

Experiencing the Reading Glove

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ABSTRACT

In this paper we describe the Reading Glove, a wearable RFID reader for interacting with a tangible narrative. Based on interviews with study participants, we present a set of observed themes for understanding how the wearable and tangible aspects of the Reading Glove influence the user experience. We connect our observational themes to theoretical notions from interactive narrative and tangible interaction to create a set of design considerations such as *enacting a role, ownership and permission, multiplicity of interpretations and boundary objects*.

Author Keywords

Tangible user interfaces, wearable computing, interactive storytelling, design

ACM Classification Keywords

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

General Terms

Theory, Design

INTRODUCTION

Many tangible systems claim to have a particular benefit of making the narrative or other content more “real” or more “engaging” by virtue of the tangible nature of the experience, but this claim is often not persuasively demonstrated. In particular, the impact of tangible and wearable design elements on the user experience of an interactive narrative has not been comprehensively explored. In this paper, we discuss the Reading Glove, a wearable interface that allows the user to engage with physical objects that are part of an interactive narrative. In previous papers we have discussed the challenge of authoring the interactive narrative content [20] and our

process of interaction design [19]. This paper presents the first study results on how using the Reading Glove impacts the experience of the story. Based on our study data, we develop a set of themes for understanding how the wearable and tangible aspects of the Reading Glove influence the user experience. We then identify areas of both challenge and opportunity in designing for tangible interactive narrative experiences.

RELATED WORK

There have been several attempts to merge research in interactive narrative with research in tangible interaction. One popular approach has been to distribute narrative fragments 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]. 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 [15]. Mazalek et al. also designed graspable “pawns” for the Tangible Viewpoints project, which were used to access different character perspectives in a multi-viewpoint story [14]. Unfortunately, all three of these systems provide little to no data on how users of the system experienced the tangible interface or the story being presented. Most of the discussion of these systems is oriented towards the technical challenges of the interface and sensor design. Our focus with the Reading Glove is on user experience and the meaning of the story and the system as interpreted by the participants. While a number of interactive systems have used a combination of glove-based interfaces and RFID technology, none of them have dealt specifically with storytelling. Instead, research with glove-based interfaces tends to focus on gaming applications [11, 13] or assistive and enabling technology [12]. The exploration of how users experience a story told via a tangible and wearable interface has not been undertaken in any detail.

THEORY

To frame our work, we present some theoretical notions from interactive narrative and tangible interaction design.

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Interactive Narrative

Hypertext

One of the earliest models of interactive narrative is the branching “choose your own adventure” structure, which matured into a new form of literature with the advent of hypertext fiction. In its most elemental form, hypertext consists of a system of narrative fragments, often referred to as *lexia*, interconnected by *hyperlinks*, which are navigated to form linear routes through much larger narrative spaces. Theorists and aficionados of hypertext positioned it as the next significant literary movement: one uniquely suited to the computational medium [5]. While the early promise of hypertext was never fulfilled, game narratives and interactive art pieces continue to investigate how to create engaging stories that can be encountered via a multiplicity of paths and support interactive exploration.

Narrative Parameters

These non-linear or open ended stories do not follow a classical narrative arc, however, and thus present unique challenges for both authoring the stories and ensuring that they make sense to readers encountering them in a variety of permutations. Bizzocchi defines a set of parameters for evaluating narrative experiences aimed particularly at game narratives which are open ended in this way [2]. These elements are: 1) Storyworld: the environment within which the game unfolds; 2) Characters: the beings that populate this game world; 3) Emotions: both the emotions shown by the games characters and those elicited in the player; 4) Narrativized Interface: how the narrative sensibilities are instantiated in the appearance and the functionality of the interface design; 5) Micro-Narratives: the smaller moments of narrative flow and coherence that occur within a broader context of game play [2]. Central to Bizzocchi’s framework is a move away from reliance on the notion of the “grand narrative arc” and a move toward understanding narrative as a multidimensional phenomenon. His concept of the narrativized interface is of particular relevance in the context of this paper [3].

Non-linear Narrative

Aarseth also looks at the ways in which traditional literary notions break down when confronted with nonlinear texts [1]. He makes a distinction between “text” and “script”: a script is comprised of the “visible words and spaces” while a text also includes a “practice, a structure, or ritual of use.” One consequence of this is that the experience of reading hypertext can be unsatisfying, as there is often a perception that the “real text” is somewhere just out of reach, and that all attempts to read the script as presented are inadequate experiences of the story. Aarseth describes this as a “metaphysical belief in a transcendental text” that is somehow outside the physical manifestation of a given story [1]. As we detail the design of the Reading Glove as a nonlinear narrative, we will return to this issue and consider how it might be overcome.

Hypermediacy and Transparent Immediacy

One of the most influential works in the study of new media forms was Bolter and Grusin’s *Remediation*, which introduced the concepts of *transparent immediacy* and *hypermediacy* [4]. In their writing, interactions with mediated experiences exist in a state of immediacy (often associated with immersion), unless something happens to jolt the viewer into an awareness of the mediated nature of the experience, which they term hypermediacy. In most interactions, people oscillate between these two modes. This state of oscillation occurs at the point of intersection between the reader and the media artifact: the interface. Bizzocchi’s notion of the narrative interface provides a useful way for thinking about that point of contact, by exploring how narrative sensibilities in the interface can reduce the disruption to transparent immediacy that occurs when a reader experiences hypermediacy.

Tangible Interaction

Boundary Objects

One of the unique affordances of a tangible storytelling system is its ability to leverage the tactile and associative properties of physical objects. There is a rich history of object use for narrative communication, elicitation and preservation. Historically, objects have allowed 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 [17]. Cassell has developed a series of such boundary objects to support storytelling and story listening in children, including Storymat and SAM the CastleMate [6]. In our the Reading Glove system, we treat the objects as situated between the world of the fiction and the world of the reader. They are material manifestations of the fiction, and are a very literal example of a narrative interface.

Heidegger

In our previous work [19], we presented an extension of Heidegger’s notions of ready-to-hand and present-at-hand as framed by Dourish [7]. 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. In some ways, Heidegger’s notions are very similar to Bolter and Grusin’s concepts of *transparent immediacy* and *hypermediacy* [4]: we see transparent immediacy as a form of being ready-to-hand while hypermediacy is akin to present-at-hand. While this oscillation between two binary levels of awareness is sufficient for understanding functional tools, and for understanding passively mediated interactions, we believe that this model misses a crucial aspect of lived experience that becomes particularly relevant when

working with TUIs. We argue that this binary model ignores the critical role that semantic meaning and context play in our relationships with designed artifacts. Heidegger's two states 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. We term this semantic engagement "present-at-mind" [19].

Present-at-mind may be used to describe any situation in which an awareness of the tool as a *locus of meaning* occurs; it encompasses the ways in which we slip between different associative awarenesses while interacting with an object or tool. This can be elucidated by extending the canonical example of someone using a hammer: 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. However, should I slip and miss the nail or hit my thumb, "breakdown" occurs and the hammer becomes present-at-hand: an awkward tool which is not performing properly and thus becomes the object of the user's attention. 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: it is present-at-mind.

In TUI research, one of the canonical properties of tangibles is a meaningful coupling of physical and digital representations [21]. In this case, the binary notions of ready-to-hand and present-at-hand are insufficient because 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 object or interface 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. The notion of present-at-mind provides us with a powerful frame for designing and understanding semantic interactions in tangible systems.

The Turn to Practice

A number of frameworks for tangible interaction exist which might be brought to bear on a system like the Reading Glove. For this study, we turn to the recent work of Fernaeus et al. They describe the "practice turn" in

design [8], which they situate as arising out of Suchman's critical take on HCI and AI from the 1980s [18] and currently exemplified in the work of Dourish on embodied interaction [7]. The turn to practice is characterized by bringing the embodied, social, contingent and subjective aspects of human interaction to the fore, while de-emphasizing the objective and dualistic approach that formerly dominated HCI as a field of study. Fernaeus et al. lay out a set of four design ideals that highlight the conceptual shifts inherent in the practice turn, relating them specifically to designing for tangible interaction [8]. The first shift is from information centric to *action centric* interpretations of interaction. Instead of understanding the physical artifacts of TUIs as simply information-laden data representations or input/output devices, this ideal suggests that they be viewed as being resources for action within a shared space of physical activity. The second shift is from properties-of-systems to *interaction-in-context*. This suggests that tangible systems can be best understood as part of a larger setting of action and use, rather than as a separate and self-contained system. The third shift is from individual to *shareable use*, highlighting the collaborative and social functions of tangible systems. Finally, they discuss the shift from focusing on objective to *subjective interpretations*. This shift requires the designer to imagine the perspective of the user of the system and how they might appropriate and adopt the technology in ways not originally planned. Fernaeus et al. suggest that one consequence of the turn to practice is to focus design and evaluation efforts on understanding "how users make meaning through interaction, and what aspects they orient themselves towards and use in their specific interactional practices" [8]. This perspective is one we adopt in this paper, as we use our study participant's words and observed actions to explicate the personal meanings and orientations they constructed while using the Reading Glove.

SYSTEM

The Reading Glove is a wearable RFID glove that engages readers in an audio-based interactive narrative by allowing them to "extract memories" from tagged physical objects.



Figure 1. The components of the glove: Arduino Lilypads, XBee radio & RFID reader

The Glove and Objects

The interface consists of a fingerless fabric glove containing an Arduino Lilypad microcontroller, an Innovations ID-12 RFID reader, and an Xbee Series 2 wireless radio [Figure 1, left]. Interactors pick up objects associated with the story, each of which has been tagged

with an RFID chip [Figure 1, right]. When the RFID reader in the palm of the glove detects a tag, the tag ID is sent wirelessly to a laptop running MaxMSP. This triggers the audio playback of recorded story fragments associated with the object. Further details on the design of the technical and interactive elements of the Reading Glove can be found in our previous paper [19]. The glove interface was chosen to invoke the metaphor of “psychometry” or object-reading, the fictional power to invoke the memories and history of an object by touching it.

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 grew out of a specific collection of meaningful objects. We started with the objects, selecting ones that invited touch and interaction, that fit together in terms of the time and place they came from, and that lent themselves to having a wide range of uses, associations, and past history. Once the objects were assembled, we generated themes and narrative uses for each of them, building these gradually into a story that was uniquely rooted in the specific items.

The Story

The Reading Glove’s story is an espionage thriller about a spy who is forced to go on the run when his cover is blown. It includes several twists and surprises, and ends with him discovering – too late – that his own agency is involved in the plot to sell him out for political gain. The story is told in the first person, as if the narrator is relating events in his own past. Each tagged object is associated with two story fragments, ranging in length from 17 to 42 seconds. The total story takes 8 minutes and 50 seconds if played straight through, although when the story is encountered via the system, it is played in a random order and at least some of fragments are likely to be played multiple times. Further details on the design of the narrative content can be found in our previous paper [20]. One of the design goals of a modular narrative like the Reading Glove is to overcome the hypertextual difficulties raised in our discussion of Aarseth above [1], that lead to a discontinuity between the experienced narrative and the “imagined real narrative”. By making the interactions about “piecing together a puzzle” rather than about “choosing between alternatives” we bypass the challenge of a text with multiple contradictory possible paths. By providing the reader with an apprehensible set of narrative objects, we delimit the possible narrative space, and reduce the sense that there is “more story” waiting just out of reach.

Scenario of Use

A reader using our system is presented with a collection of artifacts arrayed on a table. The artifacts each have a tag attached to them, much like items in a museum or at an estate sale. The reader may pick up any of these objects, and explore its weight, its texture, its scent, and any mechanically interactive elements and moving parts that it might have [Figure 2]. Should the participant bring the

palm of the glove close to the tag on the object, a chime will sound and a piece of narration will playback, in which the object is prominently featured. Navigating the narrative consists of selecting objects in order to experience their physical properties, and to reveal the pieces of narration associated with them.



Figure 2. A study participant interacting with the objects

Each object has two different pieces of narration associated with it, and is featured at two different points within the narrative timeline. The first time a reader selects an object, he is given the chronologically first piece of narration associated with it. Should he return to the object a second time, the later piece of narration will play, and a third interaction will re-play the first piece of narration. In this way, readers may return to any point in the narrative to hear it again. The one restriction on this is that no object may be “activated” twice in a row; a reader must select a new object before returning to the previous one.

USER STUDY

One of research goals of the Reading Glove prototype was to investigate the effect of a tangible and wearable interface on the experience of an interactive story. In particular, we wanted to explore the impact of the unique affordances of tangible interaction with narrative objects to support the process of narrative meaning making and present-at-mind experiences. Once the system was constructed, we ran a small user study to investigate how people experienced the interactive narrative and the novel interface. The results of this study will be used to iterate the design of the system to produce a new version and for further studies. Here we present the design insights yielded by this first study.

Methodology

We conducted a study with 10 participants recruited via email from the graduate and undergraduate population of our school. Each participant was given a short tutorial on how to use the glove to interact with a set of generic objects. After this introduction, they were presented with the story objects laid out on a table and told they could interact with them for as long as they liked. When the participants indicated that they were finished with the story, we conducted a short interview asked them to fill out a survey. Our questions focused on two basic areas: their understanding of the story and their experience of the glove and the system as a whole. In this paper, we look primarily at the interview responses as well as some anecdotal evidence from observing their interactions with the system. The interview data was analyzed qualitatively, with two of

the researchers independently coding the interview transcripts for sections of interest. These codes were then arranged into a network of themes, highlighting areas where the researchers had produced similar codes and identified recurring patterns. Because of the non-linear path which readers would take through the story, and the complexity of the story itself, we did not think that all readers would emerge with a clear and accurate understanding of the story content. We hoped that they would come away with a basic grasp of the story, and have the experience of being immersed in the storyworld through the physicality of the objects and the interface.

Observed Themes

For each of the 5 themes identified in the data, we present representative quotes from the interviews and discuss the observations made. To preserve confidentiality, participants were assigned reference numbers instead of names.

Kickstarting Imagination

The first theme we identified was that participants reported that the presence of the physical objects helped to kickstart their imaginative immersion in the story. Participant 1 said “it was definitely a different experience with the gloves and the objects at hand, because I felt that it made it more immersive in a way. Yeah, you can definitely imagine the things happening.” Participant 7 said “It’s not like reading a book...it’s set up for you, there’s already a mood. Because when you read a book, you make up your own setting but in this case it was already set up.” That same person later described the system as “having your thoughts be projected in reality...when you’re reading a book it’s like it’s all in your head and the voices are all in your head and here it’s like they’re talking and you don’t have to think about it.” Similarly, participant 8 identified the visual properties of the objects as grounding the narrative in her imagination “I create scenarios...visual scenarios in my head when I’m reading so I have very specific ideas of what things look like. So what was different about this experience is that the prop cues made the creation of the visuals seem to occur more quickly without having to get into the narrative.” The look and feel of the objects set the scene for encountering the story, helping ease them into the mood and setting of the narrative. This can be seen as a benefit, in that it bootstraps immersion into the storyworld. It can also provide a cautionary note, however, in that part of a reader’s enjoyment of a story is in the use of their imagination. If the physical system over-determines the look and feel of a storytelling environment, the reader may find themselves less drawn into the story because there is less for them to contribute.

Engaging Multiple Senses

In addition to providing a kickstart to imagining the story, we found that the physically embodied nature of the experience provided multiple modalities for the participants to acquire specific additional information. In particular, the objects served as markers for the time period. Nothing in the text of the story identified the year or era that the

narrative took place in. In the interview, we asked participants to estimate the time the story took place in, and the majority of them were able to accurately guess that it was intended to take place around the turn of the 20th century, or the year 1900. Five of seven transcribed interviewees specifically make reference to the objects when attempting to determine what the year was, remarking that their feeling of the time period came from the attributes of the physical objects.

Participant 8 talked about how she read additional information into the objects when making selections about what to interact with next. She said she focused “on context and what I thought the objects meant in terms of that context. So if the storyline mentioned he was going to be outside, or going to the wharf, I’d pick up the globe because I thought maybe it represented travel, or if he was going outside the top hat because you put on a hat when you leave.” In both of these examples, the participants have used their physical experience of the objects to fill in gaps in knowledge about the story and to infer information about the narrative that is not provided within the “script” as read by the narrator. In Aarseth’s terms, this is a part of the narrative “text”, however it is a multimodal text that relies on the embodied situation of the participants for the creation of meaning.

Engaging with the Objects

One common claim for tangible interfaces is that they can provide scaffolding and structures for external cognition, by allowing users to offload information on to the physical arrangement of the tangible objects [10]. We found that very few of the participants made use of this feature of the objects. Our first participant, in fact, did not pick up any of the objects at all, and instead just touched the glove to the tags as they lay on the table. From that point on, when we laid the objects out at the start of a session, we tucked each of the tags under or inside the objects so that they had to be picked up in order to access them with the reader in the glove. This achieved the goal of getting people to pick the objects up, but the physical engagement with the objects was still less than we expected. Most participants picked the objects up, activated the story fragment, and then set them back down in approximately the place where they had been before. Participant 8 said in the interview afterwards that she felt a hesitation about playing with the objects too much or moving them around. “For me, if objects aren’t my own, I don’t like rearranging them or moving them because it doesn’t seem like mine.” Several participants also made an analogy between this system and the experience of encountering objects in a museum. This may have influenced the desire of people to handle the objects, as museums tend to discourage this behaviour.

There was one extreme exception to this rule, however. One participant engaged fully with the physicality of the objects, beginning by putting on the top hat and the goggles and examining each of the objects in some detail [Figure 2, left]. Later, in the interview, participant 10 described this

part of his interaction: "At the very beginning, as I was just picking up these fragments, what it was most enjoyable for me to do was to interact with the objects physically like putting on the hat, putting on the goggles because they're interesting objects in their own right. Figuring out how the coffee grinder works and just kind of letting things wash over." As his time with the system continued, he began to attempt to figure out the exact order that the story fragments should go in, by flipping back and forth rapidly between objects to hear them again and again. "It was cool, I feel like I went through these stage of first just enjoying these objects for their value, for their own physical value and just listening the narration and being like oh, it's a spy story, that's cool and then realizing I could actually put these together." As he began to figure out what objects came first, he sorted them into an ordered line [Figure 2, right]. In the interview afterwards, he recalls "I can't remember at what point I began to clue in that it would be possible to arrange things, touch things in an order to make things happen. But I did. And then I started trying to create a system for keeping track of that visually, you saw what that was like where I was trying to lay things out in a 2D grid".

Establishing Connection to the Character

Although people did not physically manipulate the objects as much as we had thought they would, one area where their response surprised us was in identifying with the main character of the tale. Participant 1 said "It's easier to relate to the main protagonist, in a way, when you have the objects at hand and you can... feel what he's going into in some ways." Similarly, participant 3 said "The person going to the place...he sees different objects and there is story behind it like what he thinks about it." The objects were seen as triggers for the story, not just for the participants, but for the character in the story, as if these were his objects and he was telling his story through them.

Participant 10, who rearranged the objects extensively, described this process as being motivated not just with attempting to understand the story but with connecting to the character. "You know, I really like the narrator, I really began to feel empathetic towards him. Me trying to arrange the sequence of events it's like me trying to remember what happened...And then the act of trying to put things together and then suddenly finding this continuity, it was like 'Aha! Yes, now that makes sense to me' and somehow it also felt like now it makes sense to the character too." Other participants formed a clear connection between specific objects and other minor characters in the story. One link that we explicitly designed into the story was that one of the villains was consistently identified as the "man in the goggles", and both of the story fragments associated with the goggles object talked about this man. In the interview, when participants were asked what they remembered about the goggles object, the majority of them were able to link the goggles to the villain character. We also asked about the vase and the camera objects, which were not directly linked to a recurring character but instead to crucial plot

moments or items in the story. We found that in general, participants were less able to provide a coherent association with those objects than for the goggles. The linking of character and object appears to have been more salient and memorable than other associations.

Attracting and Distracting

The final theme we have identified relates to the intrinsic qualities of the objects themselves, which provided both an attractive gateway into the story and, occasionally, a distraction from the story. The participant who engaged most fully with the objects relates "Ok, the best part about using the glove was at the very beginning, when I felt like I could put on things. What I really wanted was to take the glove...take the hat and put it on...I wanted to interact not just like...because I had to be really deliberate. (slaps hand on the table, as if activating a tag) Whereas I really wanted to fondle this thing and look at this...it's those kinds of things. Because these things have affordances that are so rich and so inviting."

This rich invitation sometimes got in the way of experiencing the story, however. Participant 2 recalls: "When I interact with a book...all the distracting things about the book are on the outside, so I can't see them when I'm reading. Sometimes I got caught up in...particularly the rose, I just really liked the way that the brass felt and I kinda got distracted by that." This description of getting caught up in the physicality of the experience is an example of what happens when the phenomenon of hypermediacy interferes with a reader's ability to experience transparent immediacy. The same participant commented on this again when asked what she found confusing about the experience: "This isn't so much confusing, but I found when I picked up stuff I was like looking for the tag, I wasn't necessarily looking at the thing."

DISCUSSION

We can apply the lens of theory to our five observed themes in order to derive some more general design recommendations for tangible storytelling systems. This list is not intended to provide an exhaustive framework for TUI design, but to explore several important concepts for future TUI research into interactive storytelling via our analysis of user experiences with the Reading Glove.

Design themes

Enacting a Role

The first ideal listed by Fernaeus et al. is to shift from considering tangible interaction as an information-centric activity to an action-centric one. Several of the participants remarked on the fact that the act of wearing the glove and interacting with the objects led them to connect with or empathize with the main character. The actions that they took with the glove could be seen as the actions that the character in the story took, allowing the user to take on his role through physical actions. We found it interesting that participants reported a strong sense of character association and empathy through the use of the objects. We see this as a manifestation of Bizzocchi et al's notion of Narrativized

Interface, in that the logic of the interaction placed the interactors into a bodily situation that paralleled that of the character. We believe there is something qualitatively different about handling an object that a character is said to have touched and held that is not captured through reading about that object on a page, or seeing it on a screen, or even manipulating a virtual version of the object in a game. This can be seen as an extension of the "mixed-reality" type of narrativised interface [3]. As a result of this effect the interface became a site for the other significant aspects of Bizzocchi's framework: character, emotion, storyworld, and micro-narrative. This is a poetic that is unique to tangible systems, and it entails an understanding that designing an interaction is also about designing a role for the interactor to enact with that system.

Ownership and Permission

In their discussion of interaction-in-context, Fernaeus et al. talk about social and personal factors that can impact human activity, one of which is the notion of ownership and attachment. We saw this play out in implicit and explicit ways in our study, where most participants evinced a hesitation to pick up and move the objects around to any great degree. One participant specifically said afterwards that she did not feel a sense of ownership of the objects and thus did not want to rearrange them too much. This suggests that when presenting people with physical objects that are meant to be interacted with, they should be given explicit permission or at least encouragement to feel a sense of ownership of these objects. Our objects were not *obviously* interactive artifacts or toys and we believe that the lack of explicit signifiers of interactivity served to reinforce pre-existing cultural conceptions of property and ownership that our participants brought to the experience. While the tags on the objects served to indicate that each object had an interaction point, they also signified a certain "artifact" or "heirloom" quality that we believe reinforced this approach, as did the apparent age and fragility of some of the objects. Some of the hesitation we observed was also likely a result of the experimental context of the interaction: we avoided explicitly instructing the participants to handle the objects, to prevent influencing their behaviour, however this may have had the unintended consequence of not providing them with sufficient permission to interact naturally with the objects. The novelty of the interaction was also a factor. With any new media form, a certain amount of literacy is required in order to get the most out of an experience. None of our participants had any prior experience with a system like this, which shaped how they interacted with it. If there is one lesson to be learned from this experience, it is that object-based storytelling systems need to either explicitly or implicitly provide their interactors with permission to engage with the objects.

Multiplicity of Interpretations

Fernaeus et al.'s final ideal, on shifting from objective to subjective interpretations, connects to our observations of how people engage with the objects. Participant 10's playful interactions with the objects, such as wearing them

or opening them up to look inside were not interactions that the system recognized in the sense of reacting to them, but they were also not disallowed by the system. The space was left open for participants to engage with the objects in whatever way was comfortable for them. Participant 8 also touched on this notion when discussing how she picked which object to touch next, i.e. she chose the globe after hearing a story fragment about taking a ship, because she thought the globe could represent travel. The semantic and aesthetic richness of the objects lent themselves well to this kind of personal, subjective meaning-making. Sengers and Gaver discuss the role of openness in design as potentially powerful tool exploring a range of interpretations, and the multiplicity of meanings created by the participants here demonstrates the value of this approach [16]. Here we also see evidence of our notion of present-at-mind interactions. It was clear that the objects were neither invisible interfaces to the narrative script, nor were they problematic hindrances to the function of reading. Instead, the participants treated the objects as an integral part of the text, to which they could bring their own sets of memories and associations. The objects were suspended between transparent immediacy and hypermediacy, and were able to serve as a point of imaginative departure for the interactors, and as a site for grounded knowledge about the story.

Boundary Objects

The final general theme that we have observed returns us to the notion of boundary objects. Interactive systems like the Reading Glove exist in a strange suspension between the (digital/virtual) world of the fiction, and the (physical) world of the reader. Objects in this system already invoke narratives, even without the explicitly narrative layer of the digital system to underlie them. A number of our participants commented that they were more interested in the objects than they were in the pre-recorded narration that we had associated with them. The intrinsic narrative texture that surrounds these objects was one of the central criteria for selecting them for inclusion in our story. Here again, we see the objects operating in the present-at-mind mode, by retaining meaningful associations from their own intrinsic physical properties, and conjoining them with the narrative meanings that we encoded within them.

Design Considerations

These four themes provide us with some useful criteria for the design of future tangible storytelling systems. Briefly summarized, we can recommend that designers:

- **Provide support for role-playing:** Narrative interfaces can provide opportunities for the interactor's embodiment to mirror that of the characters in the story, which in turn supports a richer association with character.
- **Give interactors permission to play:** The contextual framing of the interaction can unintentionally constrain the interactor's sense of freedom to engage.
- **Design for open interpretations:** Narrative engagement increases when interactors are free to make their own meanings within the system.

- **Use boundary objects to “suture” the gap between the conceptual world and the physical world:** Semantically rich interfaces which support a wide variety of interpretations and imaginings are able to act as intermediaries between the reader and the storyworld.

Much work remains to be done in order to further test these recommendations, and to uncover other poetics of tangible storytelling systems. This initial design exploration has provided us with insight about how users experience these systems, and about how to improve future design iterations.

CONCLUSION

In this paper we have analyzed the responses of study participants using the Reading Glove to experience an interactive narrative. We have used their reported experience to craft a set of design themes that articulate some of the benefits and challenges of merging tangible interaction with non-linear storytelling. We believe our themes of *enacting a role, ownership and permission, multiplicity of interpretations* and *boundary objects* have applicability outside of the system we have designed and can help guide design thinking about tangible and wearable interaction more broadly. We provide a set of recommendations for designers to consider when crafting tangible interactive narratives.

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