The Reading Glove: Designing Interactions for Object-Based Tangible Storytelling

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ABSTRACT

In this paper we describe a prototype Tangible User Interface (TUI) for interactive storytelling that explores the semantic properties of tangible interactions using the fictional notion of *psychometry* as inspiration. We propose an extension of Heidegger's notions of "ready-to-hand" and "present-at-hand", which allows them to be applied to the narrative and semantic aspects of an interaction. The Reading Glove allows interactors to extract narrative "memories" from a collection of ten objects using natural grasping and holding behaviors via a wearable interface. These memories are presented in the form of recorded audio narration. We discuss the design process and present some early results from an informal pilot study intended to refine these design techniques for future tangible interactive narratives.

Categories and Subject Descriptors

H.5.2 [**Information Systems**]: User Interfaces – *input devices and strategies.*

General Terms

Design

Keywords

Interactive Narrative, Tangible User Interfaces, Wearable Computing, Object Stories

1. INTRODUCTION

Abe Sapien picks up a discarded weapon from the wreckage. From across the room, Agent Manning snaps at him "Hey, Fish-Stick! Don't touch anything!" Abe regards him with bemused tolerance.

"But I need to touch it," he says, "to see."

"To see what?"

Abe runs his hand along the blade. "The past, the

future…whatever this object holds."

-Transcribed and paraphrased from Hellboy [7]

In the 2004 film *Hellboy,* the character of Abe Sapien possesses the ability to read the "memories" of objects by touching them with his hands. This paranormal ability, known as *psychometry* or *object reading*, has numerous occurrences in films, novels, comics, and games. The idea of being able to extract the history and future of everyday objects is a compelling one, with potent narrative implications. Imagine being able to experience the history of a fragment of the Berlin Wall or the spacesuit worn by Neil Armstrong during his first moonwalk. While this notion remains largely relegated to the realm of fiction, tangible user interfaces (TUIs) make it possible to author interactive stories that draw on the idea of psychometry as a metaphorical context for interaction.

In this paper we describe the Reading Glove: a prototype wearable user interface for interacting with Radio Frequency Identification (RFID) tagged objects in a tangible interactive narrative system. The Reading Glove extends the sensory apparatus of the interactor into a realm of meaning and association, simulating the experience of revealing the hidden "memories" of tagged objects by triggering digital events that have been associated with them. An interactor augmented with the Reading Glove need only touch a tagged object in order to experience a narrative tapestry of its past uses.

Previous work combining tangible computing with interactive narrative has emphasized the technical and design challenges of the hardware, while providing relatively little insight into the experience of narrative when mediated by a collection of objects. In this study, we explore the potential of tangible interactions to increase a reader's awareness of story objects as narratively meaningful. We first consider the relationship between objects and narrative, before discussing the ways in which existing prototype tangible storytelling systems have used objects. The central theoretical construct of our work is the notion of *semantically present objects*. To explicate this idea we propose a new interpretation of Heidegger's notions of "present-at-hand" and "ready-to-hand". We then discuss the design challenges of constructing the Reading Glove system. We close with a discussion of a pilot user study and consider the implications of this work for future tangible storytelling systems.

2. OBJECTS AS STORIES

Every object in our lives has a story to tell. The relationship between objects and stories is one with a rich history. People use collections of books, movies, artwork, and other objects to communicate and define their identities and personalities. Kleine et al. write:

> Possessions to which there is attachment help narrate a person's life story; they reflect "my life." One kind of strong attachment reflects a person's desirable connections with others. For example, one person's photographs signify "people who were important to me at one time in my life," a daughter's ring portrays her mother's love, and another person's piece of furniture reflects his family heritage. Another kind of attachment portrays key aspects of a person's individuality…In this way, attachments help narrate the development of a person's life story [11].

People use possessions and personal artifacts to construct personal narratives [10]. Objects also allow people to communicate across social, cultural, and linguistic divides. In sociology there is a notion of *boundary objects:* artifacts that exist between two different worldviews. Boundary objects are sites of negotiation between opposing perspectives, and allow members of different groups to translate between a familiar view and an alien one [16].

In cultural heritage and museum studies, collections of artifacts are assembled as touchstones for preserving historical knowledge. Personal objects are often used for memory elicitation in the preservation of cultural knowledge. The Australian Migration Heritage Center encourages the aging members of post-war immigrant families to construct personal stories out of their meaningful objects and documents [18]. These "object stories" are part of a broader exploration of *movable heritage* which they define as "any natural or manufactured object of heritage significance" [18]. By using objects from their lives, participants are able to communicate and preserve personal stories that might otherwise be lost.

Object stories have artistic and entertainment significance as well. Myst [6], one of the most significant early narrative games, revealed its story through meaningful collections of objects and narratively rich environments. Artist and writer Nick Bantock has written several books investigating the narrative implications of collections of esoteric items. In *The Museum at Purgatory,* Bantock uses unusual objects to conjure an image of a possible afterlife, while in *The Egyptian Jukebox* he composes assemblages of tantalizing objects as clues to an extended riddle [1-2] In 2008, Rob Walker and Joshua Glenn started the *Significant Objects Project.* They hypothesized that investing an object with fictional meaning would increase its material value. To test this theory they purchased inexpensive objects from thrift stores, and invited a group of volunteer writers to compose a piece of fiction for each object. Each object and story was then auctioned off online [20]. In this project the objects and stories existed in a dialogue with each other, with fiction arising from objects and imbuing them with shades of meaning.

In each of these cases, objects are more than simply utilitarian items with a functional purpose. Instead, they are gateways into a web of human associations and meanings. The above examples indicate the potential of object-based stories to evoke deeply personal narrative associations, in effect triggering unconsciously embedded narrative scripts. Newman argues that humans are predisposed to understand things in terms of narrative [15]. He describes this predilection for narrative in terms of a set of species wide archetypal narrative scripts embedded in the human psyche [15].

It is the objects themselves that are central to the creation of rich narrative meanings in these stories. We contend that any narrative system seeking to use object associations to evoke a story needs to foreground the objects as semantically meaningful. Stories told through objects have the potential to engage senses not ordinarily invoked in traditional storytelling experiences. Touch, taste, and smell are currently underutilized for the telling of stories and their potential as additional channels for narrative information remains unexplored.

3. PREVIOUS WORK
3.1 Other Systems

There have been several attempts to merge research in interactive narrative with research in tangible interaction. One popular approach has been to distribute narrative "lexia" – modular fragments of a larger story or stories – across a series of tangible objects. Holmquist et al. describe an object-based tangible storytelling system in which readers used a barcode scanner to retrieve video clips in a narrative puzzle [9]. This system only had five short video clips: two associated with specific objects from the story, and three associated with generic tokens. The authors claim that the goal of the interaction was to heighten the user's sense of involvement in the story, but indicate that the small number of story fragments was a severely limiting factor.

Mazalek et al. created a tangible narrative system called *genieBottles* in which readers open glass bottles to "release" trapped storytellers (genies) which reveal fragments of narrative information [14]. As with the work of Holmquist et al, the authors stated that the goal of the research was to allow computer stories to bridge the gap from the digital into the physical environment. However; physical interaction was limited to opening and closing the tops of three glass bottles and it is unclear what role, if any these served in the story beyond being containers for the narrators.

Both of these systems reduce their objects to the role of generic event triggers. In some contexts, the use of more generic tokens allows the reader to imagine her own story within the system. Budd and Madej designed PageCraft, a tangible narrative system in which children created animated digital stories using RFID tagged blocks on a physical game board [4, 12]. In their prototype, the tangible objects took a generic form in order to prevent their design from interfering with the creative process of the children using them. The system allowed children and parents to tell their own stories using the physical tokens to "record" the narrative into a digital animated sequence.

Mazalek et al. made a similar design decision when creating the graspable "pawns" for their Tangible Viewpoints project. They write "the abstract manner in which these figures evoke the human form allows them to take on different character roles given different sets of story content" [13]. In the Tangible Viewpoints project, these abstracted pawns were used to access

different character perspectives in a multi-viewpoint story. Each pawn represented a specific character, which would be surrounded by projected segments of associated narrative information. Interactors could access this information through the use of a small "lens-like" tangible object. In both PageCraft and Tangible Viewpoints, the objects themselves were designed to be abstract representations of the system's digital information.

In other tangible narrative systems, the relationship between the physical interactive items and their associated digital representations is less clear. The RENATI project places the bulk of the physical representation into a large "statue". The interactor stands in front of the statue while experiencing video clips associated with three different colored RFID tags [5]. Interaction with RENATI involves placing specific tags on an RFID reader (embedded in a clear acrylic hand) when prompted by the system. If the interactor selects the wrong tag, then the system presents a montage of conflicting perspectives on the story. In this case, the interaction is limited to deciding to obey the system or not, and is accomplished by essentially pushing a button.

These prototypes all focus on the mapping of *tangible object* to *system outcome*, which tends to emphasize the system *function* of the object rather than the narrative *meaning* of the object. In each of these examples, the link between the narrative information and the tangible objects is primarily utilitarian. Whether by design, or by designer oversight, the objects in these prototypes are functional first, aesthetic second, and semantic a distant third (or not at all). It appears that the objects in these prototypes really just function as physical buttons, activating narrative information that is often only loosely connected to the objects themselves.

We contend that one of the unique affordances of an object-based tangible narrative is the ability to emphasize each object as a site for *embodied narrative meaning*. In each of the examples above, the objects are *gateways* to meaning, rather than *loci* of meaning. This is in part due to the limitations of the technology employed in their creation and in part due to a failure to frame the interactions with the objects in a way that emphasized their physicality or their specific role within the narrative.

3.2 Theoretical Background

In this paper we propose a new approach to tangible object-based narratives that more closely couples the meaning of the object with the meaning of the story. This involves rendering the tangible objects *semantically present.* To understand what we mean by this, it is necessary to look at some of the theoretical and philosophical underpinnings of tool use and tangible interaction.

In *Where the Action Is,* Paul Dourish discusses Heidegger's notions of ready-to-hand and present-at-hand [8]. Dourish interprets the notion of present-at-hand to refer to situations in which tools "breakdown", suddenly becoming the focus of our attention. He contrasts this against the notion of ready-to-hand, wherein tools disappear from our perceptions and serve as invisible extensions of ourselves. The canonical example of these ideas is of a carpenter using a hammer. As long as the interaction is proceeding smoothly the hammer is considered ready-to-hand, seamlessly augmenting the ability of the carpenter to perform the task. However, should the carpenter slip and miss the nail or hit his thumb, the hammer "surfaces" and becomes present-at-hand: an awkward tool which is not performing properly and thus becomes the object of its user's attention.

To put this in a different context, it is possible to productively map Heidegger's notions onto Bolter and Grusin's concepts of *transparent immediacy* and *hypermediation* [3]. In their writing, interactions with mediated experiences exist in a state of immediacy, unless something happens to jolt the viewer into an awareness of the mediated nature of the experience, which they term hypermediation. Therefore, immediacy is a form of being ready-to-hand while hypermediation is akin to present-at-hand. This oscillation between two binary levels of awareness is sufficient for understanding functional tools, and for understanding passively mediated interactions, but tangible interactions – particularly those in which the tangible interface is a site of meaning – do not fit cleanly into this model.

We contend that it is necessary to reexamine these notions when attempting to understand the workings of tangible and embodied interfaces. In particular, we think that these notions do not account for the ways in which objects exist at an intersection of potential meanings. The two states described represent functional extremes: either invisibly functioning or presently malfunctioning. We think that there is a third, related mode of interacting with objects that is differentiated along semantic lines instead of functional lines. For the sake of discussion, let us call this notion "present-at-mind".

This idea of present-at-mind encompasses the ways in which we slip between different associative awarenesses while interacting with an object or tool. We argue that this notion of present-at-mind may be used to describe any situation in which an awareness of the tool as a *locus of meaning* occurs.

Thus, from a first-person perspective, I can use a hammer to drive nails and as long as I do not slip or hit myself it will remain invisibly ready-to-hand. But what if I become aware of the wear of the hammer's grip, which in turn puts me in mind of my father, to whom the hammer once belonged? What if this calls my attention to a place where he carved his initials in the handle? The hammer has not broken down as a functional tool, but is no longer an invisible extension of my hand. It has shifted into a state of being present-at-mind, due to a web of associative entanglements in which it exists, rather than to a breakdown of functionality. These entanglements are unique to this particular tool: a different hammer would not evoke the same reaction. In this case the hammer is not just a stand-in for any hammer or an extension of the body, but instead a specific hammer with a specific story to tell.

This awareness does not exist in isolation from the other two Heideggerian conditions. Certain types of breakdown can trigger this awareness: the roughness of the hammer grip wearing against the palm is sufficient to interrupt the flow of the work, but once that interruption occurs, the mind is free to explore a range of awareness and associations surrounding the tool. In this case, we would suggest that one of the roles of breakdown is as a possible gateway into a present-at-mind awareness that extends beyond the moment of breakdown.

In TUI research, one of the canonical properties of tangibles is a meaningful coupling of physical and digital representations [19]. In this case, the binary notions of ready-to-hand and present-at-hand become problematic as the operation of the tangible object as an interface device often involves paying attention specifically to the object. The incorporation of a third semantic vector allows this model to account for the relationship between physical and digital representations in a tangible interface. When the tangible is present-at-mind, it exists in the mind of the reader as a meaningful physical representation; however, as an interface device it remains ready-to-hand as a functional physical stand-in for its associated digital representations.

4. DESIGN PROCESS

In order to explore these theoretical ideas within a design space, we developed the Reading Glove. The intent of this system was to create an interactive object-based narrative and an interface that leveraged natural exploratory behaviors. These behaviors support the present-at-mind awareness of the relationship between the objects and their associated narrative information.

4.1 Selecting the Objects

We had several high-level design goals for the narrative. One of our central critiques of previous object-based narrative systems is a broad tendency toward using generic objects with few intrinsic narrative associations of their own. To address this, we resolved to write a narrative that existed in both a textual form and within a specific collection of meaningful objects. We set out to write a story that required the objects themselves in order for it to be complete; a story that could not be communicated purely through language. We thus chose to begin with the objects themselves, in order to help ground the writing within what would ultimately be the medium of its communication.

Figure 1. The 12 Narrative Objects

We had some rough criteria for object selection:

- Objects should invite touch. This might mean pleasing material textures or complex objects that could not be apprehended without physical handling.

- Objects should be mechanically interactive. We favored objects with moving parts wherever possible, or objects that opened and closed.

- Objects should fit together as a collection. We looked for objects with similar color schemes, and for objects that could conceivably come from the same place and time.

- Objects should support a wide range of uses, associations, and imaginings. This was a largely subjective criterion, but we wanted objects that could conceivably tell an abundance of stories.

- Objects should appear to have a history to them. For this reason, we looked for older items, with evidence of a lifetime of use.

After several weeks of collecting and assembling, we settled on a set of 12 objects (see Figure 1). These included (top to bottom and left to right) an antique camera, an antique telegraph key, a pair of silver goblets, a top hat, a leather mask, a coffee grinder, antique goggles, a wrought metal rose, a glass vase on a metal stand, a ceramic bottle, an antique scale, and a bookend with a globe on it.

4.2 Authoring the Narrative

The full narrative creation process using these objects is a subject for another paper, currently submitted, but here we provide a brief overview. With the objects selected, we explored the different possible narrative uses for each of them and categorized these narrative possibilities into loose themes. Next, we constructed a sequence of events that could be told entirely through object associations within one of these themes. Knowing the events and objects that would comprise the narrative, we sat down and wrote out the background and setting for a central character and narrative situation around which this story would revolve.

For each object's occurrence in the plot, we wrote a short piece of narration centered on that object. These narrative "lexia", when strung together, form a single short story, told through objects. Four of these objects had only a single occurrence in the storyline, while six of them occurred twice, for a total of sixteen different narrative lexia. These were all written in a first person past tense narration, and were recorded as sixteen separate audio files. These varied in duration with the shortest running 17 seconds and the longest lasting 38 seconds. The entire narration was 7 minutes long. In order to help the reader isolate each narrative lexia from the others, a distinctive chime was placed at the beginning of each sound file.

We wanted the story to make sense regardless of the order in which participants engaged the objects. We resolved to write a story about a spy who is betrayed by his own agency for political reasons and has to flee for his life. By structuring the plot as a puzzle which is being pieced together by the central character/narrator, we were able to reflect the fragmentary nature of the interaction within the form of the story. Like a puzzle, we designed each narrative lexia with "conceptual

hyperlinks" that served as subtle guides to unraveling the mystery. Thus, when a reader selects the camera, she learns about a roll of film which was hidden inside a coffee grinder. Each lexia also includes a direct reference to its associated object.

4.3 Designing the Technology

Psychometry, when it occurs in fiction, often requires that an object be held or touched in order to reveal its "memories". We wanted to simulate this "hands-on" interaction with our system. As with the narrative design, we established several high level goals for the creation of this system:

• Interactors needed to be free to move around unencumbered by cables or other technology.

• Interactors needed to be able to use both of their hands freely, without the need for additional overt interactive "tools" or other interface devices.

• The interaction needed to encourage participants to physically handle the objects in the narrative, without interfering with the experience of the objects.

A glove-based wearable interface had the potential to address most of these goals, provided it could be made unobtrusive enough to prevent it from inferring with the tactile experience of the objects. After investigating several different sensing technologies, we settled on Radio Frequency Identification (RFID), which would allow us to tag each object individually and discretely. In order to read the information on these tags we designed and built a portable RFID reader which could be embedded in a soft fabric glove. The Reading Glove hardware is comprised of an Arduino Lilypad microcontroller, an Innovations ID-12 RFID reader, and an Xbee Series 2 wireless radio. These components, along with a power supply, are built into a fingerless glove (see Figure 2).

Figure 2. The Reading Glove (large image), and components (top row, left to right): Arduino Lilypad Microcontroller, Xbee Wireless Radio, Innovations ID12 RFID Reader

The RFID reader is located in a small pocket on the palm of the glove, while the remaining components are secured within a pouch on the back of the hand. The glove has an adjustable

wrist strap and no fingers, which allows it to fit most hands comfortably. Figure 3 shows how these components are connected to each other.

Figure 3. Circuit Diagram for the Reading Glove hardware

The glove wirelessly transmits RFID tag information to a laptop computer running Max MSP, a programming environment which allows for easy prototyping of audio and video interactivity (see Figure 4). The signal is routed to a state switch in Max which triggers the playback of any associated media assigned to each tag.

Figure 4. Reading Glove Program in Max MSP

As the hardware reached completion we needed to make some decisions about the interaction logic of the system. The RFID reader transmitted a tag's ID every time it detected it, which

meant that an interactor holding an object or turning it over in her hands could generate multiple activations from the same tag. We felt that re-triggering the audio every time the tag was detected would frustrate the interactor, and ultimately discourage physical play with the objects. However, the audio clips required between 17 and 38 seconds to listen to, which meant that a simple delay between activations was not a satisfactory solution. A delay had the potential to make the system feel unresponsive, or non-functional. To solve this problem we chose to "lock out" any given tag after the initial detection event, rendering it inert until a new tag was triggered. This meant that if an interactor wanted to interact with an object multiple times, he would need to switch to a second object, and then return to the first.

For objects with multiple lexia, we were faced with the dilemma of how much authorial control we wanted to exert over the reader's experience of the different fragments. If we configured the system to play these in chronological order we would be structuring the way in which the story was presented, at least at an intra-object level. We were concerned that doing this would discourage interactors from exploratory interactions with the objects by quickly revealing the limitations of the available options. We made the decision to instead have the associated lexia presented at random, knowing that this was not a perfect solution. The random triggering of the lexia on an object meant that it was much more likely that an interactor would miss a fragment of the story; however it rewarded sustained interaction and exploration.

One final design challenge was discovered during our initial testing of the finished Reading Glove. We had initially set out to make the tags on the objects as unobtrusive as possible, in order to avoid interactions with the tags as "buttons" instead of with the objects themselves. This meant finding creative ways to disguise the tags on the objects without interfering with their ability to be read by the glove. Unfortunately, it quickly became evident that this was going to be impossible. The passive RFID tags work through principles of induction: when the electromagnetic field generated by the reader is intercepted by the antenna on the tag it *induces* a small current in the tag, which is enough to power a tiny transceiver attached to a tiny piece of memory containing the tag's identification code. The effective range of this system is ordinarily a few inches, however, when the tag is placed in proximity to a metal object this range drops substantially or disappears entirely, depending on the metal. During the object selection phase we were unaware of this constraint and so 4 of the 10 objects used in the story were comprised of enough metal to render any tags in direct contact with them inoperative. This forced us to abandon our initial goal of disguising the tags entirely.

Instead, for the four problem objects – the metal rose, the antique camera, the silver goblets, and the telegraph key – we located the RFID tags on paper tags, wrapped in brown duct tape to blend in with the color-scheme of the objects. The remaining objects were tagged directly, using the same brown duct tape as a visual indicator of the tag's presence. One participant remarked that the paper tags made the objects feel like "artifacts from a museum collection". However, this meant that each tag had a clear visual indicator of its presence on an object.

4.4 Testing the Technology

We have not yet performed a formal study of this work, but we have run a set of informal user trials, intended to interrogate some of the above design decisions in preparation of doing a more extensive study.

Participants, selected from the graduate student population, were asked to interact with the Reading Glove story for as long as they liked. Each participant was given the same set of instructions, including information about the functioning of the glove. Each session was videotaped for future review and analysis. A short video of the studies may be viewed online [17]. Two of the seven participants did not speak English as their first language, which we were concerned would problematize their experience of the audio narration, however only one of these participants experienced any difficulty with the story, which we discuss below.

We structured this study to focus on several questions intended to explore the functioning of the objects as *semantically meaningful* artifacts and the operation of the glove as a natural interface:

1. Could participants successfully piece together and recount the basic story?

2. Could participants map specific objects to specific narrative information and themes?

3. Was there a correlation between time spent engaged with the objects and the comprehension of the narrative?

4. Did the glove-base interaction qualitatively change how interactors approached the objects compared to a non-wearable version?

To test the first three questions, we asked participants to re-tell the story to us, and asked targeted questions about specific objects. To test the fourth question we split the participant group in half randomly. One group interacted with the objects while wearing the glove and the other group was instructed to leave the glove palm-up on the table and scan the objects over it. Due to time limitations, only seven participants were able to complete the study, with four wearing the glove and three scanning objects over a stationary glove. With such a small study population we cannot draw generalizable conclusions; however the anecdotal evidence and critiques from the participants provided valuable insight into certain aspects of the Reading Glove's design.

One concern with this study was that the population from which the participants were drawn was not wholly representative of the general public. Participants in this study were "tech-savvy" graduate level researchers, many of whom had a direct interest in games, narrative, tangibility, and interaction. In our experience, graduate students interacting with research prototypes tend to get caught up in trying to second-guess the technology. Given that our goals for this study were to critique the design of the prototype this was not necessarily a drawback in this case. The pilot study ended up bearing a close resemblance to a process of expert review. At this stage in the design, we believe that this is a suitable and valid mechanism for critiquing the work.

Our biggest concern with this first prototype was that participants would allow the novelty of the interaction to

distract them from the narrative content. The system as designed is meant to be *read* rather than *played with*, and we worried that participants would grow impatient with the length of the audio files, or that the oral nature of the story would prove inaccessible to participants accustomed to visual and textual narratives. We were pleasantly surprised when six of the seven participants took the time to thoroughly "read" the story. Unsurprisingly, there seemed to be a direct correlation between time spent engaged with the prototype and overall narrative comprehension, across both conditions. Table 1 shows the time each participant spent interacting with the system before deciding to stop reading.

Of the seven participants, six were able to successfully recount the central details of the story. Only Participant 4 was unable to reconstruct the sequence of events when asked to. To a certain extent this was likely due to language comprehension issues, as Participant 4 was not entirely confident in her English language abilities. This might also account for her taking less time to interact with the system than the other participants, who all had a greater mastery of the language.

Table 1. Participants' Reading Time

Condition	Participant #	Time Spent Reading
Wearing Glove	**Participant 1**	**12 min 26 sec**
	Participant 2	**10 min 46 sec**
	Participant 3	**12 min 12 sec**
	Participant 4	**7 min 3 sec**
Not Wearing Glove	**Participant 5**	**12 min 58 sec**
	Participant 6	**11 min 59 sec**
	Participant 7	**12 min 53 sec**

When asked to describe the role of specific objects in the story or specific object themes, all participants were able to make meaningful connections, regardless of which group they belonged to.

4.4.1.1 Touching & Triggering

Interestingly, for at least one of the participants the glove-based interaction interfered with her ability to engage with the objects to the extent that she desired. When asked what she liked about the interaction, Participant 1 said "I like that I could touch things…I love touching things! When I go to a museum I suffer because I can't touch things." This excitement over touching the objects interfered at first with her ability to access the narrative information, because she would pick up an object and trigger an event, and then would set the object down and want to play with other objects while listening to the first event. Unfortunately, picking up new objects triggered new events, interrupting the previous lexia before she had finished listening to it. She expressed frustration over the pacing of the system saying "Even though I was able to touch I couldn't really touch them as I wanted…I can touch, but I have to wait so it was really slow when I had to wait, and I wanted to keep touching things and inspect them, but I wasn't able to fully finish inspecting them until I was finished hearing [the audio triggered by the initial touch]."

Although she was not happy with the ways in which the glove limited her exploration of the objects, after the first time that she inadvertently triggered an event, she learned to only handle objects when she wanted to learn more about their role in the narrative. This raises a design question: had she been able to interact freely with any object without triggering responses, would she have been able to maintain a coherent mapping of which lexia were related to which object? We discussed how the interaction could be changed to better satisfy her expectations, ultimately concluding that had she been in the second group that was not wearing the glove that she would have had a more enjoyable interaction.

We can apply the terminology introduced above to this situation to gain a better understanding of what was going on. When Participant 1 first picked up an object and received the audio feedback the object was ready-to-hand, or transparently immediate. In this situation, the object operated as the instantiating point for the narrative event. When she set this object down, however, and picked up a new object, the associated narrative event interrupted this immediacy, creating a moment of breakdown where she was forced to grapple with the objects as interactive instruments, rendering them present-at-hand or hypermediated. In order to correct for this unwanted behavior, she was forced to re-engage with the first object, and to stay engaged with it while experiencing the associated lexia. This creates conditions that foster a present-at-mind experience of the object, by encouraging the interactor to linger on details of the object that might otherwise be passed over.

4.4.1.2 Memories & Objects

Most of the participants commented that they enjoyed the way in which the story fit together like a puzzle, and many of them commented on the ways in which the objects served as external referents for the story content. Participant 2 remarked that "it was interesting how I could tie specific memories to specific objects."

Participant 3 said "I really like the fact that in addition to the audio you have these, sort-of touchstones, so like you can go back and listen to that part of the story, you have like…a visual. Just like in real life if you're remembering something, like if you're looking around your room and you see…'I remember getting that statue at GenCon' or something. So having that visual touchstone as a memory holder I think is a cool thing." Participant 7 also enjoyed the objects, and also remarked on his general enjoyment of non-linear narrative. In these cases we see evidence of the participants engaging the objects at a semantic level, which we frame as present-at-mind.

This non-linearity presented far fewer problems than we had initially anticipated. Participant 2, for example, never listened to several important pieces of the story. However, when asked to recount the chain of events he was able to fill in the gaps in the story based on his understanding of the lexia on either side of the missed pieces. Aside from Participant 4, Participant 6 had the most difficulty constructing a picture of the narrative. When asked about his experience he said that he was considering each narrative lexia as an isolated "allegory", and that he felt the overall message was "too subtle" for him to grasp. This may have been in part due to the path that he took through the objects, although further analysis of each

interactor's "navigation" of the story is needed before this can be fully understood.

In observations of the relationships between the participants and the objects across the two groups, it was clear that the group wearing the glove spent much more time handling the objects, playing with them, and generally engaging with their physicality. The three participants in the second group all exhibited the same interaction pattern. They would pick up an object, scan it over the glove, and then set it back down on the table while they listened to the associated audio clip. We do not have enough data to conclude whether or not this had a measurable impact on the participants' narrative comprehension, however. This initial study suggests that the glove based interaction may well afford a richer experience of the tangible objects.

5. CONCLUSIONS & FUTURE WORK

The initial testing of the Reading Glove indicates that it has the ability to communicate a rich and detailed non-linear narrative experience that is largely grounded in physical artifacts. More time needs to be spent with the video data of the pilot study before any further work can be done on this project, however an obvious next step is a more formal controlled experiment. In particular, it would be interesting to compare a version of the story with the objects against a version using generic tokens.

Our observations of the initial round of interactions have suggested possible quantitative measures which may be used to triangulate both the observations of the interactors and the analysis of the interview data. In particular, we think it will be very interesting to combine coded video data with system logs in order to get a clear picture of how long each participant is interacting with each object, and in what order the participants are encountering the narrative lexia.

We would also like to put this system in the hands of a less tech-savvy population. These initial studies helped us to learn where the system broke down, what things interactors found confusing, and what information should be provided to the participants before beginning. We intend to use the knowledge gleaned from this study to construct a more formal protocol to further investigate this system.

In this paper we have presented a new wearable interface for tangible interactive storytelling, inspired by the paranormal notion of psychometry. Psychometry represents an extension of the human sensory system into an external realm of meaning and association. Our system augments the semantic perceptions of the interactor, revealing a stratum of memory encoded in a collection of compelling objects.

One goal of this system was to author an object-based story where the objects were *loci* of narrative meaning. In order to understand this, we proposed an extension of the Heideggerian notions of present-at-hand and ready-to-hand, which have been used in HCI to understand the ways in which tools are more or less "visible" at a functional level. We argue that in order to understand tangible interfaces at a narrative level it is necessary to consider a third vector: present-at-mind. In order to explore a semantically present tangible interface in greater detail, we designed the Reading Glove system, which uses a new authoring methodology to couple story events and associations

with physical artifacts. The iterative design process of this system demonstrates an integrative approach to tangible storytelling, and that the initial success of the prototype indicates the value of this method. We believe that for tangible storytelling there needs to be a close relationship between the content of the system and the design of the interaction and tangibility. In order to accomplish this, the design process needs to be able to address both of these concerns in dialogue with each other.

Our initial testing of the Reading Glove, via an informal expert review process, indicates that it is possible to communicate a rich narrative experience along audio, visual, and tactile modalities. The pleasure which our interactors displayed in their interactions with the Reading Glove is encouraging, as was the ease with which they adapted to the wearable interface. We believe that by designing systems to be present-at-mind it is possible to author richly meaningful interactive experiences.

6. ACKNOWLEDGMENTS

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