and instruct the bead to its left to take a Bead ID of 1. This message propagates leftward down the necklace. Each bead appends to the packet critical information about itself including: the four bit Bead ID, a single bit indicating whether the bead's memory is full, and a single bit indicating that the bead is an amulet or not. There are additional bits available for future support of different types of media.

When attempts to transmit the packet farther to the left time out, the system will recognize that it has reached the other end of the necklace. At that point, the packet will contain a complete list of all of the beads on the necklace and their characteristics.

"Right" and "left" are admittedly somewhat fluid concepts here, because they depend on one's point of reference. Indeed, because beads can be put on the chain backwards or upside down, "right" and "left" can vary from bead to bead. It is during this phase of the route discovery process that each bead determines its orientation. Bead 0 determines the master orientation of the necklace. Each individual bead can either be normal or backward. If a bead detects that it is backwards, it redefines its concept of "right" and "left" for the duration of the route.

The final step in the assignment process is distributing the routing table to each bead. This left-most bead transfers this table to the bead on its right, which copies it into its own memory and then passes it to the bead on its right. This continues until the message has reached bead 0, and the end of the necklace. At this point, a stable name space has been established.

4.5 Using the network

Communication on the logical layer is based on the fact that the bead network is laid out like a number line. If a bead wants to send a message to a bead with a lower number than its own, it sends it to the right. If a bead wants to send a message to a bead with a higher number than its own, it sends it to the left.

In addition, each bead acts as a relay. If an incoming message is destined for a bead with a number lower than its own it passes it immediately to the right. Similarly, if a bead receives a message destined for itself, it will open the packet and act appropriately on its contents.

Logical layer commands are fairly straightforward. Large streams of information, such as images, are broken down into 68 byte packets. Two of these bytes are taken up by header information and another two are taken up by a UDP-based checksum (Lee, 1999). The 64 byte payload size was imposed because it is the largest amount of data that can be written to the image storage EEPROM at any one time.

At the moment, there is no facility for numbering packets and reassembling them at the destination. It is assumed that packets will reach their destination in the order in which they were sent. If there is network contention, streams originating from the amulet are given precedence on the network (under the assumption that they represent the user's most recent commands). Other packets are discarded. This approach was adopted largely because the beads do not carry enough RAM to support buffering.

4.6 High-level protocol

Once a stable routing table has been established, it is possible to access and manipulate the data stored on the beads. High-level messages, like route discovery messages, are sent across the necklace in 68 byte packets. Data objects larger than 64 bytes in size, such as images, are broken into packets and transferred across the network. All high-level messages must originate from a bead with a valid Bead ID and must be destined for a bead with a valid Bead ID. This information is encoded in the packet header.

Packets fall into three broad categories: requests, image data, and directives.

Image data packets are the most common type of message and are generally sent in response to an explicit user command. When a user presses the push button on a bead, for instance, that bead it examines its routing table, determines the Bead ID of the amulet, and then transmit the image in 64 byte chunks to the amulet.

Requests are somewhat less common on the network and are used mostly for synchronization. Request messages allow any bead on the network to access information stored on any other bead on the necklace. The StoryBeads desktop computer interface retrieves the images from the necklace by issuing image requests to each bead on the necklace.

Directives are also relatively uncommon on the network. They allow beads to modify the databases of other beads. The directive "delete", for instance, allows either the user to remove an image from a bead. Normally only the amulet and the computer interface issue directive messages.

4.7 Beads as independent devices

Storage beads can function both as nodes on a network and as independent storage devices. As nodes, they allow other devices to access and modify their data. As independent devices, their functionality is necessarily more limited due to the lack of a powerful user interface. Nevertheless, users can trade images between two beads without using the amulet as an intermediary simply by

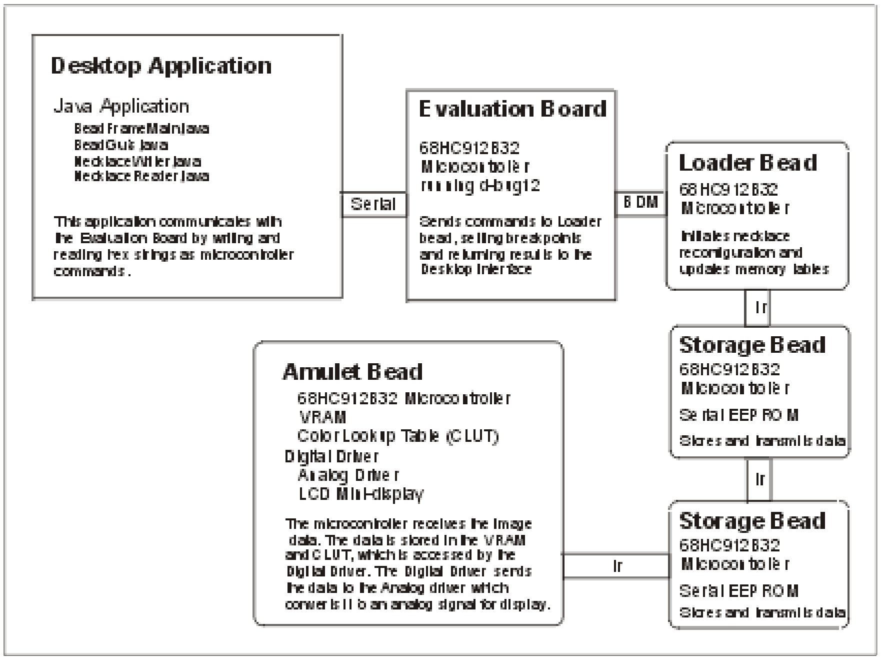


Figure 1: System Diagram of StoryBead necklace connected to Desktop User Interface.

holding them end-to-end and pressing the bead's push button. If no other bead is in range for image trading, the bead detects the time out and instead increments the current image number. By judicious use of the push button, the user can choose which image she wishes to trade with another and then transmit that image.

4.8 Desktop User Interface

The desktop application is used for organizing images and downloading image files to the beads. In the graphical user interface the user can organize images by describing them and putting them on graphic representations of beads. There are two ways to describe StoryBead images. Images can have textual descriptions attached to them and are also associated by the keyword of the bead that contains them. Each bead is given a thematic keyword. Thematic keywords are single words used to describe the contents of a bead. For example, a bead with a thematic keyword "flying" might contain pictures of bugs, birds and airplanes. When images are placed in a bead container they are tagged with that bead’s thematic keyword. Metadata for an image is assigned by the user in the interface and consists of the textual description, the thematic bead keyword and the destination bead for the image. To provide flexibility in the interface there is a scratch space for holding images not yet placed in a bead container. A user can also develop a thematic keyword bank, a scrolling list of keywords that can be dragged and dropped on a bead to tag it. Once a necklace configuration is built it can be downloaded to the necklace by selecting menu pulldown item that initiates the process of sending the images to the images and text to the necklace via the serial port. The desktop interface communicates with the entire strand of beads through a serial port connected to a "loader bead." The loader bead, the first bead in a necklace, sends commands to the strand of beads to read and write data to and from the desktop interface.

Users can save necklace configurations for future uploading and subsequent downloading to the necklace.

4.9 System Diagram (see Figure 1)

5 StoryBead Evaluation

5.1 Technical Evaluation

The StoryBeads hardware proved relatively robust in practice. Users quickly learned how to use the beads to trade and organize images. Our route discovery process also allowed users to add, remove, and rearrange beads. Infrared noise and some users' propensity to reconfigure the network while packets were being passed revealed the need for a sturdier error checking system and for more powerful logic to deal with network contention and timeouts.

It is also very difficult to create a truly immersive user experience with the current generation of batteries, storage devices, ir transceivers, and microprocessors. Long battery life, at some level, requires a diminishment of the user experience, either through slower, reduced-power components or through elaborate power-saving heuristics that disable portions of the device. Incorporating a battery sufficiently powerful battery into the

StoryBead more than doubled the size and tripled the weight.

For the first user tests the participants could download images from a desktop interface, trade images, string beads together and have the sequence read back to the desktop application. The viewing bead at that time was still under development.

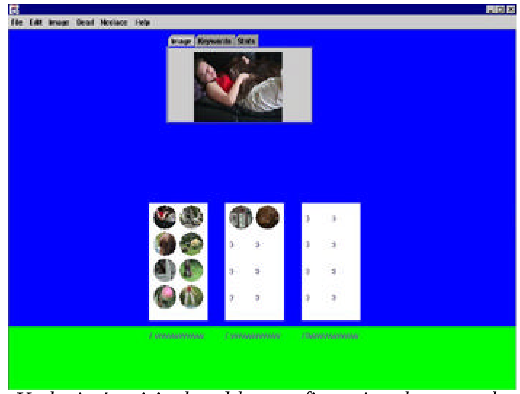
5.2 Activity Evaluation

Two girls, Mara and Katherine, were the first participants in our user tests. They arrived on the test day, only one had used her digital camera to record images. They decided to go for a walk and take some pictures. While getting their jackets the girls saw bags of glass beads that we had planned to give them after the testing. The bead bags went into the girls' pockets and they set out to gather some pictures. The girls took pictures of each other, people they encountered on the walk who they knew and pictures of nature. All of the photographs were shot in documentary style. There was no composing of subject or design of environment.

After arriving back at the lab, the girls downloaded their pictures onto their individual PCs. Each girl had a PC configured to run the desktop application. The digital cameras assigned sequentially numbered filenames to their pictures. The girls renamed their picture files. If this step were not taken opening pictures in the StoryBeads application would be random without any relevant association between the filename and its contents. Each girl opened the desktop application, then turned on each storage bead arranging a string of four next to the loader bead. They uploaded the existing contents of the empty beads, which appeared on the desktop as four rectangles each with eight spaces to place images. The girls opened their image files, placed them in the desktop application and wrote descriptions for each image. It took two hours for downloading pictures from the cameras, renaming them and putting them into the desktop application adding keyword descriptions. In the middle of the process Mara took a break and built a bracelet from her glass beads and some copper wire she found around the lab.

The girls were offered seeded content of sequenced stills from cartoon episodes if they wanted to start with those stories. Both girls preferred to use their own images. When one accidentally opened a cartoon still, she kept it, but singularly, not as part of a seeded sequence.

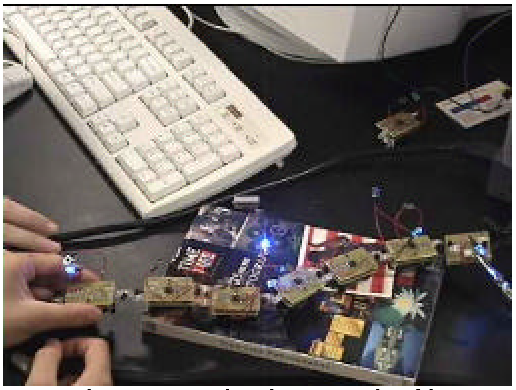
Mara completed her Story Bead necklace configuration first. She decided to put images on two out of four beads.



Katherine's original necklace configuration shown on the Desktop User Interface.

She downloaded the contents of her necklace configuration to the storage beads. Katherine had more images to annotate. Meanwhile, Mara took out her glass beads and began to sort them by type and color on the floor. Once Katherine was finished she began to download her configuration to her set of storage beads. The system crashed. Since the configuration was not saved, Katherine would have to remake a new configuration replacing and annotating all the that had been lost. While we were troubleshooting, Mara joined Katherine in bead sorting. They each sorted their glass beads. They traded a few beads, Katherine wanted mostly yellow, and began to collaborate building a necklace for Mara. While sitting on the floor they each had one side of the necklace string and were stringing beads, talking and, occasionally, asking my opinion on the next bead for the necklace. Katherine and Mara had never met before but were sharing stories about their families and summer activities while building the glass bead necklace.

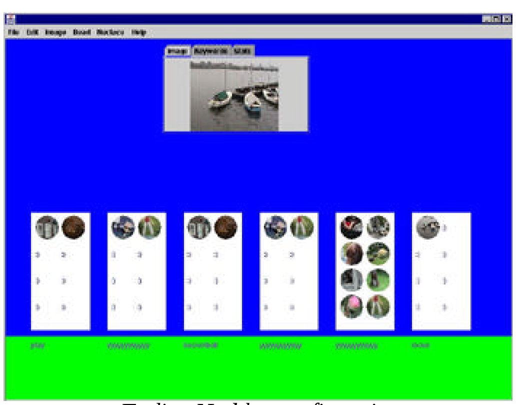
Girls stringing glass beads while storytelling.



Girls arranging a shared Story Bead necklace.

The StoryBeads were back up and running. Katherine re-entered some of her previous images into the interface and left one bead blank. The images were uploaded successfully to the necklace. During this test the beads were not in their plastic casings. We needed to tell the girls how the beads worked, mainly, how to press the button to trade images. They held beads up to other beads and traded images. When a bead was full of images, and no green flashed on an attempted trade, the girls tried to turn them around to fit more images through the infrared port not used in the previous trade.

After trading images, the girls moved to one desktop machine and strung all their beads together to look at the images, much like their collaboration building the glass bead necklace. They uploaded the images to the interface and viewed them. Two beads had files corrupted during the trade. They were taken off the necklace. The images were again loaded into the desktop. The girls saw the traded images and described their images and told other stories that the images reminded them of to us and to each other.



Ending Necklace configuration

At the end of the activity, we asked the girls to describe their experience. They assured us it was fun and they just looked tired because they had to get up early to come to the lab. They liked taking the pictures and trading them with the beads. They also gave us some suggestions as to other ways that the beads might be fun. Mara thought the beads should not be expensive so people could afford to have a few of them. Mara also thought it would be fun to play games on the beads. The beads could get games from the desktop and would let you play the game while you walk around. Katherine thought that you could have a special bead that you could put things on, things no one else would see, even if they found the bead. It wouldn't be like the rest. She also thought the battery power ran out too fast. Beads should be smaller and have batteries that last for a long time, maybe making a bead charger for overnight. They both agreed that the beads should be prettier, more like the glass beads, in different colors and designs.

5.3 Comments

The glass beads were present during the Story Bead testing accidentally. Their presence and the girls' use of them showed a storytelling forum that was meditative, conversational, and engaging much like Winnicott's exploratory play space. The girls were facing each other involved in conversation about the activity of building and interjecting personal stories instead of communicating with a desktop machine, as in part of the Story Beads activity. They saw the beads as a way to organize and show their own images. The time and steps to get images on the system could be viewed as a disconnected tedious process that might be relieved by adding a gaming element to the UI.

The exchanges between the girls about the images in their stories were descriptive. They told who was in the image, where it was taken or what it was about. Stories from Katherine about her dog were expressed while she was renaming the files but not in the UI. When she first opened the file she told me why her dog was named Orlando and how her sister had followed Orlando around for an entire day snapping photos. Orlando was moving so fast he was only half in the pictures, not one picture showed him sitting still. In the UI she used a more generic description "dog" or "face," in the case of a close up. It is much more a keywording system than one that encourages stands of descriptive text, which might be concatenated into a textual version of sequential story. The UI keywording activity could be designed to encourage the association of related images or the wrapping of stories around a single image. The girls thought was not necessarily important to have many pictures on a bead. They suggested one bead with lots of pictures or many beads with one each. Their critique was more object focused than story focused.

6 Conclusions

The StoryBeads were successful in that story fragments could be organized into collections and images described. It was clear from the first user testing that images were not sequenced into a linear story as in, for example, a film. Individual images were traded and described in oral stories, one image to one story or piece of story. A strength of the system is its ability to allow both personal and co-construction of story. Users can build their own stories, contribute to another user's stories or participate in a co-authored story. The redescription of story content using text was not a primary activity as it was imagined when the system was designed. The StoryBeads do encourage repurposing of content by physical manipulation, stringing and trading physical beads, by digital repurposing as images are traded to a new author and by the redescription of content as images acquire description histories over time.

In the future, the storytelling activity can be extended in few ways. We would like to build another version of the beads with scaled back storage capacity yet room for the distributed storytelling engine, a computational decision maker, as a way for the content to be searched and displayed. This would mean relieving the system of the intense computational load of shipping image data from memory to storage and from bead to bead so as to free up the processor for managing the storytelling algorithms. Image data could be stored as a referencing filename instead of the actual image and the users could connect and view their stories using a web browser connected to a central server which would hold all users' images. Another option for gathering images would be delivery of an image to projection screens in an architectural space. The infrared protocol could be adjusted to the IrDa standard to allow bead communication with other hand held or portable devices, such as cell phones or PDAs.

Another approach would be to increase mobility, meaning freedom from a desktop machine and the ability to construct stories while moving through the world. This would involve implementing another mode of communication for the beads, using a short-range wireless connection, instead of the nearest neighbor infrared interaction. Recording beads could also be added to the system to allow pictures to be taken, and annotated, within the system. This would integrate the activity of collecting stories into the necklace.

Aesthetically, as suggested by the girls in the test group, the beads could be more colorful. The plastic casings can be dyed or sandblasted to create effects on individual beads. Another option is finding ways to cast the beads directly into acrylic instead of in a resin case. This would only be feasible if the batteries did not need to be replaced by opening the bead cases, as is the case now.

StoryBeads is a new tool. The users will become more knowledgeable in their construction techniques, physical and cognitive, as the medium is exposed to the public and as authors use the tool imaginatively as they face the constraints and opportunities of the medium.

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