An Exploratory Study of Storytelling Using Digital Tabletops

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Mehrnaz Mostafapour

Abstract

Storytelling is a powerful means of communication that has been employed by humankind from the early stages of development. As technology has advanced, the medium through which people tell stories has evolved from verbal, to writing, performing on stage, and more recently television, movies, and video games. A promising medium for the telling of stories in an in-person, one-on-one or one-to-many setting is a digital table—a large, horizontal multi-touch surface—that can provide quick access to visuals and narrative elements at the touch of one's hands and fingers. In this work, I present the results of an exploratory study on storytellers' interaction behaviours while working with digital tables, and its physical counterparts of sand and water. My results highlight some of the differences in these media that can both help and hinder a storyteller's narrative process. I use these findings to present design implications for the design of applications for storytelling on digital multi-touch surfaces.

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Chapter 1 Introduction

Storytelling is an expressive form of art that can empower people to express their thoughts, beliefs, and emotions through narrative. The idea of storytelling often invokes thoughts of common media such as books, movies, and video games, but people tell anecdotes to one another every day around dinner tables, campfires and water coolers. When telling a story, people often make gestures with their hands, arms, and body to enhance the story, to build suspense, to exaggerate emotion, or to simply better engage the audience. Digital tables—interactive, multi-touch surfaces that can be manipulated with one's hands and fingers (e.g., FTIR (Han, 2005), DiamondTouch (Dietz & Leigh, 2001), or ThinSight (Hodges et al., 2007) are a promising medium through which these anecdotal stories could be told, as the audience and storyteller can gather around the table, much like they would at a dinner table or a psychotherapy session, and they support the ability to perform gestures that are immediately observable to the audience. The digital surface can then be used as a supportive medium that the storyteller can adopt to further enhance the storytelling experience; that is, their storytelling gestures could be made to have a greater impact on their story. A narrator can use on-screen objects to set the scene of a story, to draw paths or elements relevant to the plot of the story, or to improve a description of a story's characters (see Figure 1-1). People from different age ranges can benefit from narrating a story; however, in this work I focused more on the adult narrators.

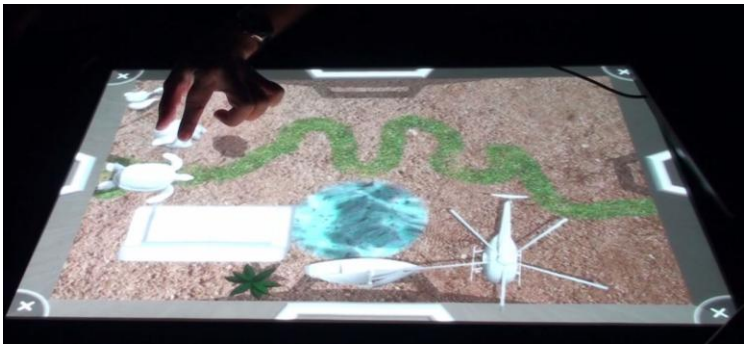

Figure 1-1 Shows a screen shot of a participant's story that benefits from visual artifacts to represent the place in which the story is happening.

1.1 Motivation:

Storytelling is a powerful means of communication that has been employed by mankind in a wide range of fields from pure entertainment to therapy or education (Polkinghorne, 1988; White & Epston, 1990). Adopting ideas, inspirations, and beliefs into a story and constructing narratives, not only exercises our creativity (Jalongo, 1995), but also improves our cognitive abilities as people make sense of events and incidents in their lives by developing meaningful narratives (Burner, 1986).

Given the importance of storytelling, several research prototypes have already been developed to support storytelling on digital surfaces (Helmes et al., 2009; Hancock et al., 2010; Daemen et al., 2007). However while the purpose of these applications is to enable users to create a story to illustrate, the focus of this research has been on the design of the applications, rather than on the development of a fundamental understanding of storytelling and the role of physical actions in the process of illustrating a story. People benefit from hand gestures while describing and discussing different subjects. Hand gestures can also be used to better describe a story or engage audience. In this work I have studied the way people benefit from hand gestures to manipulate on-screen objects to illustrate story events.

As Landauer (1998) describes, one of the basic steps in designing an interface is to comprehend what people do and how they prefer to perform it. Kuutti et al. (1996) assert an interface designer should know what activities users do, what actions are required to do them,

and what reason (motivation) is behind their actions. Given the absence of a study on users' interaction behaviour while telling a story, I decided to explore people's behaviour while creating and telling a story, with the intent to inform the design of such applications. More specifically, I studied what actions people do to incorporate common story elements (i.e., characters, setting, and plot) into a story, how they select their desired story characters, how they make a scene, and how they express story events through manipulating figurines. Understanding users actions and behaviours while telling a story, will help to inform the design of interactive technology that leverages the process of creating and narrating a story.

1.2 Research Problem

The general research problem was to understand users interaction behaviour while creating and narrating a story on a digital table. That is, what users do and how they prefer to do it while narrating a story. This question was broken down into the following questions:

- What are the common elements with which a story can be created?
- How do people represent those elements?
- How do people interact with objects in order to express story events?
- What are the potential design implications for a storytelling application?

1.3 Methodology:

I took the following steps to address the research questions:

1. Performing a literature review of the use of storytelling in entertainment, education, psychotherapy, and promoting collaboration and creativity and the state-of-the-art digital storytelling applications designed for each of those purposes.
2. Performing a literature review of HCI research methods developed for user interaction studies in order to find a proper method to follow.
3. Designing an exploratory study to investigate users' interaction behaviour, both in physical and digital environments while creating and narrating a story.
4. Analyzing the data gathered from the study and framing them in meaningful formats.
5. Providing a set of design recommendations based on the findings of this study.

1.4 Contributions

I had three main contributions in this thesis:

1- I presented a study that investigates users' interaction behaviours through the lens of common story elements (i.e. characters, setting, and plot) and provided insight into the way people interact with objects to incorporate these elements to create and narrate a story:

How they transition between including different elements to create a story.

How they select their story characters.

How they make a scene for their stories.

How they make use of gestures and actions to convey story events.

2- I provided insight about a set of new gestures on digital surfaces (i.e. narrative gestures), through which the narrator wants to convey a point to an audience.

3- I suggested a set of design guidelines for designing storytelling applications on digital tabletops, based on the findings of this study. The following is the list of design suggestions:

- To incorporate both browsing and searching features into the design of a storytelling application.
- To enable narrators to create and modify their story characters.
- To facilitate the process of adding characters to the scene in a way that does not distract the narrator from storytelling.
- To provide a storage area in which narrators can store their desired figurines and add them later during the story.
- To design the interface in a way that enables narrators to add their desired figurines to the scene all together or one at a time.
- To facilitate the process of adding and positioning figurines in a way that narrators can focus on designing the scene rather than struggling with working with the interface.

- To enable users to fix some of their desired figurines and make them unmovable on the scene so that they don't be hit and moved unintentionally.
- Since narrators prefer to be engaged in the process of manipulating characters and perform character actions, developing more engaging interaction techniques (e.g. using dragging instead of tapping) might be a better design decision.
- The more embodied narrators feel with manipulating objects the more they can focus on storytelling, so designers should highly value the development of appropriate interaction techniques specific to narrative applications.
- To promote the desire to represent character actions through amplifying character actions with computer animation.
- Designers should also be aware of narrative actions while designing interaction techniques for narrative applications, in order to avoid using them for a different purpose.

1.5 Thesis Organization:

The thesis is organized as follow:

- **Chapter 2. Background**: In this chapter I first described different applications of storytelling, and then focused on the state-of-the-art digital storytelling applications designed for each. I also represented the state-of-the-art research on users' interaction behaviour.
- **Chapter 3. Method of study and result**: In this chapter I elaborated on designing the study, which includes purpose of the study, participants, and the method of study. And then described the results.
- **Chapter 4. Findings:** In this chapter I presented a qualitative analysis of results that followed by suggesting set of design guidelines.
- **Chapter 5. Conclusion**: In this chapter I described how the research problem has been met and addressed concluding remarks and future work.

Chapter 2 Related Work

This chapter provides an overview of the literature relevant to studying interaction behaviour while creating and telling a story.

The related work is divided into four categories: *a review on applications of storytelling in the real world and digital applications designed to support them, storytelling applications designed on digital surfaces, hand gestures and interaction techniques for digital surfaces, and physical vs. digital interactions*. I first present a comprehensive overview on how storytelling is employed in different domains, and then described state-of-the-art digital applications designed for each domain using different types of new technologies. I then review the storytelling applications specifically designed for digital surfaces. Next, I present an overview of research on hand gestures and interaction techniques. Finally, I describe the related research investigating interaction behaviour both in physical and digital environments to develop design decisions.

2.1 Storytelling

Storytelling is a powerful means of communication that plays a substantial role in human life in many different ways. Storytelling not only entertains people, but also has been employed for several other purposes. In this section, I present an overview of how storytelling is employed in the domains of education, psychotherapy, and promoting creativity and collaboration. I then explain how digital technologies have been exploited to support storytelling in each domain.

2.1.1 Storytelling and Education

Humankind has used storytelling from the early stages of the development of language, in order to convey messages and to teach children. Studying the concept of narrative and its applications in education and learning has received increased attention since the 1970s. Researchers have shown that people perceive the world in a narrative manner and comprehend the cause and effect behind an event through narratives (Polkinghorne, 1988; Brookover, 1975; Burner, 1986). Pederson (1995) regards storytelling as the origin of

teaching and de Jalongo et al. (1995) discuss different ways in which storytelling can promote students' critical thinking, comminication, and self exploration skills. Nowadays, storytelling is not only considered as a generic teaching tool, but is also used as a teaching tool for specific majors such as management education (Abma, 2003; Gold, & Holman, 2001), health care education (Davidhizar, 2003; Haigh, & Hardy, 2011), learning language (Ryokai, Vaucelle, & Cassell, 2003; Tsou, Wang, & Tzeng, 2006; Peck, 1989; Fitzgibbon, 1998), and legal education (Craig McKenzie, 1992).

Given the advantages of storytelling in education, some researchers have exploited new technologies to support storytelling digitally. Edutainment is the combination of entertainment and education, in order to make the learner more engaged. For example, Song et al. (2004) created a system in which people can virtually explore a museum, and have incorporated a dynamic and live virtual tour guide that explains details based on the users' location. The Immersive VR Decision Trainer (Ponder et al., 2003) is another interactive narrative application, in which the trainees learn to make decisions through a simulation of an health emergency in a virtual reality environment.

In this thesis, I investigate the use of storytelling in a 3D environment on a digital table. While this previous research has explored the use of narrative in 3D virtual environments for the purposes of education, they have not considered the use of a digital table to present this 3D environment, which would not require expensive hardware, or immersive goggles that occlude the storytellers' view of the world around them. Moreover, this research has not focused on the physical actions and interactions required to tell the story, but rather on the design and development of the visuals.

2.1.2 Storytelling and Psychotherapy

The benefits of storytelling that are useful for education have also been shown to be effective in therapy. Narrative therapy was first introduced by Michael White and David Epston (1990), and was further promoted in psychotherapy by other researchers (Winslade, 1996; Speedy, 2000) Storytelling is considered as a powerful means of engaging in dialog with a client in psychotherapy sessions, as it causes the patient to be more engaged in the process, to

reflect his/her self into the story, and to touch deepest emotions. (Rennie, 1994; White, 2001). The use of storytelling has been developed and used for specific types of psychotherapy such as child psychotherapy (Brandell, 1984; Gardner, 1993; Friedberg, 1994), group psychotherapy (Schwartz & Melzak, 2005) and cancer psychotherapy (Chelf, 2000; Høybye, Johansen, & Tjørnhøj, 2005).

While there are few examples of research done to design digital applications in the field of psychotherapy (Wrzesien et al., 2011; de Sá et al., 2010) that make use of virtual reality technology, there is only one digital application developed to support expressive and narrative therapy (Hancock et al., 2010). This application is developed based on a specific kind of narrative therapy called sandtray therapy (Bradway & McCoard, 1997; Kalff, 2003), in which a patient expresses his/her feelings through constructing a mini-world in the sand and narrating a story to the therapist about this world. This method is currently used in the practice of therapy, both for children who cannot easily talk to a therapist, and for adults with cancer and Alzheimer's disease who have difficulty discussing or communicating their "inner disturbance", but can more easily do so through storytelling (Chelf et al., 2000).

Digital surfaces are a promising medium for narrative therapy, as they provide a shared display on which a patient can dynamically tell a story and express his/her feeling in real-time to a therapist. The findings of the work presented in this thesis can contribute to the design of future applications such as this.

2.1.3 Storytelling and creativity

In addition to its benefits for education and therapy, storytelling is an effective means of creative expression, as people can organize their thoughts and make sense of the world through creating a story (Burner, 1986; Friedberg, 1994). Creating a story is usually a challenging process in which a person puts different parts together in a way that makes sense. There have been several attempts in HCI to support creativity through narrative applications. Vaucelle et al, (2002) developed an application to enhance children's creativity They developed a toy that plays back a child's voice as the voice of story characters. This exciting experience may motivate the child to be more creative in a narrative engagement. Cassell and Ryokai (2001)

also developed and application that enables children to tell stories using stuffed animals. With their system, the child's voice is recorded and can be played later through the stuffed animal (i.e., to make it sound like the animal is talking). Children can practice creativity while working with this application by creating a story about these stuffed animals.

While there has been several digital storytelling applications that motivate users to create a story and be creative, this research has not focussed on the interactions and gestures people use to tell these stories, but instead on the design process and technology used to create these systems. In this work, I explore users' interaction behaviours during this creative process through a qualitative study, with the intent to inform the design of interfaces, such as these, that enable users to both create and narrate a story in real-time.

2.1.4 Storytelling, communication, and collaboration

This creative expression through stories provides a mechanism through which people can convey their thoughts, emotions and beliefs. Storytelling is considered to be a powerful means of communication and has been employed as a tool to communicate complex matters in groups (Santoro, Borges, & Pino, 2008; Wenckus, 1994; Valle , Prinz, & Borges, 2002).

Several attempts in HCI have attempted to support collaboration through storytelling using new technologies. OTTomer is an interactive narrative system in which children can learn how to cooperate with each other to free their planet. The process takes place in a room where the children can virtually experience the story (Valinho & Correia, 2004). Cappelletti et al. (2004) also developed a storytelling application using a DiamoundTouch digital table (Dietz & Leigh, 2001), to promote collaboration of children. In this application, children can drag a ladybug object to a recorder, where they can record a part of a story and play it later. Helmes et al. (2009) also developed an application for digital tables in which children can tell stories together by taking pictures of their desired objects to create story characters.

While the work in this thesis does not directly contribute to the collaboration side of storytelling, it instead contributes an understanding of how an individual creates a story, and may be used as a baseline to study how people can create a story together. On the other hand,

this thesis focuses specifically on the physical and narrative actions that people perform while telling a story, which is likely strongly connected to a story's communicative power. The work presented here can contribute to this understanding to guide designers to not interfere with this communication potential when designing digital storytelling applications.

2.2 Storytelling on Multi-touch surfaces

Most of the digital storytelling applications used for education, therapy, collaboration, and communication have been developed on a variety of hardware. However, there have been several examples of storytelling systems developed for digital surfaces. These prototypes support a variety of storytelling features, such as the ability to move and rotate photos (Decortis, Rizzo, & Saudelli, 2003; Helmes et al., 2009; Daemen et al., 2007) or 3D toys (Hancock et al., 2010), to draw on the background (Helmes et al., 2009; Daemen et al., 2007; Hancock et al., 2010), to record the story being told (Apple storykit..), as well as the ability to add one's own content, such as images from an existing photo collection (Daemen et al., 2007) or captured from the surrounding physical environment (Helmes et al,. 2009). The purpose of building these storytelling prototypes and applications has included enabling collaboration (Cappelletti et al., 2004; Decortis, Rizzo, & Saudelli, 2003; Helmes et al., 2009), and therapy for children (Hancock, et al., 2010), or persons with aphasia (Daemen et al., 2007).

Our work builds on this research by providing an understanding of how people make use of gestures to provide expressive power while telling a story, with the intent of informing the design of such applications and to both support this expression and minimize interference between expressive gestures and gestures used to interact. Specifically, my work uses the prototype built by Hancock et al. (2010) for the digital condition in my study. I describe this prototype in detail in the Study Design section 3.3.2.

2.3 Hand Gestures on Multi-Touch Surfaces

There has been a recent surge of studies that investigate gestures used on multi-touch surfaces in order to understand and develop natural, ergonomic, or novel interaction techniques (Morris,Wobbrock, &Wilson; 2010; Moscovich, 2007; Hancock, Carpendale, &

Cockburn, 2007; Wu & Balakrishnan, 2003; Rekimoto, 2002; Nielsen et al., 2004; Hinrichs & Carpendale 2011; North et al. , 2009) . While the focus of these research is to develop better interaction techniques for digital surfaces, I am working to understand the nature of interactions and gestures used while telling a story.

In this thesis, I investigate how people interact with objects in the context of storytelling, specifically how they manipulate objects to represent character actions, create a scene, or navigate the plot of a story. Therefore, the focus of this work is not to design specific interaction techniques, such as the number and combination of fingers used to interact with the objects (Wu et al. , 2006; Moscovich, 2007; Hancock, Carpendale, & Cockburn, 2007; Rekimoto , 2002), nor to identify people's expectations about what command a gesture should invoke (Morris, Wobbrock, & Wilson, 2010) , but to study the nature of interactions and physical actions that are used by participants to perform story events and character actions. I thus observe physical and digital interactions, using an approach similar to Hinrichs and Carpendale's (Hinrichs & Carpendale, 2011) but in the context of storytelling, rather than exploring content in a museum setting.

2.4 Physical vs. Digital Interactions

Comparing the method of interaction with objects in a 2D and physical 3D space helps to integrate aspects of physical manipulation into the design of multi-touch devices. For instance, Scott et al. (2004) studied collaborative interactions in the physical world to provide their territoriality framework that can be applied in the design of collaborative applications on digital tables. Terrenghi et al. (2007) studied the nature of interactions in a 3D and 2D world by asking participants to sort a set of pictures and to complete a puzzle in the physical environment and on a digital table. North et al. (2009) compared gestures used to manipulate many small objects in three different mediums, physical, multi-touch, and mouse, to understand the similarities and differences between the interactions used in these environments. These examples used controlled lab studies, where they asked participants to complete tasks in different environments. However, in this work, I observe how people express themselves through objects in different environments when telling a story, rather

than completing a work task. I also included a third condition (water) part way between digital and physical.

2.5 Summary of Related Work

In this chapter I explained how people benefit from storytelling in different domains and presented some examples of HCI research prototypes developed for each purpose. I then presented a comprehensive overview of the state-of-the-art interactive storytelling applications on digital surfaces. I then continued with demonstrating an overview of existing research methods for studying users' interaction behaviours on digital surfaces and narrowed this demonstration down to comparative studies in HCI in which researchers investigate the methods of interaction and manipulation of physical versus digital objects. In this method, researchers aim to gain an insight into the nature of interactions with tangible objects in order to recognize and understand users' interaction behaviour. This understanding helps with integrating aspects of physical interactions into the design of digital applications, while exploiting exciting digital features. In the following chapters, I describe the design of my study, which was inspired by this method of research.

Chapter 3: Study method and results

In this chapter, I describe the design and procedure of a qualitative laboratory study that aims to investigate people's interaction behaviour while creating and narrating a story, with the intent to inform the design of storytelling applications.

While there are several storytelling prototypes developed on digital surfaces, there is not yet a deep understanding of a narrator's interaction behaviour while creating and telling a story, and whether and how this behaviour differs from other digital surface interaction, such as work tasks or playing games. An understanding of this behaviour can help to provide insight into the requirements of such an application (Landauer, 1988), and my study aims to provide this understanding for storytelling applications.

To frame this investigation, I looked at narrative interaction behaviour through the lens of narrative elements identified in prior analyses of literature, to see how a narrator interacts with objects and makes use of hand gestures to incorporate these elements and visually creates a story. This literature suggests that a story usually consists of three main elements: characters, setting, and plot (Abrams, 1999; Magill, 1997). This analysis thus focused on how storytellers incorporate these elements into a narrative in order to create a story.

3.1 Study Methodology

Designing interfaces and interaction techniques to facilitate people interacting with digital technologies is often the goal of research in HCI. A common research method is to study and compare the nature of interaction with physical counterparts to the digital medium, to help improve the nature of interaction with virtual objects in digital mediums (Scott, Carpendendale , 2004 ; Terrenghi et al, 2007; North et al., 2009; Underkoffler, 1999). This comparison not only provides an insight into people's natural and preferred method of interaction, but also inspires designers to integrate aspects of physical interaction in the design of digital applications (Terrenghi et al., 2007). For instance, understanding that people tend to use both hands in an asymmetric way to interact with objects in physical conditions, has inspired designers to develop new, more effective interaction techniques for digital

surfaces in which users can perform actions with both hands working together (Terrenghi, 2007).

Consequently, in order to gain an in-depth understanding of users interaction behaviour, I conducted an exploratory study in which I compared the way people interact with tangible objects to create and tell a story (physical storytelling) to the way people interact with virtual objects to create and tell a story (digital storytelling). I analyzed participants' interaction behaviour to see how they make use of their hands to manipulate objects while selecting their story characters, making a scene for their stories, and representing story events and character actions. More specifically I looked at the order in which participants incorporated story elements into their stories, the way they chose their story characters (i.e. how they searched for their desired characters), the way they made a scene (i.e. how they pick, place, and position figurines on the surface), and how they manipulated figurines to represent story events.

I predicted that the interaction behaviour and the way people manipulate objects in physical environments might be different from virtual environment. The differences between users' interaction behaviours in these media can be analyzed and used as a source of design suggestions that can facilitate and improve users' interaction in virtual environments. Moreover, I expected the gestures used to illustrate a story might be different from the gestures used to do regular tasks (e.g., moving objects to locate or opening and closing menus) as illustrative gestures are used to convey a point so might be done differently from gestures used, for instance, to issue commands to the computer.

3.2 Storytelling Medium

There are a variety of digital mechanisms that could be provided to enhance the storytelling experience, including the ability to draw on the screen, to assemble images in a storyboard, or the use of an open-world videogame (e.g., Minecraft). In my study, I chose to use an existing storytelling prototype (Hancock et al., 2010) that was intended for use in a form of art therapy called sandtray therapy (Bradway & McCoard, 1997). Sandtray therapy is a technique often used for therapy with children in which the child tells a story to the therapist

in a physical sandbox using toys chosen from a shelf. By having a child make a scene in the sand, the aim is to have the child naturally engage in the creative expression of their own thoughts and feelings.

I chose this medium for several reasons. In particular, this prototype had already been designed with the specific intention of providing a medium for storytelling that has a physical equivalent (a sandbox). It is also used by therapists for the expressed reason that it is easy for most people to quickly engage in the storytelling process, without the intimidation of a blank page or canvas. Therapists also regularly use this technique in their practice, and so results from this study can have direct impact on the design of technology to support their work.

3.2.1 Storytelling on digital surfaces

People have been telling stories since before recorded history. While stories can include different sets of main elements, the basic and common elements of stories are usually defined as *characters*, *setting*, and *plot* (Abrams, 1999; Magill, 1997). In this section, I define these three basic elements of a story to provide a lens through which to investigate the way people create a story and to explore the gestures they use to perform that story in front of an audience. I connect these definitions to interaction by describing the open questions the study aims to investigate related to each element.

> ***Characters***. A character is a person, animal, or creature who takes part in a story's actions (Abrams, 1999; Magill, 1997).

During physical storytelling, characters can be conveyed through a combination of verbal utterances and visual representations of the characters themselves. While selecting characters is a fundamental step for creating a story, it is not very clear how people select their characters. Do they want to express all the characteristics of their story characters visually? Do they prefer to search for specific types of characters? Does browsing figurines help people to be more creative? Can noticing a figurine trigger people to make new stories?

> ***Setting***. The setting of a story is the time and place in which the story takes place (Abrams, 1999; Magill, 1997).

In physical storytelling, a narrator can convey the setting of a story again through both verbal utterances and on-screen content. The storyteller could describe the time of year or place in the world, could include a photo of trees losing their leaves, or could bring in 3D scenic objects, like trees or buildings. But, it is still not well understood how people would want to represent a scene when using physical artifacts to tell a story. How do they arrange scenic elements? How do they transition between two scenes in the same story? How does it affect the quality of the storytelling?

> ***Plot.*** The plot is a series of events and character actions that form a story (Abrams, 1999; Magill, 1997).

To convey a plot with figurines in sand, water, or on a digital table, the storyteller again can use a combination of dialog and visuals, but could also use animations or physical gestures to advance the storyline. The narrator can manipulate objects to convey specific character actions. For example, a wild character might move quickly across the screen, or a quiet character might tip-toe instead. While many options exist to convey character actions, it is not yet clear how people interact with objects to express story events through a digital multitouch surface.

While many options exist for people to incorporate these story elements, it is not yet clear how people express them through a digital multitouch surface. I thus conducted a study to elucidate these expressive gestures and requirements of such an application.

3.3 Study Design

As discussed in Chapter 2 (Section 2.3), researchers have heavily studied physical interactions to provide a basis for developing interaction techniques in digital mediums (Scott, Carpendendale , 2004 ; Terrenghi et al, 2007; North et al., 2009; Underkoffler, 1999). This method of research inspired us to study and compare how people narrate and perform story events in both physical and digital conditions. This comparison can help provide an in-depth insight of the nature of actions used to interact with objects, and users' behaviours, while telling a story in physical and digital environments. I thus performed an observational

study in a lab setting in order to observe how users create and narrate a story in three different media: a physical sandbox, a tray of water, and a digital sandbox. My aim was to explore and compare how users interact with tangible and virtual objects to create and convey a story to an audience. Therefore, participants were asked to tell a story in the environments using both tangible and virtual objects. In this way, I could observe what the common steps are through creating a story, and how participants manipulate objects in each environment to convey story events. This study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo (See Appendix C).

3.3.1 Participants

Twenty-nine undergraduate and graduate students participated in this study (11 female, 17 male). Their ages ranged from 19 to 45 years (*Mdn*=26). Six participants (21%) did not own and had never used a multi-touch device before. Among the twenty-three who owned a multi-touch device, such as a smartphone or tablet, twenty (87%) had used the device for more than a year. Only two participants (7%) had worked with a digital table before. Each participant was thanked and received a $10 gift card to a local establishment.

3.3.2 Apparatus

To understand the nature of interactions while illustrating a story participants were asked to illustrate a story in digital and physical environments. In physical conditions I tried to replicate the setting in a sandtray therapy session in which the patients were provided with a tray of sand and a set of figurines placed in shelves to choose from (Kalff, 2003). In the digital condition I used the Sandtray application (Hancock et al., 2010) which provides a simulated virtual setting of a sandtray therapy environment for both adult and children.

In the digital condition, participants created and told a story on a SMART Table, a rear-projected tabletop with a 71.5 cm (diagonal) multi-touch screen. The table's surface is 91.5 cm × 74 cm with a resolution of 1024 × 768 pixels and a height of 64.5 cm (See Figure 3.1). The software used for the study on the digital table was Hancock et al.'s sandtray application (Hancock et al., 2010) (See Figure 3.3). The Sandtray application is a java-based program

which supports multi-touch interaction (See Figure 3-8). This application includes three main drawers; the characters' drawer includes a set of figurines (See Figure 3-4), the paint drawer enables users to draw on the background (See Figure 3-6), and the resizing drawer enables users to resize figurines (See Figure 3-7). In the digital application the figurines were placed in a drawer to overcome the space constraint.

This prototype supports the telling of a rich narrative by enabling narrators to move and rotate objects both in a 2D and 3D space (See Figure 3-5). Narrators can move objects on the surface with one point of contact, and rotate them in a 2D space through two points of contact. These same two points can be used to lift or lower an object by spreading them apart or pinching them together. In order to rotate objects in a 3D space, narrators need to have two fixed points of contact and use a third touch to rotate the object in the space along any desired axis. For a more complete description of the implementation of this interaction technique, see Hancock et al. (2007) and Hancock & Carpendale (2010).

In both the sand and water conditions, participants completed the story in two 90 cm × 70 cm trays with a depth of 16 cm, one filled with sand and the other with water. The top edge of both trays was adjusted to be equal in height to the SMART Table. The seat was adjusted so participants could easily reach all the available areas on the digital table and within the trays. A set of different toys was provided next to the two trays (See Figure 3.2).

Note that a rabbit, a turtle, and a tree figurine were provided in all the environments, but the other physical and digital figurines were not similar in any way. Two groups of toys were provided in physical conditions, including a group of 6 decorative items and a group of 44 animal figurines. Some of the toys were specifically made for water (Bath toys), so that they float on water and do not sink. Participants could choose any of the toys for both the water and sand conditions, regardless of whether they were bath toys (i.e., intended for use in water). Also 161 figurines were provided in the digital table from which 6 figurines were different types of tree and flowers figurines. A rabbit and a turtle figurine were among these figurines. The rest of figurines included some animals, some fictional characters like wizard, some furniture figurines like coach, and some transportation vehicles like airplane or car.

Note that people can draw on sand by digging in it, which is why a painting tool was provided in the digital condition to enable users to draw on the background if they wish. Participants were not able to draw on water, but they could use figurines to decorate the background (e.g. a participant placed a butterfly on the water and said that this is the finish line).

Note that I decided to use an existing application (as it is) to replicate a virtual environment of a sandtray therapy setting and used a sand and water tray with a set of figurines to replicate the sandtray therapy setting in physical environment. The focus of this work is more on studying interaction behaviour and hand gestures of narrators while manipulating figurines to create and tell a story. And the results and conclusions extracted from this study are not related to the number of figurines or drawing tools provided in the study.

Figure 3-1: A digital table.

Figure 3-2: Physical conditions' setup.

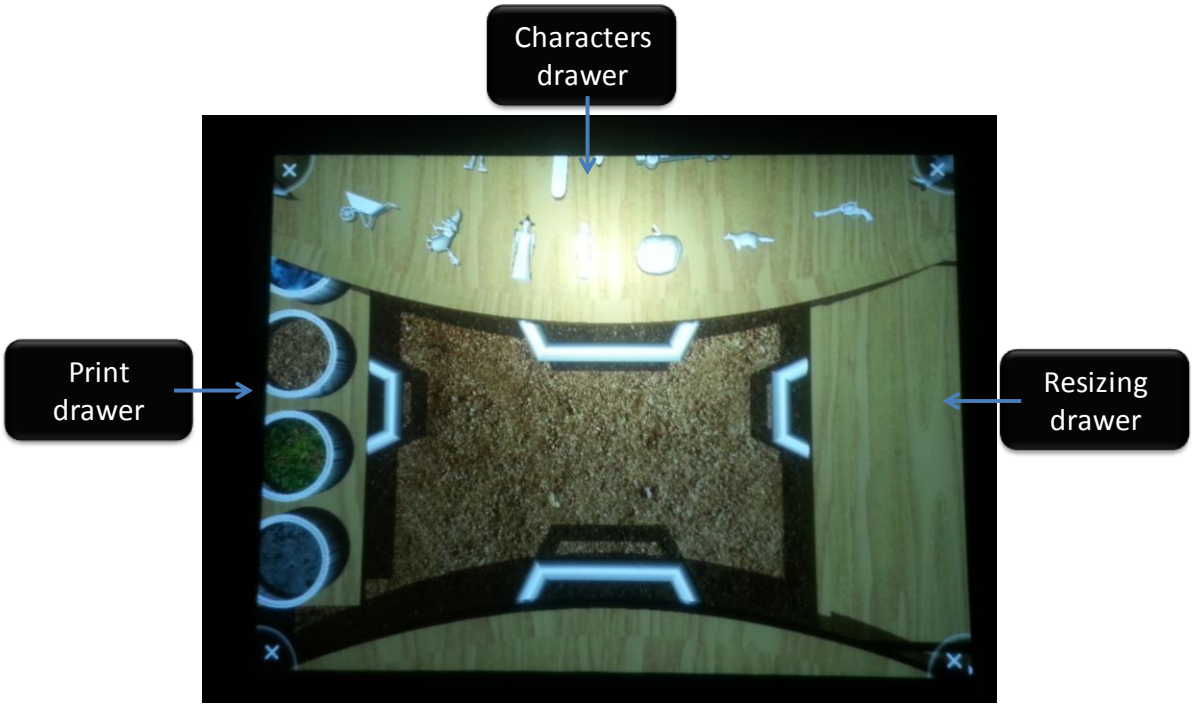

Figure 3-3: A screen shot of the Sandtray application.

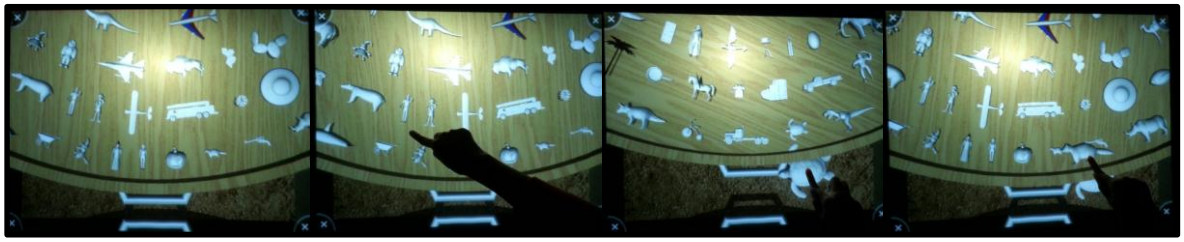

Figure 3-4: Characters Drawer (Picking two figurines from the drawer).

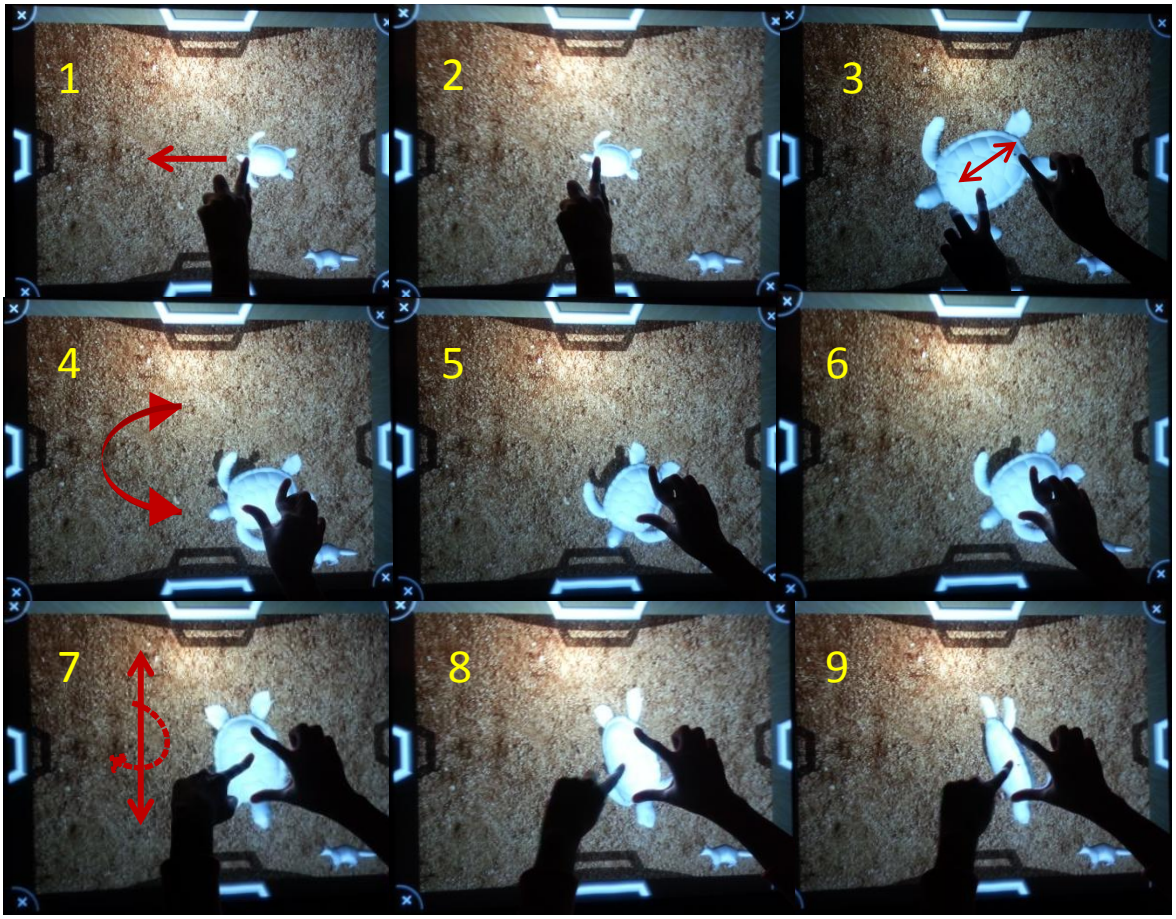

Figure 3-5: Manipulation of objects. Image 1 and 2 show that a user is dragging a turtle through touching it. Image 3 shows a turtle is lifted through spreading figures apart. Image 4, 5, and 6 show that a user is rotating a turtle through touching it and rotating it with two fingers . Image 7, 8, and 9 show that a user is rotating a turtle in a 3D space through fixing it with two fingers and rotating it with a third finger.

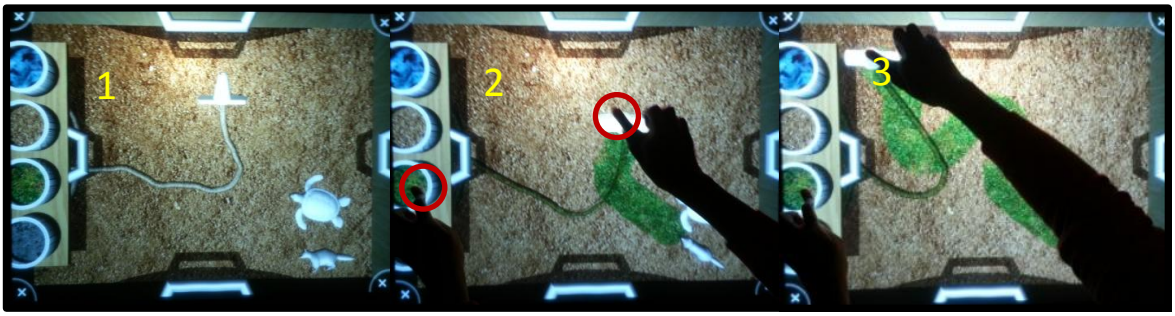

Figure 3-6 shows a user that is using the paint drawer to draw on the background. In image 2 and 3 the user is holding one finger on the green color and is drawing a path of grass by moving the nozzle on the background.

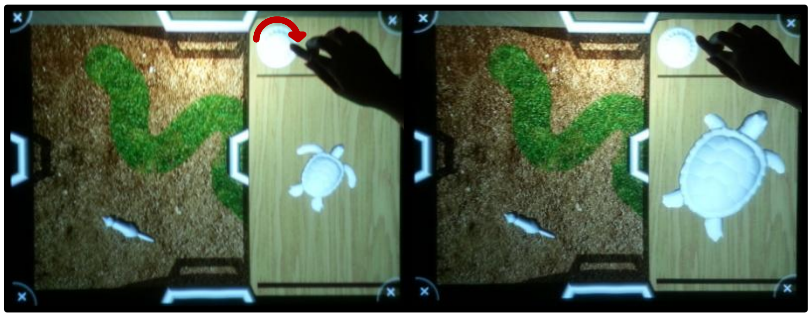

Figure 3-7 shows that the user has placed a turtle in the resizing drawer and is spinning the resizing knob to adjust the size.

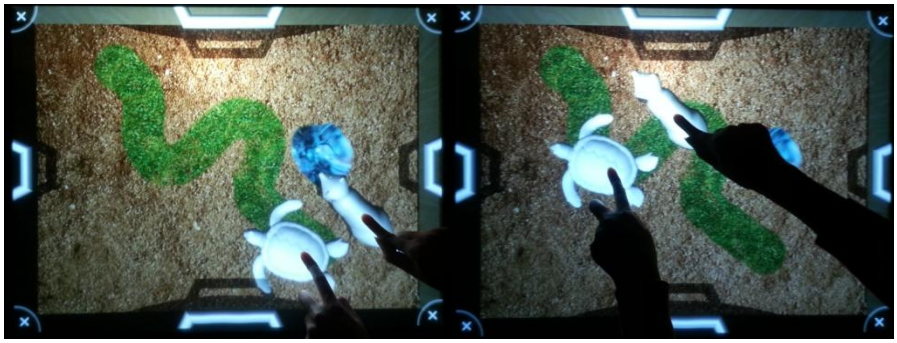

Figure 3-8 shows the application is a multi-touch application in which users can touch and move more than one object at a time.

3.3.3 Conditions

There were two main factors considered in this study:

- Storytelling medium (sand, water, digital)
- Story type (fixed, free-form)

I used a mixed design, with the storytelling medium as a within-participants factor, and the story type as a between-participants factor.

3.3.3.1 Storytelling Medium

In order to understand and compare how people manipulate objects to perform story events in physical and digital mediums, I designed a lab study in which participants were asked to tell a story in three different environments: namely sand, water, and a digital table. The sand condition was intended to replicate, as closely as possible, the physical setup used in sandtray therapy, in which participants could tell a story by placing and moving characters and scene elements in physical sand, without limitations on how they use their hands and fingers to grasp and manipulate objects. The digital condition was intended to provide a virtual version of that same medium, in which participants could move and rotate on-screen 3D figurines using Hancock et al.'s (2007) three-touch technique, as well as resize objects and paint the background. However, this technology requires the use of a 2D surface to interact through the contact points of participants' fingers. I introduced a third condition, namely water, to allow for both forms of interactions. Meaning that participants were able to either touch and push, or grasp and move objects to manipulate them.

3.3.3.2 Story Type

Besides having different mediums for telling a story, I included another factor that imposed different constraints on the story to be told. Specifically, to understand the differences in behaviours and creativity based on whether participants had a *fixed story* structure, or whether they were required to create and develop a *new story* themselves. The levels of this factor were intended to approximate situations where the story had been rehearsed or was somehow known beforehand, or whether it required more creative work in generating content on the fly. While this condition was included in the design of this study, the analysis of the

story type condition is beyond the scope of this dissertation. Thus, I leave the analysis of creativity and behaviour with and without restrictions on storyline as a potential next step.

3.3.4 Task

All of the participants were given a short summary of the famous children's story, *The Tortoise and the Hare,* to read (See Appendix A). In the given story, the rabbit was a boastful character that was challenged by the tortoise to a race. The rabbit lost the race as he got some sleep along the way. Additional setting information (e.g., place, time, etc.) was not described to participants. Each participant started by reading the story, and then proceeded to tell his/her story in all three environments. The order of storytelling media were counterbalanced using a Latin Square. Fourteen participants were asked to tell a *fixed* story and keep the theme of the story (a race between two characters) but were allowed to change anything else in the story such as the characters, scene, beginning or the end of the story. The other fifteen participants were asked to tell a *free*-form story and were allowed to change anything in the story, including the theme and plot. Each session was videotaped and participants completed a post-study questionnaire, which included several demographic questions and asked participants to explain how comfortable they were while manipulating objects in different environments, the extent to which they could express the feelings associated with story's characters in each environment, and their suggestions on how to improve the application.

3.4 Data collection and analysis

I followed a two-pass video analysis strategy as proposed by (Jacucci, 2010). I first watched the study sessions to understand and find meaningful or common behaviour between participants when creating a story. During the first pass of analysis, I noticed that participants usually performed common actions to include the basic story elements in their stories. They selected and employed figurines to represent story characters, they created a scene through placing figurines on the background or drawing on the surface, to show the place in which the story was happening, and they manipulated figurines to represent character actions and story events. I thus classified physical actions into actions on characters vs. scene elements,

and used the order of actions to understand plot progression. I illustrate these patterns of behaviour by visualizing the order of these actions (See Section 3.5.1).

In the second round of analysis, each of these story elements was considered as a step that participants took to create a story. I focused on each step to see what participants did to incorporate story elements and how they interacted with objects in each of these steps.

To elucidate narrative and expressive actions I specifically focused on the gestures used to represent the character actions and story events (plot). I thus identified character actions through verbal expressions and matched these with physical actions and gestures used to represent this character action. For example, 'dragging' is a physical action (See Figure 3.9), so when a participant said "the rabbit went to the finish line" (verbal expression) while dragging it (physical action), it was coded as: dragging (physical action) was used to move a character forward (character action).

Figure 3-9: Dragging an object

After analyzing and coding the study sessions, a participant's session was randomly selected to be coded by another lab member to independently validate the codes. The evaluator was provided with a set of physical actions and a set of character actions and was asked to watch the participant's session and assign the physical actions to character actions. The results of the second independent coding were identical to the first coder's (i.e., the same set of actions were identified to have been in that participant's video, and no additional actions were

identified). The second evaluator also coded the order of actions to be exactly the same as the first coder. Therefore, the *K* value in Kappa's inter-rater agreement method was equal to one.

3.4.1 Elimination of Participant Data

Note that the results from five participants were eliminated from the data. Three of them were eliminated because they only narrated their stories in two environments, as they did not have enough time to complete the whole study in an hour. Also, the results of a fourth participant were eliminated because she was not easily able to work with the digital table, so the experimenter had to help her during the study. A fifth participant performed a story on the digital table without any verbal expression (She did not speak and only moved the figurines around the surface), so the experimenter was not able to make note of dialog and match them with character actions. Consequently, the total number of participants whose data were analyzed in this work is 24. Three of these five participants three were in the fixed-form condition and two in the free, and so the analyzed data still included twelve in each level of this between-participants condition. Participants told their stories in the environments following different orders. Table 1 shows the number of participants who told their stories in each conditions, after elimination of 5 participants.

Conditions	# of participants
Digital-Sand-Water	4
Digital-Water-Sand	4
Sand-Water-Digital	4
Sand-Digital-Water	5
Water-Digital-Sand	4
Water-Sand-Digital	3

Table 1: Number of participants in each condition

3.5 Results: First Pass

This section provides a qualitative analysis of the first pass of the video results of the study. As mentioned before, the common elements that form a story are characters, setting, and plot. Therefore, I looked at the data through the lens of these elements to understand how people incorporate these elements into a story to create and narrate it.

In the following sections, I first describe the order in which participants incorporated story elements into their stories (3.5.1). I then describe how participants selected their story characters (3.5.3). After that I analyzed how they made a scene (3.5.4), and interact with figurines to place them on the scene in each environment (3.5.5). I then analyzed how participants manipulated figurines to represent character actions and story events in each environment (3.6 , 3.7).

3.5.1 Order of incorporating story elements into a story

Participants used different methods to represent story elements. They used figurines to represent story characters, they drew on the background and used decorative figurines, such as trees and flowers, to represent the setting of their stories, and they manipulated figurines to perform character actions and convey story events to represent the plot. The participants followed different orders to include these elements in their stories. For instance, some of the participants started the storytelling process by picking the story characters, while others started it by making a scene for their stories. In the following sections, I separate these different types of behaviour by the different storytelling media, as these strategies tended to differ between the digital table, sand, and water.

3.5.1.1 Digital Table

I divided participants into three groups based on the order that they incorporated story elements to create their story:

- Group 1, Prepare-everything: This group (15 participants) got the story scene and characters ready before they started telling the story. They, then, started narrating the story using what they already had on the scene.

- Group 2, Prepare-with-flexibility: This group (7 participants) made part of the story scene and picked the characters, and then started narrating the story. They then added more scenic elements and story characters whenever needed, as they told their stories.
- Group 3, No-preparation: This group (2 participants) started narrating the story from the beginning, while adding story characters and scenic elements to the scene, as the story proceeded.

In order to visualize these different behaviours within each group, I developed the following graph (See Figure 3.10).

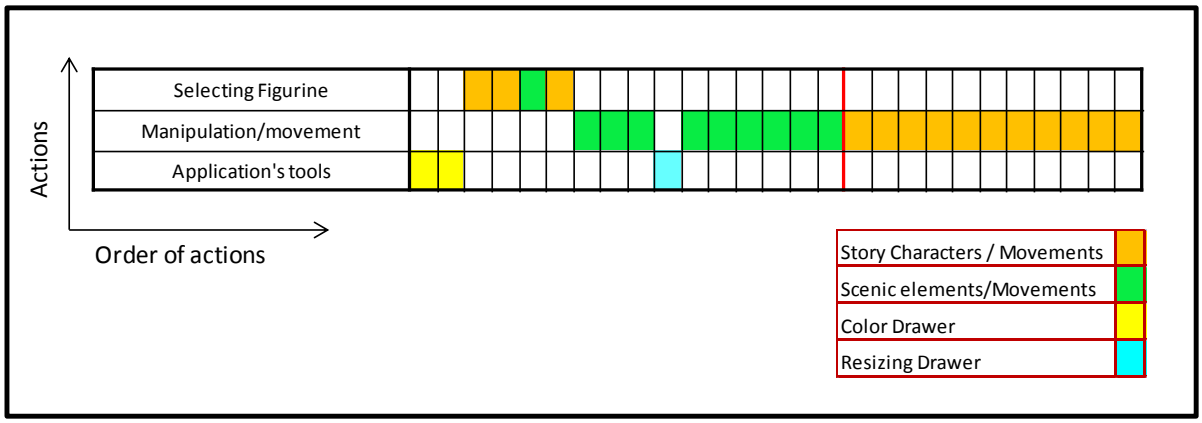

Figure 3-10: An example of the behaviour followed in the Prepare-everything group

Figure 3.10 shows the order in which a participant from the first group followed different actions to create a story. The *x*-axis shows the order of actions from left to right, and the *y*-axis includes three different categories of action: selecting figurines, manipulating or moving figurines, and using the application's tools. The colours are used to indicate both different story elements (orange/green) and type of tool in use (yellow/blue). Orange indicates that the action is on a *character* (e.g., a rabbit or turtle), green indicates that the action is on a *scenic* element (e.g., tree or flower). Note that *plot* can be discerned in the graph through the order of actions (*x*-axis). The red line in the middle of the graph shows the moment in which the participant started telling the story. This moment is recorded when a participant said something like, "once upon a time ...", "so the story is about...", et cetera. Participants did not tell anything related to the story before the red line.

To illustrate this graph, Figure 3-10 shows that the participant has started his session by colouring the background using the paint drawer (yellow color in the third row of the graph), he colored the background using two different colors (two yellow cells). He then picked two story characters and one decorative figurine and again one story character from the figurine drawer. Then, he started to locate and position figurines on the scene. He performed three types of actions (for instance dragging), and then used the resizing drawer and resized one figurine. He then continued with locating and positioning the scenic figurines. After the red line, he started telling the story and all the movements and actions were on the three character figurines (he made no changes to the scene after this point).

Note that the surface of the digital table was not very sensitive, so participants sometimes had to do an action, for instance rotating an object, a few times to be able to rotate an object. I counted all the actions done for the same purpose (e.g., to reposition a character), as one action.

The following graphs are three examples of participants' behaviours, in each group.

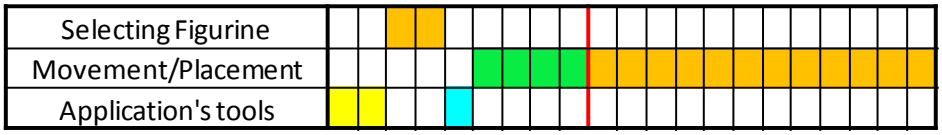

Figure 3-11: An example from the prepare-everything group digital table (Participant #20)

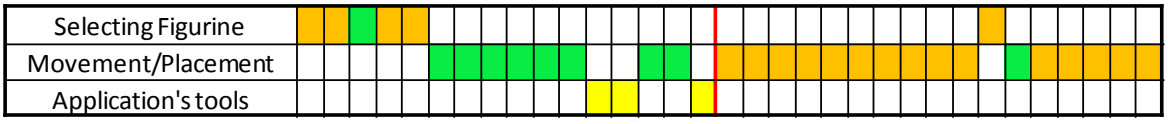

Figure 3-12: An example from the Prepare-with-flexibility group on digital table (Participant #19)

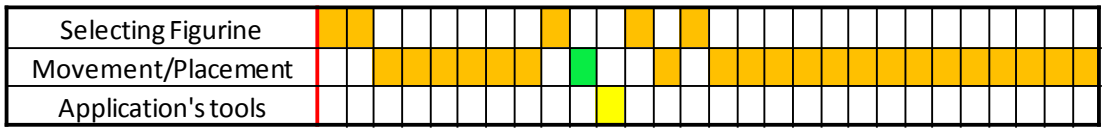

Figure 3-13: An example of the No-preparation group digital table (Participant #24)

All the participants in prepare-with-flexibility and no-preparation groups group (See Figure 3.12 and 3-13) changed the given story in some way. Most of the items added to the scene during the story were something that was not mentioned in the initial given story. For instance, a participant added a clock during the story to the scene, which was not included in the script given to them.

3.5.1.2 Sand:

I observed all three types of behaviour discussed in the digital environment in this environment as well. However, in this environment 17 participants were in the prepare-everything group, 5 participants were in prepare-with-flexibility group and the same 2 participants plus another participant were in the third group. The following graphs present examples of behaviours from each group (See Figure 3-14,3-15, and 3-16).

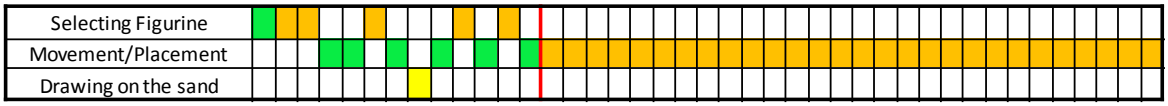

Figure 3-14: An example from prepared-everything group in sand (Participant #8)

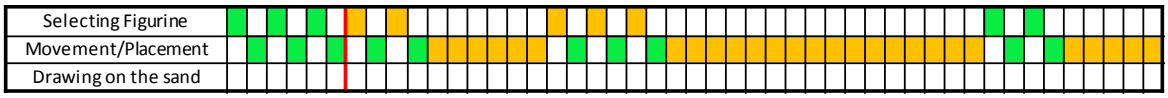

Figure 3-15: An example from prepared-with-flexibility group in sand (participant #10)

The behaviour of participants of no-preparation group in sand However was not exactly similar to digital table, as they had their first story character in hand before starting the story and they added more characters and decorative figurines as the story proceeded. The following graph presents and example of this group (See Figure 3-16).

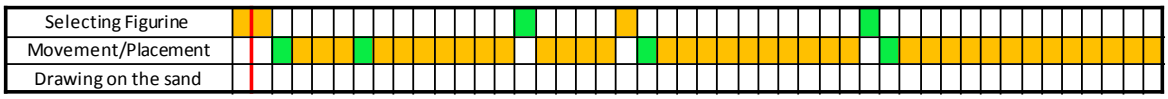

Figure 3-16: An example from No-preparation group in sand (participant #24)

3.5.1.3 Water:

The same types of behaviours were also observed in the water. The prepared-everything group included 19 participants who picked all their desired figurines and made a scene for their stories before starting the narration. The prepared-with-flexibility group included 4 participants who picked a number of story figurines before starting the narration and added more figurines to the scene as the story proceeded. And there was only one participants who did not prepare anything before narrating the story in the no-preparation group. Following graphs show examples of behaviours from each group (See Figure 3-17, 3-18, and 3-19).

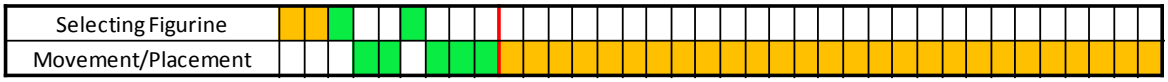

Figure 3-17: An example from the prepared-everything group in water (Participant #16)

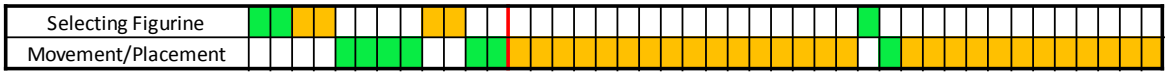

Figure 3-18: An example from the prepared-with-flexibility group in water (participant #8)

Figure 3-19 The participant from the no-preparation group in water (participant #11)

3.5.2 Manipulation of objects

One important aspect to consider when designing applications for multi-touch devices is to understand the nature of interaction with the application. In this study, I observed that the nature of interaction with the figurines is notably different between the story elements. That

is, the way participants manipulated figurines to make a scene is completely different from the way they manipulated them to perform and represent character actions and story events. (See area 1 and 2 in Figure 3-20).

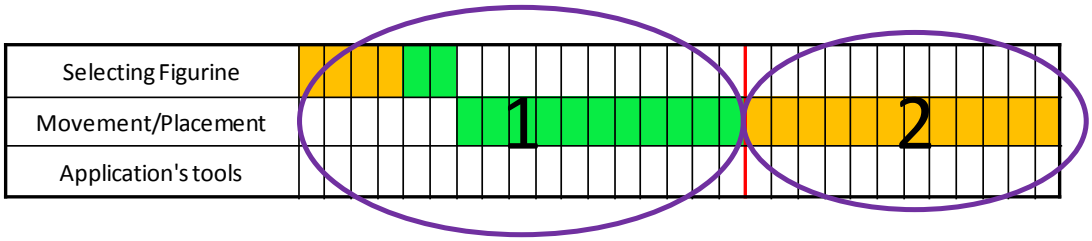

Figure 3-20: Different types of manipulation of objects

When participants were creating a scene, their main focus was on *task completion*, meaning that they aligned their primary actions on what scene they were creating rather than how they were creating it. In contrast, participants primarily focused on *how to perform* a task when they were narrating a story and performing character actions. For instance, the bottom set of images in Figure 3-17 shows a participant who is simply dragging a figurine (a rabbit) to locate it on a desired spot on the background, to create a scene. However, the top set of images of the figure shows the same participant rotating a figurine (a dinosaur) right and left while dragging it, in order to show that the dinosaur is moving to another location. In both cases the task is moving a figurine from one location to another; however, in the first case the focus is more on the *completion of the task* which is locating a figurine on the desired spot, whereas in the second case, the focus is more on *how to perform a task*, in order to represent how the dinosaur moves (character action).

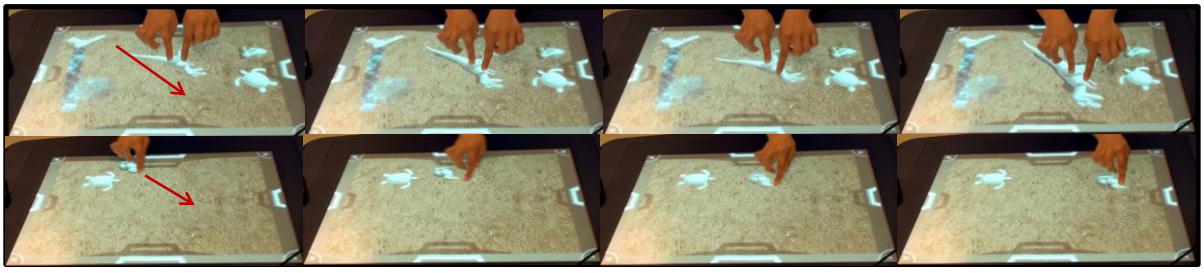

Figure 3-21: Narrative actions Vs. Regular actions

In the following sections, I focus on analyzing the manipulation of objects while participants were narrating a story. I describe and compare the way that participants manipulated figurines to represent character actions and story events between the environments.

3.5.3 Selecting desired figurines

The storytelling process usually started with the participants looking at the available figurines. Participants had two general approaches towards selecting figurines. They either were looking for a specific figurine to find, or they were browsing the available figurines to find something that seemed to be interesting. For instance, a participant said "I want to add a child, I hope I can find it," so she opened the character drawer and looked for a child figurine and found it and picked it. She then told a story about how a child thinks and what he wants in his life. In another example, a participant asked the experimenter whether there was any turtle in the character drawer, and then started looking for it. These examples were *target-oriented*, in which the participants were looking for specific figurine to have in their stories. In another example, a participant opened the character drawer, started rolling it, saw a wizard, a weapon, and a couple of other figurines and decided to pick them and add them to the scene. He then told a story about how the wizard killed a bad person who wanted to use his power against people. After the experiment, the experimenter asked if he had planned this story before working with the table, and he said "No, I added the wizard and I made up a story that has a wizard in it." Noticing the wizard while browsing might have been a *serendipitous* finding that led him to be creative and make up a story.

However, in most of the cases searching and browsing are not completely separate from each other. That is, while looking for a specific figurine, a person may find something that catches his/her eye and select it. For instance, while a participant was looking for a turtle, he saw an octopus, and said, "Oh, an octopus! I obviously have to have an octopus in my story," and picked it and continued his search to find the turtle.

I developed the following graph based on my observation of participants' behaviour towards selecting a figurine. (See Figure 3-22)

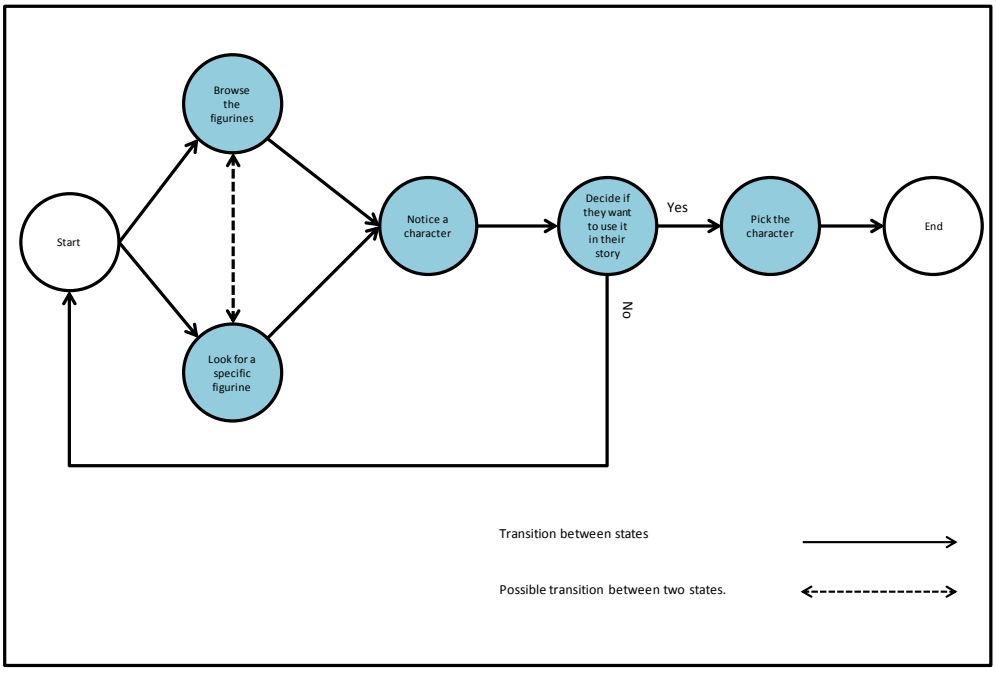

Figure 3-22: A visual model of how participants selected their desired characters.

Figure 3-22 shows that participants start looking at the available figurine to either look for a specific figurine or only to browse the figurines. They can switch between these two phases; that is, they can find an interesting figurine while looking for another. Navigating figurines usually ends when they notice a figurine that they like, and decide whether they want to have it in their story. If they decide to include it in their story, they pick the figurine, and if they decide to not add it, they continue looking at the figurines.

I also observed that sometimes, when participants couldn't find their desired figurine, they used something else to represent that figurine. For instance, one of the participants was looking for a flag to represent Mexico, but she could not find it so just picked a gun and a cactus and told the experimenter that this cactus and gun represented Mexico.

3.5.4 Making a scene

Participants made a scene to represent the place in which the story was held. Locating story characters on the background could represent part of the scene. However, some of the participants expressed the setting with more detail, by using decorative figurines or drawing on the background, or both. The following graph shows how participants made a scene in the different environments.

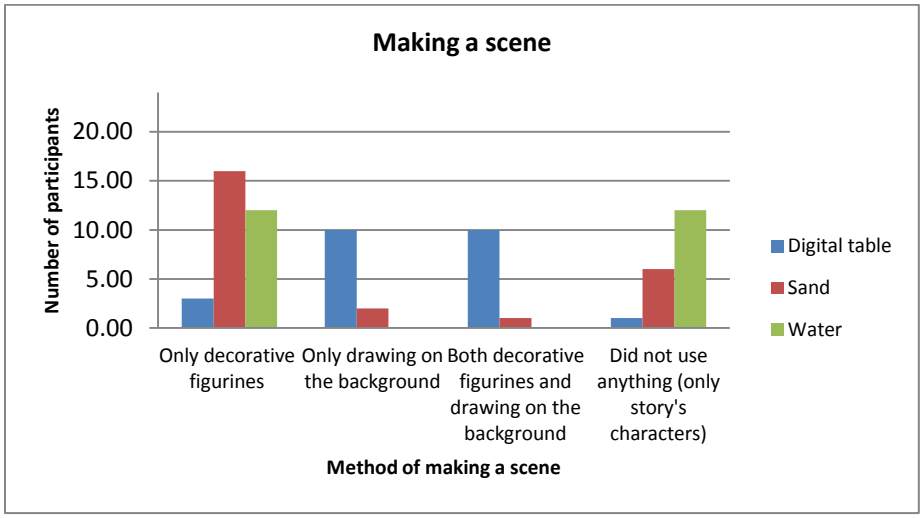

Figure 3-23: Creating a scene in different environments.

Figure 3-23 suggests that all the participants, except one, created a scene for their stories on the digital table. However, these numbers are not statistically comparable between environments, as the available decorative figurines and features on the digital table were more than the other conditions. Nonetheless, this observation might suggest that providing participants with exciting features may motivate them to use them. It is also worth noting that participants could dig in the sand to draw on the background, yet they still drew more on the background on the digital table. This observation is ripe for future studies, as it is still unclear whether this is due to an inherent difference in digital vs. physical storytelling, or instead to the visibility of the feature in the digital application. That is, the handle on the drawer and paint nozzle suggested the ability to paint, whereas the sand had no visible hints to indicate that action.

3.5.5 Interacting with figurines to make a scene:

In this section, I describe my qualitative observations on how participants picked their story characters and made a scene in the physical and digital environments. The following figures show several snapshots of participants creating a scene in different environments. (See Figure 3-24, 3-25, and 3-26)

Figure 3-24: A process of creating a scene in sand.

Figure 3-25: A process of making a scene in water.

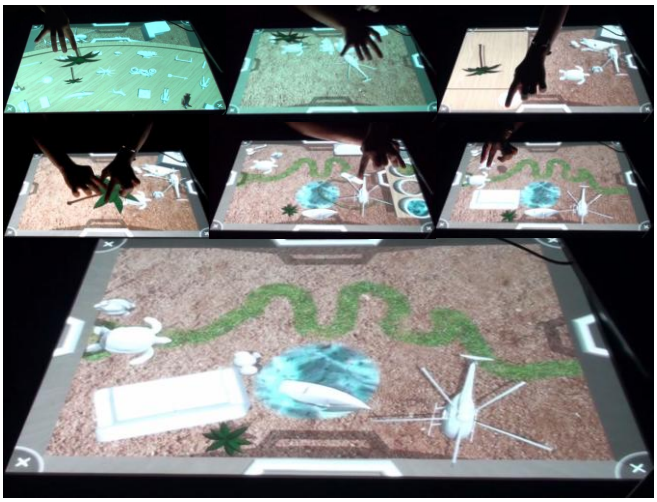

Figure 3-26: A process of making a scene on the digital table

I observed two different types of interaction behaviour when picking characters and placing them on the background. The following figures illustrate these two types of behaviour.

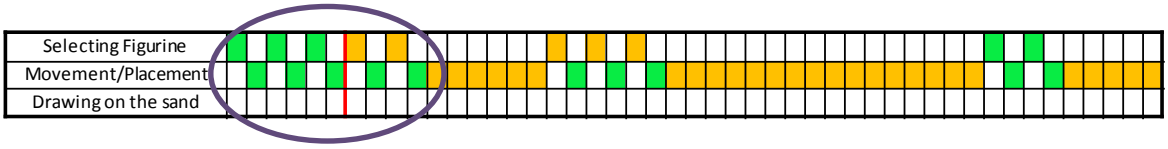

Figure 3-27: Making the scene through picking and placing figurines one at a time.

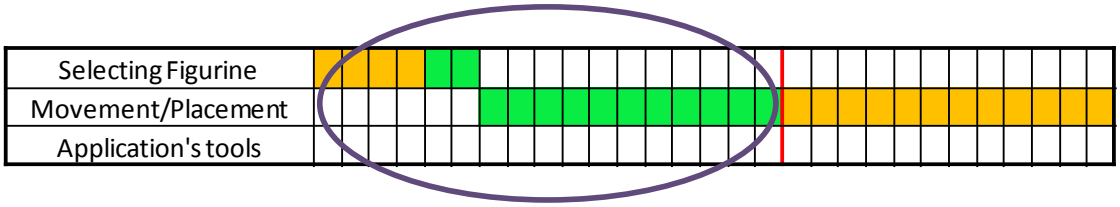

Figure 3-28: Making the scene through picking all the figurines and then place them.

Figures 3-27 shows the first type of behaviour in which a participant is constantly switching between picking figurines and placing them on the background. Meaning that he/she picks a

figurine, places it on the background and then picks another figurine and places it again and so on. However, Figure 3-28 shows the second type of behaviour in which the participant first selects all (or most of) his desired figurines and then places them on the background.

Both types of behaviour were observed in both physical and digital environments. However, the first type of behaviour was mostly observed in the physical environments and the second type of behaviour was mostly observed in the digital environment. For instance, Figure 3-25 shows a participant who first picked a tree and placed it on the water (first type of behaviour), he then picked three more figurines (a butterfly, a frog, and a turtle) and held them in his hand (second type of behaviour), and then picked a flower and put it on the water (first type of behaviour). He then placed all the figurines he was holding onto the surface one-by-one. So in this case the participant presented both types of behaviour.

3.5.5.1 Holding and Storing Figurines

Although in physical environments I observed that participants sometimes hold multiple figurines in their hand (See Figure3-29), no participants put any figurine on the surface (sand or water) for storage to later use in the story. In contrast, on the digital table this was common practice. This may be due to the design of the application, as participants had to open the character drawer to bring their desired figurines on the surface and then close the drawer to be able to locate and position the figurines on the background (See Figure 3-30). Consequently, using a part of the table as storage simplified this process.

Figure 3-29: Holding objects in hand

More specifically, on the digital table I observed that participants made a storage area on the corner or side of the table in which they could store some figurines to add/delete to/from the scene whenever needed (Figure 3-30). However, in the physical environments, participants always used the storage provided close to the trays for this purpose (See Figure 3-30).

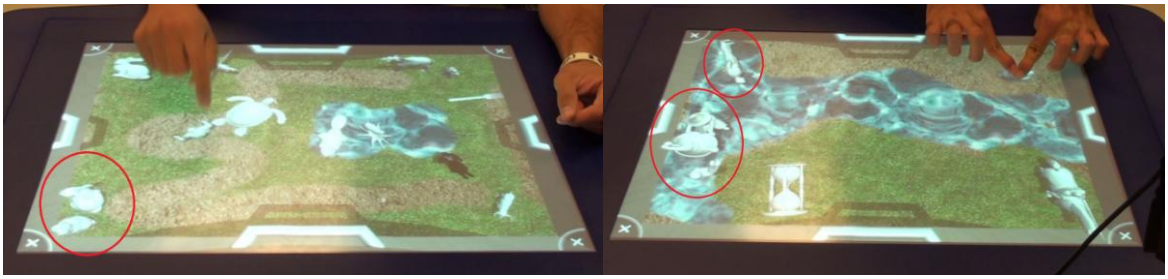

Figure 3-30 : Storage area

Figure 3-31 : Character drawer blocks the surface

3.5.5.2 Adding/Deleting Characters to Adjust the Scene

I also observed that participants sometimes added/deleted some figurines to/from the scene, based on the current storyline. Meaning that the only figurines that were in the scene were the ones that were part of the story at the time. For instance, a participant removed the audience of the race between the rabbit and turtle (a bunch of animals) from the scene, when he said "the audience thought the turtle will lose the game, and they started going home and said, 'this is such a boring thing.'" He later on put them all back while saying, "The animals who left came together and said what happened, happened."

3.6 Results: Second Pass

In this section, I describe the results of the second pass of the video data, in which I analyze how physical actions correspond to character actions in the story.

HCI researchers have heavily studied and compared hand gestures used in the physical and digital world to comprehend the similarities and differences in the way people interact with virtual and tangible objects. This comparison helps researchers to first understand the nature of interaction and the limitations in each environment, and second, to use the physical metaphors as a design resource to develop better interaction techniques for digital mediums (Scott, Carpendendale , 2004 ; Terrenghi et al, 2007; North et al., 2009; Underkoffler, 1999). In this work, I focused on narrative behaviour and compared the way that people manipulate objects in the sand, water, and on a digital table while narrating a story. This comparison gives us a better understanding of the nature of interactions with virtual and tangible objects, while narrating a story. To provide this analysis, I first identify the *physical actions* that were used to tell the story, and then show how these actions were used to convey *character actions* in the plotline.

3.6.1 Physical Actions

Participants could freely move their hands in physical sandtray to manipulate objects. However, they were limited to a 2D surface while working with digital table, so hands could only move along two axes, and thus, manipulation of objects was only possible through touching the digital surface. Water is an in-between environment which has some elements of both sand and the digital table; in water, participants could touch and move (or push) bath toys as they did on digital table, or they could grasp and move figurines, as they did in sand. (See Figure 3-32).

I observed that participants used adopted actions to do the same behaviour in different environments. These actions are similar in nature, but have been adapted to each environment. For instance, sometimes while participants were describing a character, they grasped it in their hand; participants adopted the same action by touching a figurine on the

digital table. In the following section, I show this appropriation of actions between environments.

To better describe and compare narrative actions used in each environment, I classified them into three groups of actions, namely in-place actions, movements, and rotations (Table 2). I describe each of these gestures in detail, and how they were classified in each medium.

	Narrative Action
In-place actions	Holding/touching
	Jiggling
	Repeated lifting
	Repeated 2D rotation
Movements	Dragging
	Lifting and moving/dragging
	Repeated lift and drag
	Zigzag drag
	Moving while jiggling
Rotations	2D rotation
	3D rotation

Table 2: Narrative actions

3.6.1.1 In place actions

In place actions one of the most used actions during storytelling. I observed different types of in-place actions on the digital table, including touching, jiggling, repeated lifting, and repeated 2D rotation.

Holding/Touching: Sometimes during the storytelling process participants grasped and held a figurine in their hand while narrating a story. Grasping and holding a figurine in the sand changed to touching a figurine on the digital table. However, both actions (i.e. touching and grasping) were observed in the water, as it was possible to perform both gestures (Figure 3-32).

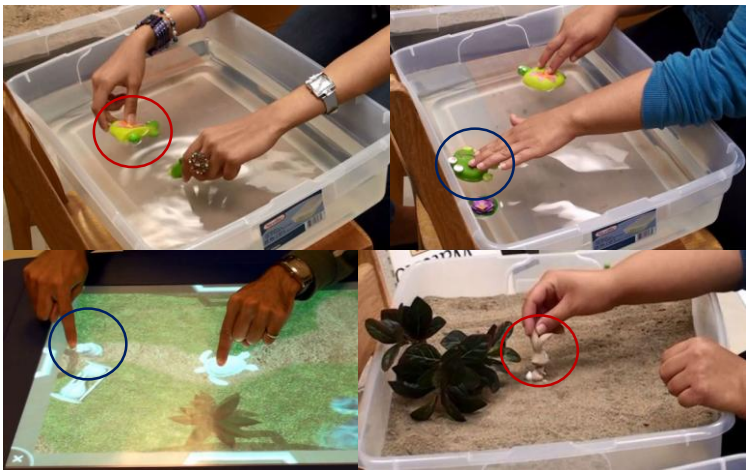

Figure 3-32: Grabbing vs. touching

Note that touching is different from tapping. By touching, I mean touching an object for more that 2-3 seconds (until the character action is complete).

Note that participants used both bath and regular toys in the water to represent story characters. Using regular toys afforded grasping, as they would have sunk in the water otherwise. Thirteen participants used bath toys, three participants used regular toys, and eleven participants used a combination of bath and regular toys in the water. Among the participants who used bath toys, only two participants manipulated figurines on the water through touching them and not grasping them, during the whole story. There were some incidents in which participants touched objects in the water, however, that was more to control them from moving and floating on the water, and not to manipulate them.

Figure 3-32 suggests that although touching figurines happened both in water and on the digital table, hand gestures used to touch a figurine were different in these environments. The number of fingers used to touch a figurine in water usually was more than the number of fingers used to touch a figurine on the digital table.

Figure 3-33 : Touching an object in water versus digital table

Jiggling: This action was done through very fast and small-ranged motions. In both physical conditions, participants *grasped* objects to jiggle them (See the right picture shown in Figure 3-34); however, on the digital table, participants *touched* objects to jiggle them (See the left picture shown in Figure 3-34). Again the same behaviour was done through different gestures in different environments.

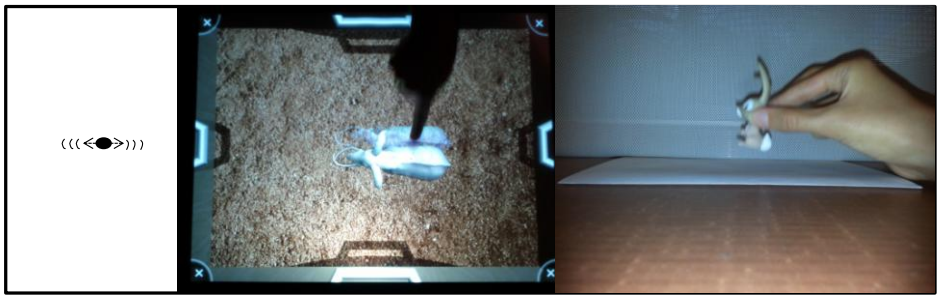

Figure 3-34 : Jiggling

Repeated lifting: This action was done through repeated up and down movements in both physical environments. The same action was adopted on digital table and was performed through repeatedly pinching an object (See Figure 3-35).

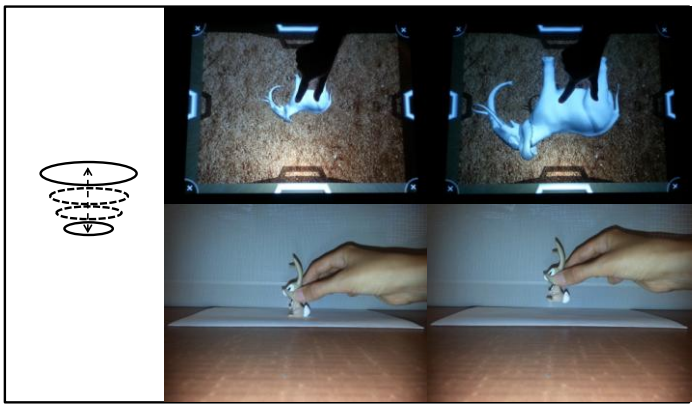

Figure 3-35: Lifting

Repeated 2D rotation: Participants sometimes rotated an object left and right repeatedly. Figure 3-36 depicts how this action was done in both physical environments and on the digital table. Participants always grasped an object and rotated it in physical conditions (Figure 3-36).

Note that, rotation was easy to differentiate from jiggling on digital table since rotating a figurine on the digital table requires rotating its orientation, however, jiggling is done by slightly changing its location. Repeated rotation was hard to recognize from jiggling in physical conditions. Consequently, I considered all the 2D rotation and jiggling actions as jiggling in physical conditions.

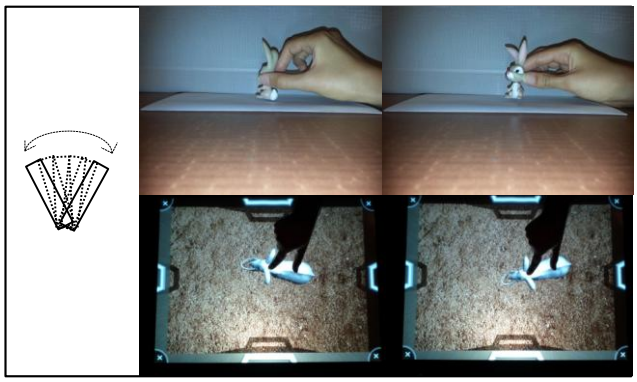

Figure 3-36: This figure depicts repeated rotation in both digital and physical environments.

3.6.1.2 Movements

I observed that participants moved objects from one location to another location in different ways, including dragging, lifting and moving, repeated lifting and moving, and zigzag movements. The following describes how these movements were performed in the physical and digital environments.

Dragging: Participants sometimes dragged objects to move them from one point to another point. By dragging I mean moving an object while it always has a point of contact with the surface. Dragging on the digital table was done through touching an object and moving it forward. I only observed one incident in which a participant dragged a figurine on sand through pushing it forward with one finger. (See figure 3-37). In the water I observed two ways of dragging. The same two participants who touched figurines in the water, performed dragging through touching and moving figurines, and the others grasped objects with hand and moved them on the surface while they had a point of contact with the water. (See Figure 3-37).

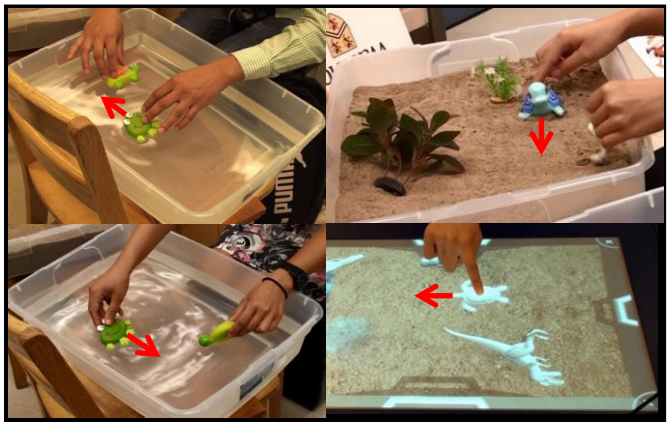

Figure 3-37 : Dragging vs. moving

Lifting and moving (Lifting and dragging): In physical conditions, participants sometimes grasped an object, lifted it and moved it to another location and put it down. Participants performed the same action on digital table through lifting and dragging an object (see Figure 3-38).

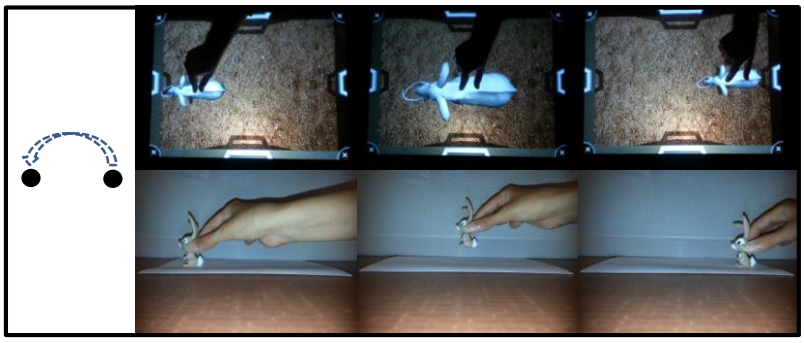

Figure 3-38 : Lift and drag

Repeated lift and drag: This action is very similar to the previous action. The only difference is that participants did several small and continuous lift and drag to move an object from one location to another location. This action was observed in both physical and digital environments.

Zigzag dragging: To represent movement, participants sometimes rotated an object to left and right while moving it. Figure 3-39 depicts the way that participants performed this action in both the physical and the digital environments (see Figure 3-39).

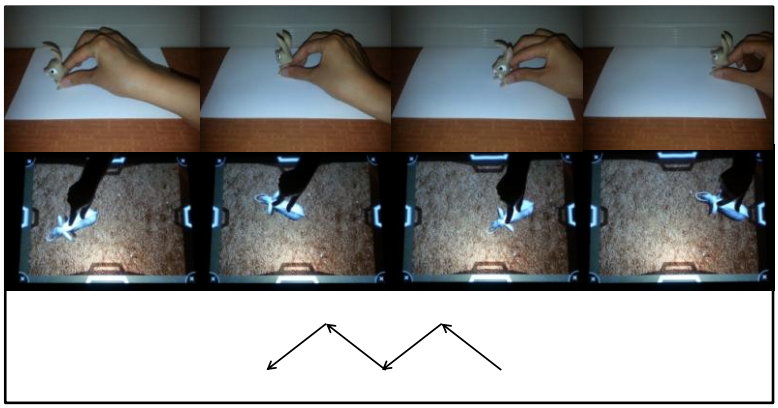

Figure 3-39 : Zigzag dragging

Moving while jiggling: This action is hard to capture and show in a picture. But it is performed through jiggling an object while moving it forward. It was performed through

grasping and jiggling an object while moving it, on physical conditions. And was performed through touching and dragging an object while jiggling it, on the digital table.

3.6.1.3 Rotations

2D rotation: This action was done through grasping and rotating an object in the both physical conditions, and was performed through touching and rotating on the digital table (See Figure 3-40).

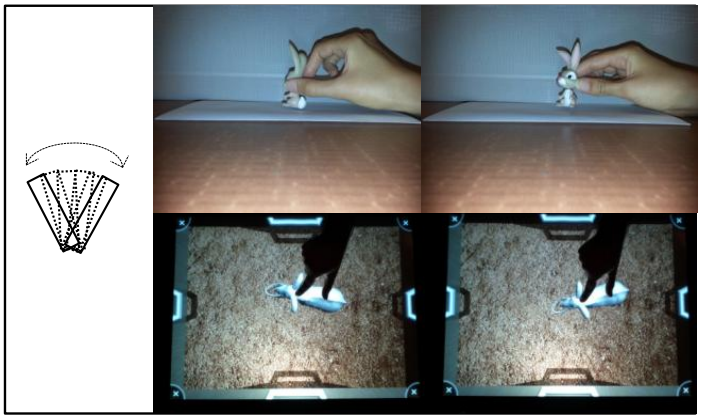

Figure 3-40 : 2D rotation

Among the in-place actions, repeated 2D rotation was hard to differentiate from jiggling in physical environments. In the digital environments participants had to use at least two fingers to rotate an object; however since, participants usually grasped objects in hand in physical conditions and moved it, it was hard to recognize if they are doing jiggling or repeated 2D rotations. Therefore, I counted all the jiggling and repeated 2D rotation, as jiggling in physical conditions. And that is why there is no 2D rotation action in physical environment.

3D rotation: This action again was done through grasping and rotating an object in the both physical conditions. 3D rotation was performed through the shown gestures in Figure 3-41, on the digital table.

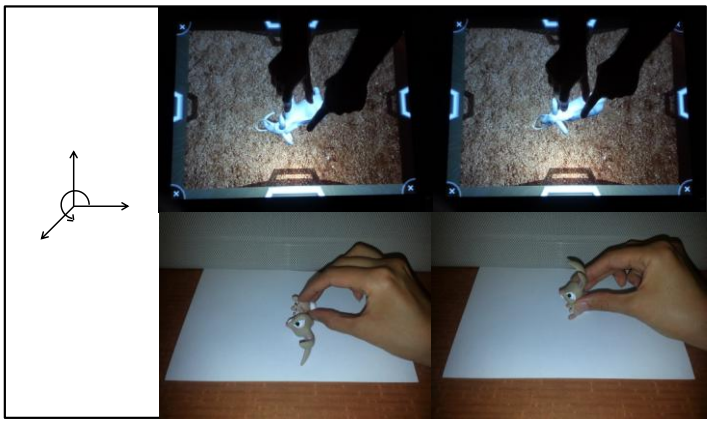

Figure 3-41 : 3D rotation

Hand gestures above the table: Participants were not always playing with characters. They sometimes were explaining character action and story events while performing some types of hand gestures above the surface (e.g. pointing to a character) and describing story events through verbal utterance (see Figure 3-41).

Figure 3-42 : Hand gestures above the table

For instance, a participant said “the rabbit said, ‘I am not a rabbit I am a little princes that evil changed me to a rabbit!’", while just pointing at the rabbit from above the table.

3.6.2 Character Actions

I observed that participants not only benefitted from verbal expressions to narrate the plot of a story but also played with figurines to represent and perform story events. In this section, I explain how participants used the narrative actions described in the previous section to convey characters’ actions and story events.

A *character action* is any action that a character performs during a story, and was identified through verbal utterances, such as “the rabbit walked”. While watching study sessions in the second round I recorded every action and the related dialog to analyze how character actions are performed by participants. For instance, if a participant said that the rabbit took a nap while rotating it, I coded it as sleeping (character actions) was performed through rotating an object (physical action).

Note that any story has its own plot, meaning that character actions and story events are specific to each story. For instance, a story may be about characters who want to climb mountains while another story may be about characters who are sitting in a room and are talking to each other. Therefore the nature of character actions and story events is different from story to story. Consequently, I could not capture all the possible character actions in this study. Besides, the focus of this work was to explore narrative actions on digital surfaces and not to explore all the possible character actions that may happen in a story. Meaning that, I were interested in understanding how people employ existing actions (e.g. rotating or lifting), to perform character actions. Do people want to represent the actions through manipulating the figurines or do they just want to explain them in words? Do they use the easiest way to represent a character action, or do they want to exactly show how the character action happens? For example what do they do to represent jumping? Do they just move an object and explain that it is jumping, or do they actually try to manipulate the object in a way that simulates jumping?

To investigate these questions, I picked character actions that were part of at least four story plots (The minimum of four appearances of these character actions), and analyzed how they were performed. Note that these character actions were not necessarily part of all the story plots.

The following table shows the character actions that were selected, and the number of participants who actually had these character actions as part of their stories. Note that I did not analyze the data of the fix and free forms of story conditions separately, since I did not see any connection between the way that participants performed a character action and the form of the story they were telling. The way that participants manipulated characters was

more related to the character actions rather than the story. For instance, participants represented talking through a set of physical actions such as jiggling, repeated 2D rotations, etc, and the way they performed it was not related to the story told but was related to the talking action.

	Digital table	Sand	Water
# of participants whose story characters experienced a type of emotion such as anger, excitement, or happiness	10	9	5
# of participants whose story characters talked to another character at some point	24	24	24
# of participants whose story characters laughed	7	6	3
# of participants whose story characters danced	5	3	2
# of participants whose story characters moved from one location to another	24	24	24
# of participants whose story characters looked at/for/around	24	24	24
# of participants whose story characters slept	13	16	18
# of participants who described the story characters' physical appearance, thoughts, or conditions	24	24	24

Table 3: Character actions

3.6.3 How Participants Used Physical Actions to Enact Character Actions

Participants performed characters actions through a set of physical actions. As mentioned in section 3.5.2, the actions used to represent character actions are different from the actions used to do regular tasks such as bringing characters to scene, drawing on the background, etc. Therefore, I call the physical actions used to represent character actions, narrative actions. Narrative action is an action through which the performer wants to show how an action is being done. For instance, a narrator may perform repeated 2D rotations to show that a character is crying. The repeated 2D action in this case is a narrative action through which the performer was going to narrate something (i.e. the character is crying).

The following graphs show how participants employed physical actions (i.e. narrative actions) to perform character actions or describe a character. In all the following graphs, the *x-axis* shows different types of *physical actions (narrative actions)* and the *y-axis* shows the *percentage of participants* who represent the character action, through the related physical action for at least one time.

Note that, a participant might have performed a character action (e.g. moving) through more than one physical action (e.g. dragging) during different times in a story. For instance, a participant might have performed 'movement of a character' through a set of physical actions such as dragging, lift and drag, or zigzag dragging at different times during their story.

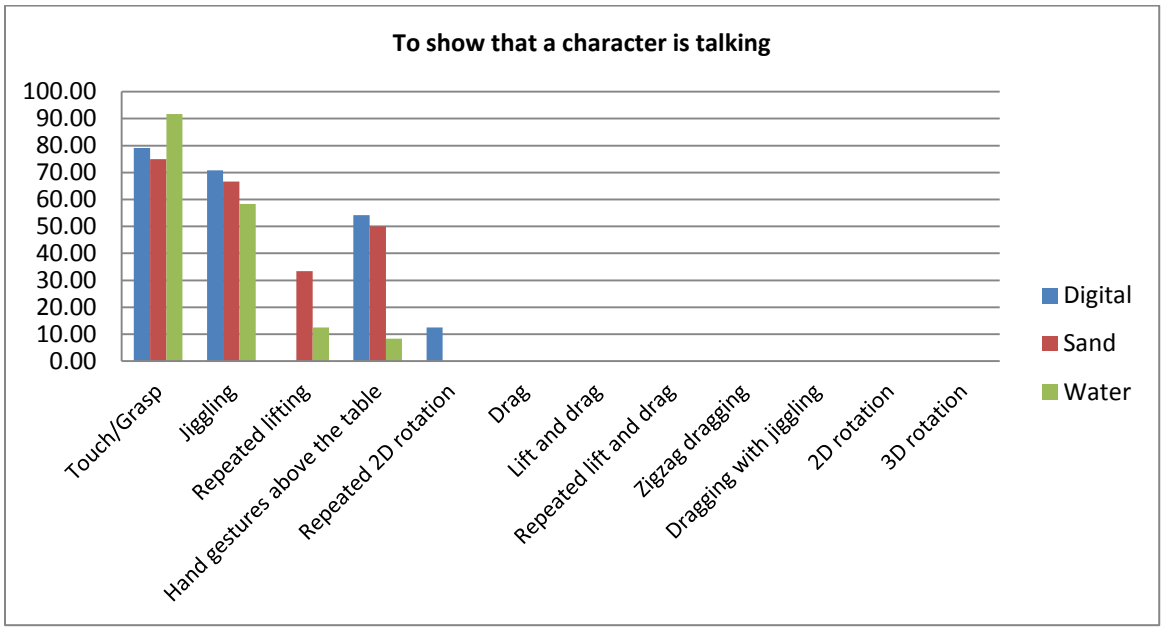

Figure 3-43: Presenting that a character is talking.

As figure 3-43 suggests, talking was performed through different types of in-place actions. Repeated lifting was not used to represent talking on the digital table. Remember that repeated 2D rotation was considered as jiggling in physical environments, as they were performed in a very similar manner.

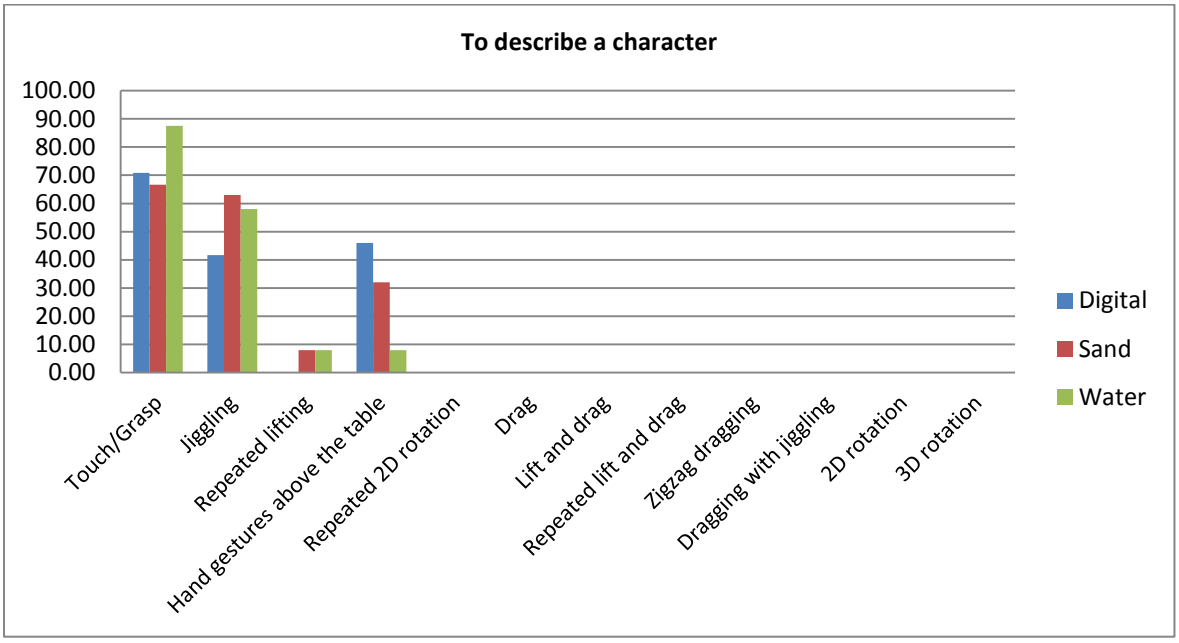

Figure 3-44: Describing a character.

Figure 3-44 suggests that participants usually tend to touch/grasp characters while describing them. Also the graph highlights again that gestures above the table aren't used much in water, and that even though repeated lifting is not often used, it is never used in digital. There also are less jiggling in digital and more touch/grasping in water.

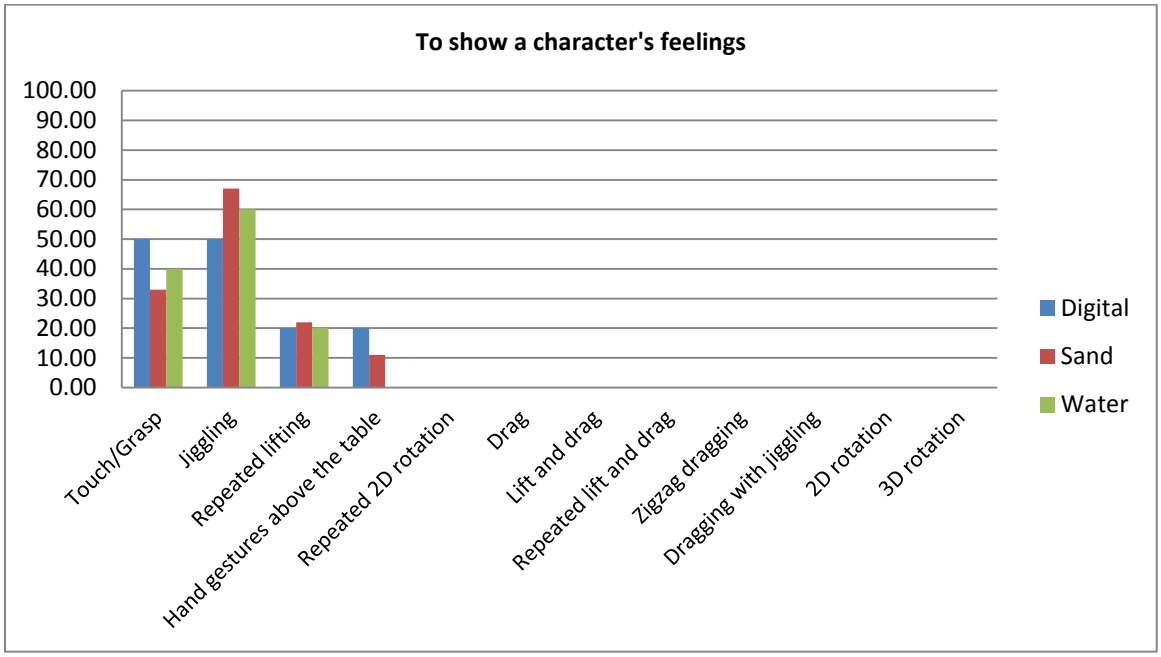

Figure 3-45: Showing a character's feelings

Figure 3-45 suggests that jiggling actions were frequently used to represent characters' feelings. This figure also shows that sometimes participants only touched/grasp characters while talking about their feelings.

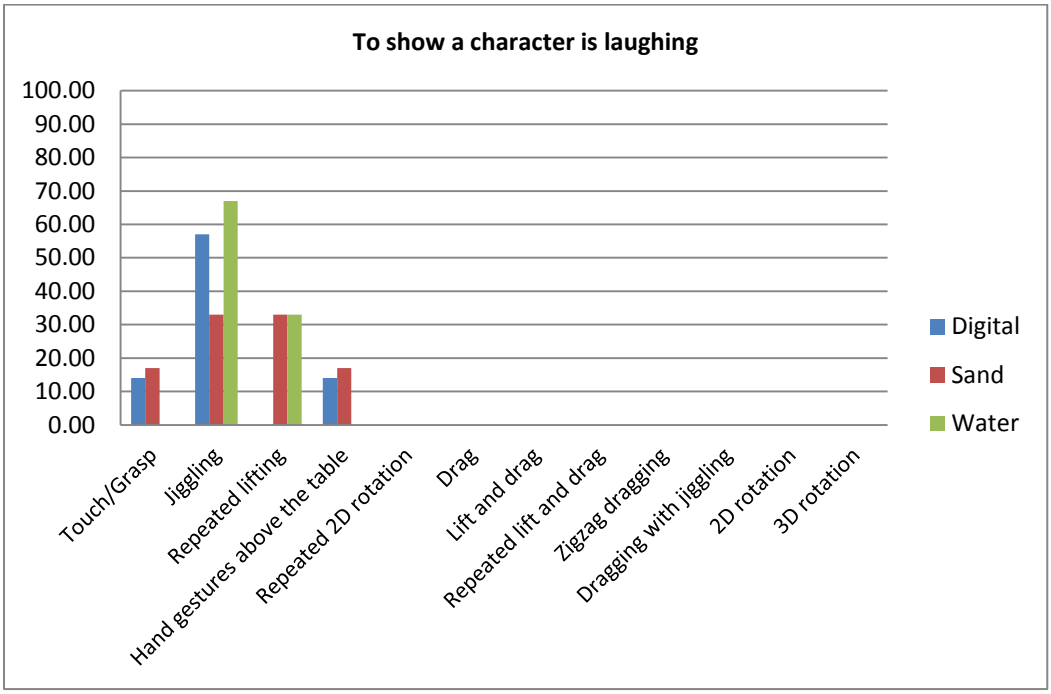

Figure 3-46: Showing that a character is laughing

Figure 3-46 suggests that laughing was often performed through jiggling. Besides repeated lifting was more observed in physical conditions, that again suggests that this action was hard to be performed on the digital table.

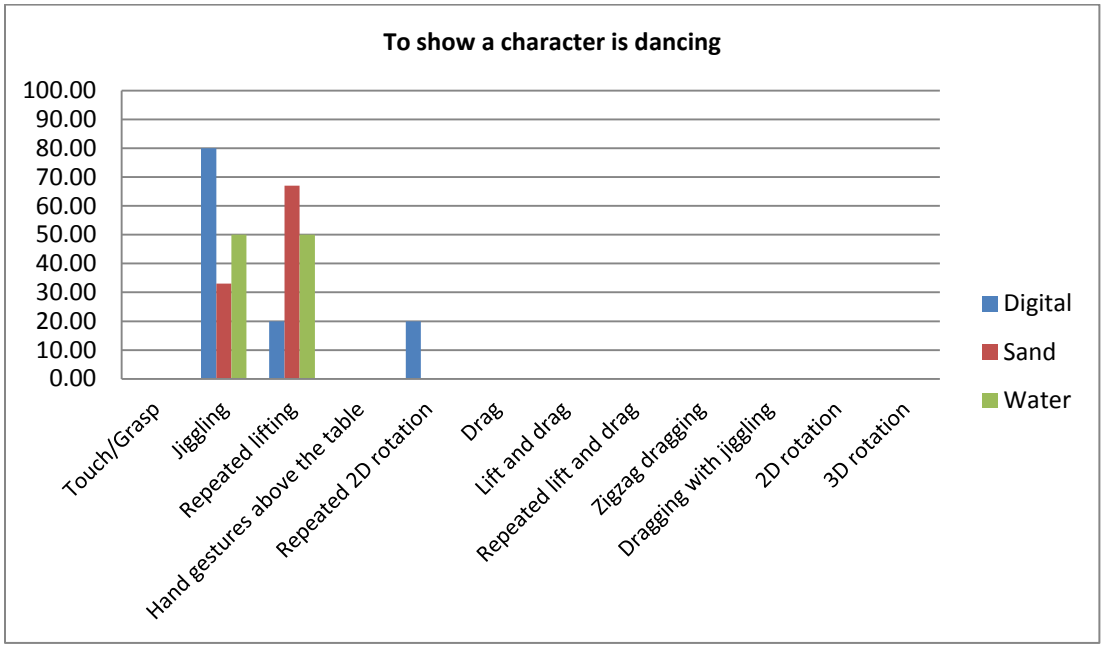

Figure 3-47: Showing that a character is dancing.

Figure 3-47 suggests that jiggling was used more on the digital table and repeated lift and drag was used more in the sand, to perform dancing. Both actions were used in water equally. Note that the reason that repeated 2D rotation is not observed in the physical conditions is that all the 2D rotations were counted as jiggling in physical conditions.

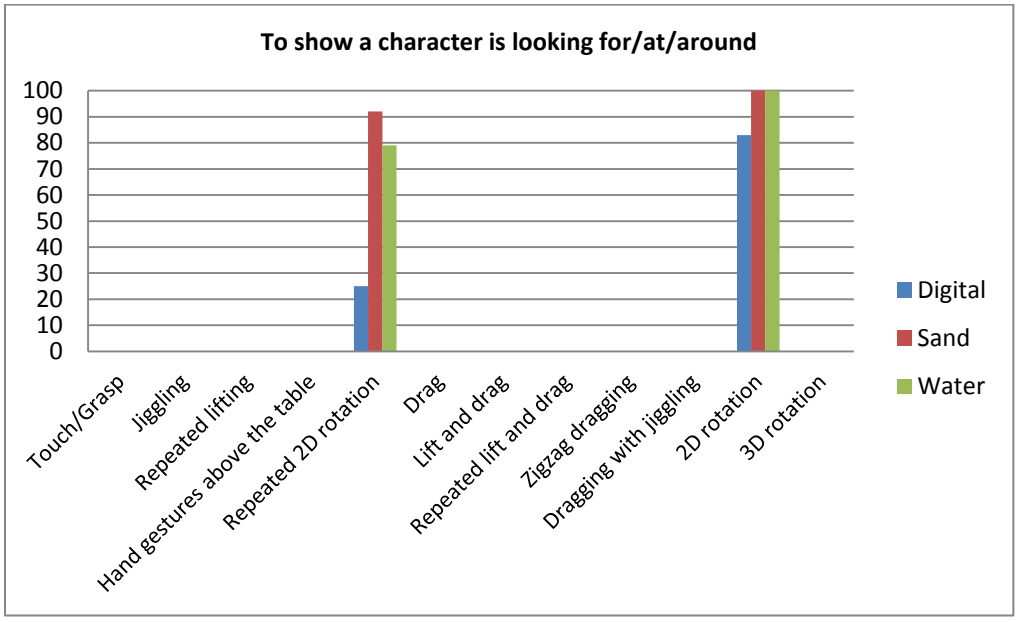

Figure 3-48: Showing that a character is looking at/for/around.

Figure 3-48 suggests that 2D rotation and repeated 2D rotation were used exclusively to represent that a character is looking for/at/around. However, repeated 2D rotation was less common on the digital table, which may indicate that this action was not easy to perform on the digital table.

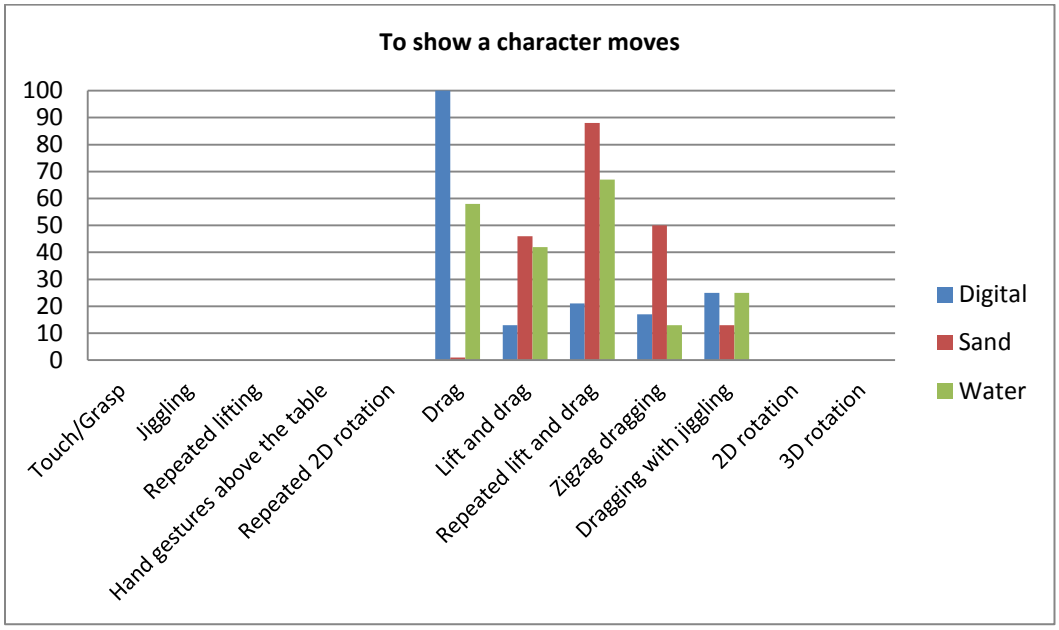

Figure 3-49: Showing movements.

Figure 3-49 suggests that repeated lift and drag was more popular in the sand. And dragging was more common on the digital table.

Note that I considered all types of movements as one character action (i.e., moving from one location to another), as participants did not usually state the type of movements they were performing. For instance, they did not say that the turtle was crawling, or the rabbit was jumping, instead they usually said the turtle went to the finish line, or the rabbit went somewhere. However, they performed how they moved differently (See Figure3-49).

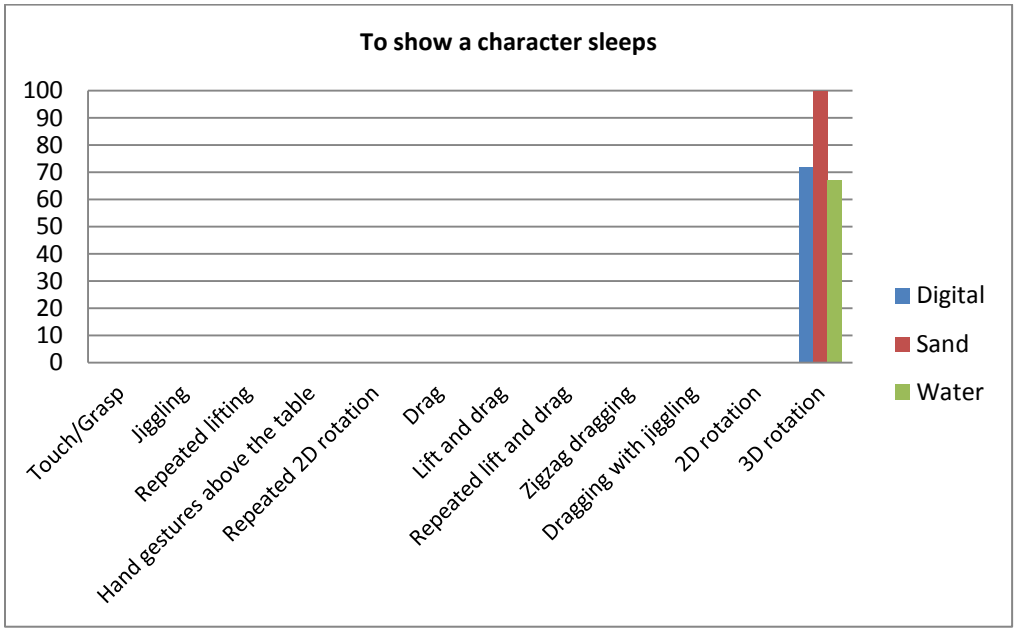

Figure 3-50: Showing that a character sleeps

Figure 3-50 suggests that when the participants had a character fall asleep, they performed this action only through 3D rotations. In the sand, *every* participant had this happen at some point during the story and represented it in this way. However, on the digital table only 72% of participants performed the action at all, and in the water only 68% did. As this action was universally done in the sand, this may indicate an inability to perform this action in the digital environment. Nonetheless, the other physical condition (water) had a similar result, indicating this may be due to the need to interact in this 2D space to control 3D objects, However, it should also be noted that, since the bath toys were in a horizontal positions, the participants who used bath toys did not need to rotate them in water, so this inability to rotate in 3D may be more specific to digital surfaces.

3.7 Other Differences in Storytelling on Digital Tables, Sand, and Water

In this section, I describe more observations on the differences in how participants manipulated objects in physical and digital environments.

3.7.1 Playing with the active character

I observed that participants always manipulated the active character (i.e. the one who is playing the role at the moment) in physical conditions. However, on the digital table, participants sometimes manipulated other characters while narrating a part of the story, which was about another character. For instance, a participant was rotating a character (that was not in the right position) while explaining what the other character is thinking about. This phenomenon might have been due to the difficulty manipulating objects on the digital table. Participants had to spend more time to manipulate an object (i.e. to rotate it) on the digital table, due to the inability to reach in and grasp virtual objects, and this caused them to hold the character that they wanted in a specific position and orientation, instead of manipulating the active character.

3.7.2 Bimanual versus manual actions

I observed that participants sometime used both hands to represent simultaneous actions in the story. For instance they moved two figurines at a same time to represent that they are racing with each other (Figure 3-51).

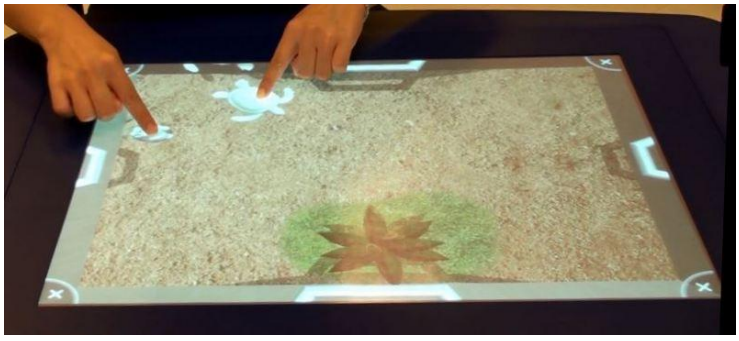

Figure 3-51: Using both hands in an asymmetric way

I also observed that participants were always working with a single figurine to locate or position on the digital table. However, in the physical conditions, participants sometimes placed two figurines on the surface at the same time. The locations of these figurines were always very close to each other and participants used both hands in a parallel way to place them on the background (See figure 3-52).

Figure 3-52: Placing two objects at a same time in sand

3.7.3 Crossing hands

I observed several incidents on the digital table in which participants crossed their hands while moving two objects simultaneously (Figure 3-53). However this incidents was never observed in physical conditions.

Figure 3-53: Crossing hands

3.8 Summary

In this chapter, I described the method and the procedure of my study and presented the observational results of participants' interactive behaviour while telling a story. I analyzed participants' behaviour through the lens of main story elements and provided a detailed analysis of what they did and how they manipulated objects while incorporating these story elements into their stories. I found out that participants followed different orders when incorporating story elements into their stories, and transitioned frequently between different phases. I also observed that participants either knew what figurines they wanted to add, or just browsed the available figurines until something caught their eye. I also found, that participants sometimes picked up all their desired characters at once and then added them to

scene and sometimes picked up and added one figurine at a time. Moreover, I observed that participants tended to perform all the character actions in order to visually represent how they happened. I also observed that the gestures used to perform regular tasks (e.g. picking up a character, or opening or closing a menu) were different than actions used to narrate a story and perform story events. The following chapter represents the design implications deduced based on the results described in this chapter.

Chapter 4 Design Implications

Participants in this study were observed performing physical actions that corresponded well with the basic elements of a story: characters, settings, and plot (Magill, 1997).These results show that quick transitions between creation and manipulation of character and scene elements is essential for this kind of physical storytelling, and that digital storytelling varies somewhat from physical (sand and water) storytelling. In this chapter, I describe how these findings can be interpreted to help designers provide support for character, scene, and plot elements of a story. I support these more general statements by contextualizing them with evidence from related work.

4.1 Supporting Characters

Characters are the backbone of any story, especially when people are visually narrating a story on a digital table, there is thus a need to represent story characters using a form of visual artifacts. Therefore, providing storytellers with appropriate features and tools to represent story characters is a fundamental part of any storytelling application. As described in 3.5.3 the following graph represents participants' behaviour when selecting a figurine.

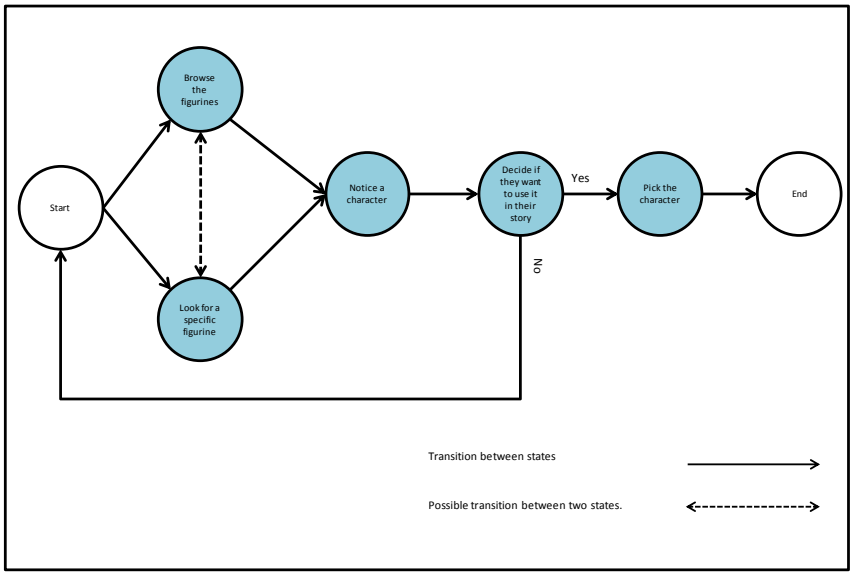

Figure 4-1: The process of selecting a figurine.

As mentioned before, participants either browsed the available figurines until a figurine caught their attention, or they knew what figurine they wanted and searched for it directly. This observation has been highly reflected in information science and web search communities. Chen et al. (1998) state that, people usually seek information for two different purposes: they either want to explore the available information to become familiar with it and to find something interesting there, or they look for a specific piece of information to find. Jul and Furnas (1997) express these behaviours through the terms "search by navigation" and "search by query". Olston and Chi (2003), use more common terms "browsing" and "searching" to describe these behaviours. They define browsing as "the process of viewing pages and navigating between them" and define searching as "the process of entering a search query into a search engine". These definitions generally imply that people usually search when they exactly know what they are looking for, and browse when they do not.

While people can benefit from both searching and browsing in information seeking, it is not clear how they can benefit from these methods in seeking a story character. In the following sections I compare searching and browsing in the context of storytelling.

Searching may enable storytellers to quickly find the figurine that they are looking for while browsing can be time consuming, especially when a large number of figurines are available. For instance, a person who wants to tell the *Red Riding Hood* story probably needs a red riding hood character. Searching in this case, might be a more appropriate way to find the desired figurine between all the available figurines. On the other hand, browsing allows a storyteller with an undefined or a vague picture of what figurines they want, to get a better idea about what they prefer, while navigating through the available figurines. That is, during the process of browsing figurines, they may be inspired by a figurine to develop a new story or revise their current story in a creative way. In the example mentioned in chapter 3, a participant claimed that he made up a story after seeing the wizard figurine. In another similar incident, a participant picked a 'boy riding a horse' figurine, and told a story in which the boy helped a princess who was changed to a rabbit by a witch. The idea of this story might have been developed when the participant saw that figurine. These observations and

other similar observations, suggest that providing storytellers with browsing tools might increase the chance of serendipity and motivate them to be more creative.

Morse (1970) stated “browsing may be defined as a search, hopefully serendipitous”. Thus, a design decision could be to employ the search mechanisms that increase the chance of serendipity findings, so that storytellers notice more interesting characters while searching.

While providing users with searching tools speeds up the process of selecting their desired figurines, browsing enables them to explore more figurines so that they may plan a story based on the observed figurines or be motivated to revise their current plan in a creative way. Considering advantageous and disadvantageous of browsing and searching, a design consideration would be to address them both in the application. This can be done through either integrating both methods in one tool in order to enable users to do both searching and browsing at a same time, or to provide separate tools to support these two behaviours. for instance, designing a searching tool which not only provides the related figurines but also suggests some random figurines. Or categorizing the available figurines into defined categories (e.g. flowers, mammals, Disney characters, etc), so that people can browse while not spending too much time for finding a desired figurine.

Moreover, as mentioned before, some users want to have specific type of character in their stories. But since it may not be practical to capture all the possible figurines in an application, it is also important to think about methods of enabling users to create their own story characters. For instance, enabling them to modify and customize predefined creatures (e.g. a predefined human body in which the head and clothes can be customized), or enabling them to draw their desired characters and make them movable.

I also observed that users follow two different approaches towards adding story characters to the scene. They either choose all their story characters before starting telling the story, or they add them eventually during the story. Participants who added some story characters during the story usually knew what they wanted to add. Therefore, one design consideration would be to facilitate the process of adding characters to the scene, so that users who eventually add their story characters, don't get distracted by this process. For

instance, by employing a search engine that has a voice recognition feature, narrators could say the name of a figurine that they are looking for (e.g. “dog”) to add it to the scene.

4.2 Supporting Setting

The scene represents the backdrop in which a story happens. To represent the scene, participants located story characters on their desired spots on the scene. They also sometimes drew on the background and used decorative figurines to express more detailed information about the place.

As mentioned in section 3.5.1, 92% of participants in the sand and digital table conditions and all the participants in the water condition, told their story after they selected all or part of their desired figurines and placed them on the background. I also observed that participants focus more on what scene they were creating rather than how they move figurines to create a scene. Both of these observations suggest that storytellers usually have their stories in mind while selecting figurines and making a scene. So, by the time the figurines are selected and the scene is created, the narrator has a clearer picture of what he/she is going to tell. Understanding that storytellers are actually in a planning state while creating a scene, is an important aspect to consider when designing the interface and interaction techniques. That is, the designer should consider that storytellers need to concentrate on developing different angles of their stories (such as where to put the characters, what the place is like, etc.), rather than focusing on working with the interface. Consequently, using more simplified and adopted interaction techniques, helps storytellers to focus more on making the scene, rather than the process of intricately moving a character. For instance, instead of dragging a figurine from one place to another across the digital surface, storytellers could tap on a figurine and on a desired spot to place it on that spot less precisely.

Moreover, as mentioned in Chapter 3, participants had two general approaches towards bringing figurines into the scene. Some of them first picked their desired figurines, and then located them on the scene, while others picked and placed one figurine at a time. Whether selecting characters and making a scene are two different mental processes is beyond the scope of this work, but this study does show the existence of these two behaviours. One

possibility would be to use the available space so that both methods are available (i.e., selecting figurines and then making a scene, or switching between selecting and placing figurines). For instance in the current design of the application, when the character drawer is open, it blocks the surface, so picking and locating characters is not possible at a same time. However by making the characters' appear transparent, smaller, or in a different shape, storytellers may be able to place a figurine on the scene, right after selecting it.

Scott et al. (2004) describe storage territories as the space in which users tend to keep their personal objects. A similar phenomenon is observed in the context of storytelling in which participants added/removed characters to/from the scene during the story. Participants used the corner of the digital table, to temporarily store the removed characters. However they used the storage provided beside both physical conditions to store the characters, and not the corner of the trays. A design suggestion, adopted from participants' behaviour in both physical and digital environments would be to provide participants with a space in which they can store their story characters (perhaps separate from the main screen space) to be able to quickly remove and add figurines to the scene, during the telling of the story a similar phenomenon is observed in the context of storytelling

I also observed that sometimes participants unintentionally hit decorative figurines (e.g. trees, flowers, etc.) while manipulating story characters in the digital environment. This type of accident usually caused distraction and confusion. Therefore, a design suggestion would be to enable storytellers to fix the position of objects that they don't want to be moved. For instance, a corresponding interaction design would be to define a functionality that allows storytellers to freeze objects (i.e., make them unmovable) by drawing a circle around them.

4.3 Manipulation of objects while narrating a story:

One of my main findings in this work was about understanding the differences between narrative actions and regular actions on a digital surface. I defined a narrative action as an action during which the focus is more on performing a task instead of accomplishing it, and also observed that people use character actions to express and convey story events.

The figures in section 3.6. suggest that participants preferred to be engaged in the process of performing character actions. For instance, the percentage of participants who represented talking through in-place actions is more than the percentage of participants who did it through moving hands above the surface (see Figure 3.39). This observation implies that they usually preferred to interact with an object (e.g. touching it, jiggling it, etc.) while saying that it is talking. Therefore, designing less interactive and less dynamic interfaces may not be an appropriate design decision for narrative applications. The Sandtray application allows users to be engaged in the process of moving objects around the surface, but for instance, an interface in which storytellers have to tap on two spots to move an object from one location to another location may not be a suitable design for a narrative interface, since narrators would like to perform movements while telling a story.

Moreover, the interaction techniques designed for a narrative interface should be simple so that manipulating objects is easy to execute. This is because trying to perform complicated interaction techniques may distract storytellers from telling their stories, as they have to focus on performing a specific gesture instead of focusing on what character action they are performing. For instance, the digital sandtray application enables storytellers to perform a 3D rotation movement. Being able to move objects in depth is a valuable feature, as storytellers can perform for instance, a character lying down while describing that it is taking a nap. The technique designed for rotating an object is a three-touch technique (Hancock, Carpendale, & Cockburn, 2007) which requires two points of contact to touch an object and a third point of contact to rotate it in a 3D space. Figure 3.45 suggests that 100% of participants represented sleeping through 3D rotation in the sand; However, this number was 71% on the digital table. One of the reason for having fewer participants perform 3D rotation on the digital table might be due to the difficulty. Sometimes participants wanted to rotate an object in a 3D space, but after several attempts they could not, so they just gave up. Therefore, while enabling participants to manipulate objects in a 3D space has value in a narrative application, some work could still be done to improve or simplify this technique.

Interaction techniques play a crucial role in a narrative application, as the more embodied storytellers feel with manipulating objects, the more they can focus on the story, rather than struggling with manipulation. Thus, designers should highly value the development of appropriate interaction techniques specific to narrative applications.

I observed that participants preferred to perform character actions, not only to feel more engaged in the process of storytelling, but also to represent how character actions happen in a story. That is, they don't just want to be engaged in the process of moving a character, but they prefer to show how it is moving. For instance, figure .. shows a participant who wants to represent the movement of the dinosaur through dragging it while rotating it to left and right (probably to display that a big animal moves slowly). A design suggestion would be to promote this behaviour (i.e., the desire to represent character actions) through amplifying character actions with computer animation. That is, an animated movement can be associated with a specific type of gesture, so that when a user performs the gesture the corresponding animation activates. For instance, when a user drags an object quickly, the object moves as it is running. Or when a user jiggles a figurine, the mouth of the figurine moves to represent talking.

Designers should also be aware of these narrative actions while designing interaction techniques for narrative applications, in order to avoid using them for a different purpose. For instance, in Windows 7 and 8, jiggling a window minimizes all the other opened windows on the background. This same interaction technique would not be suitable for a narrative application, as it would interfere with the storytelling process. Designers should consider this desire to animate by hand when creating this kind of performative interface.

Previous research recommends designing the interface in a way that storytellers can use both hands in asymmetric ways to work with the application (Terrenghi et al. , 2007).For instance, the non-dominant hand plays a supportive role (e.g., to hold a ruler) while the dominant hand performs the primary action (e.g., drawing a straight line). This recommendation is usually addressed through designing the interface in a way that storytellers need to use both hands to do a task. For instance, in the Sandtray application

storytellers need to use both hands in order to color the background. However, I observed that participants sometimes used both of their hands to perform story events. This mostly happened when they performed two simultaneous character actions. For instance, they used both hands to show that two characters are moving at the same time (e.g. racing with each other). This observation suggests that bimanual interaction techniques may need to be reconsidered for narrative applications. This may be a unique case were symmetric action (e.g., moving two figurines independently with two hands) is more desirable than the usually recommended asymmetric action (e.g., having the actions performed with the dominant hand depend on the actions performed with the non-dominant hand).

4.4 Summary

In this chapter I reviewed the result of my study from Chapter 3 and provided several design implications based on them. These design implications consist of the recommendations for facilitating the process of selecting story characters, creating a scene, and manipulation of characters. Table 4 summarizes the design implications discussed in this chapter.

Observation	Design Implication
Participants sometimes were looking for a specific object and sometimes were just browsing the available figurines	Incorporating both browsing and searching features into the design of a storytelling application. Enabling narrators to create and modify their story characters.
Participants sometimes added more story characters and changed the scene as the story proceeded	Facilitate the process of adding characters to the scene in a way that it does not distract the narrator from story telling
Participants sometimes stored their story characters in the corner of the table	Providing a storage area in which narrators can store their desired figurines to add them later during the story
Participants sometimes picked and added a figurine to the scene one at a time and sometimes picked all their desired figurines and added them afterwards	Design the interface in a way that enables narrators to add all their desired figurines in either way (i.e. at once or one at a time)
Participants were in a planning state while designing their stories' scene	Facilitate the process of adding and positioning figurines in a way that narrators can focus on designing the scene rather than struggling with working with the interface
Participants sometimes unintentionally hit the decorative figurines	Providing users with features to fix the position of the objects
Participants wanted to be engaged in the process of storytelling and manipulating objects	Less interactive and less dynamic interfaces may not be a good design decision in these cases
Participants conveyed story events and character actions through manipulating figurines	The more embodied narrators feel with manipulating objects the more they can focus on storytelling so designers should highly value the development of appropriate interaction techniques specific to narrative applications.
Participants manipulated figurines to represent how a character action happens	A design suggestion would be to promote this behaviour (i.e., the desire to represent character actions) through amplifying character actions with computer animation
Participants used a set of irregular actions (i.e. narrative actions) while illustrating a story	Designers should also be aware of these narrative actions while designing interaction techniques for narrative applications, in order to avoid using them for a different purpose

Table 4: Design implications

These design implications can be incorporated in the design of narrative application, using different techniques.

Chapter 5 Conclusion and Future Work

Storytelling has many applications in education, therapy, and entertainment. Moreover, people can practice communication and creativity, and develop stronger comprehension skills through storytelling. Technological advances in interactive surfaces make them a promising medium through which to provide users with new and exciting possibilities to create and perform stories for an audience.

Given the importance of storytelling and technological advances in interactive displays, it is no surprise that there are several attempts in HCI to support storytelling on digital surfaces. While the work done in this area mostly focuses on the design of new tools and features to integrate in the design of storytelling applications, an absence of a well-founded study of storytellers interaction behaviours motivated me to conduct an exploratory study to gain an in-depth understanding of narrators' behaviour, with the intent to inform the design of narrative applications.

Within this thesis, I presented an overview of the related work on the benefits of storytelling, on digital storytelling applications, and on digital tables and their storytelling benefits (Chapter 2). Following methods of research common in HCI, I designed and conducted an exploratory study in which I aimed to comprehend storytellers' interaction behaviours while creating and narrating a story. In this study, I compared narrators' interaction behaviours in both physical and digital environments to better understand the nature of interaction while narrating a story. I then analyzed the results through the lens of main story elements (i.e. characters, setting, and plot) to illustrate how storytellers incorporate these elements to create a story and find meaningful patterns (Chapter 3). Finally, I presented my findings on users' narrative behaviours and discussed design implications on digital narrative applications (Chapter 4).

5.1 Research Contributions

The main objective of this work was to gain an in-depth insight to narrators' interaction behaviour while creating and narrating a story using digital tabletops. I thus conducted an exploratory study to investigate storytellers' behaviour.

The main objective of this work was to gain an in-depth insight to narrators interaction behaviour while creating and narrating a story using digital tabletops. So I conducted a large exploratory study to investigate storytellers behaviour.

1- In this work I presented a new lens (i.e. main story elements) through which I analyzed storytellers interaction behaviour while creating and narrating a story. The result of my research provide a deep understanding about how storytellers select their story characters, how they make a scene, and how they manipulate objects to convey story events.

2- I suggested a set of design guidelines for designing storytelling applications on digital tabletops, based on the findings of this study including :

- To incorporate both browsing and searching features into the design of a storytelling application.
- To enable narrators to create and modify their story characters.
- To facilitate the process of adding characters to the scene in a way that it does not distract the narrator from storytelling.
- To provide a storage area in which narrators can store their desired figurines and add them later during the story.
- To design the interface in a way that enables narrators to add their desired figurines to the scene all together or one at a time.
- To facilitate the process of adding and positioning figurines in a way that narrators can focus on designing the scene rather than struggling with working with the interface.
- To enable users to fix some of their desired figurines and make them unmovable on the scene so that they don't be hit and moved unintentionally.

- Since narrators prefer to be engaged in the process of manipulating characters and perform character actions, developing more engaging interaction techniques (e.g. dragging instead of tapping) might be a better design decision.
- The more embodied narrators feel with manipulating objects the more they can focus on storytelling so designers should highly value the development of appropriate interaction techniques specific to narrative applications.
- To promote the desire to represent character actions through amplifying character actions with computer animation.
- Designers should also be aware of narrative actions while designing interaction techniques for narrative applications, in order to avoid using them for a different purpose.

3- I also introduced a new class of gestures used by narrators on a digital surface in order to convey story events and character actions.

5.2 Limitations

Conducting exploratory studies is more suitable when the goal is to become familiar with a phenomenon or behaviour while there is no specific baseline to build upon. Therefore, there is no hypothesis to test and evaluate during this type of research. Instead, the outcome of an exploratory study is a better understanding of the activity being observed, and potentially a set of hypotheses that can be evaluated in future work. Consequently, while conducting exploratory studies leads to observing more natural behaviour and can provide insight into a phenomenon, it may not provide a very precise answer to specific research questions. In this work I could get an in-depth insight into the behaviour of storytellers and suggested a set of design guidelines. However, the effects of these suggestions on the storytelling process are not completely clear until they can be evaluated through a controlled lab setting. Besides, further studies are required in order to incorporate these suggestions into the design of storytelling applications, as each suggestion can be implemented through a verity of ways.

5.3 Future Work

One obvious next step to this work includes implementing the design suggestions from Chapter 4, and then evaluating them in a controlled lab setting. Another next step would be to analyze and compare interaction behaviour between free and fixed-form stories in the data that were collected (the second, unanalyzed condition). Another potential next step could be to investigate how multiple narrators could create and tell a story using a shared digital display. Another next step could be to extend this exploration to other storytelling settings. For instance, designing a storytelling application for a classroom may have different requirements from a storytelling application designed for sandtray therapy.

A future investigation could also explore different methods of promoting positive traits in behaviour (e.g. creativity, comprehension skills, etc.) through designing digital narrative applications. Developing mental models of how people create and narrate a story could be another possible direction for future work. These mental models could be used to more easily develop appropriate interfaces that facilitate the creation of a narrative.

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Appendix A : Questionnaire

Name:

Gender:

Age:

Have you used multi touch devices before ?

If Yes, How long have you been using multi touch devices? Which kind of devices have you used?

Please answer the following questions carefully:

- On a scale 1 to 5 how much could you express the feeling associated with the story's characters through working with real objects (In the sand)? And why ?
- On a scale 1 to 5 how much could you express the feelings associated with the story's characters through working with virtual objects? And why?
- On a scale 1 to 5 how comfortable were you while working with virtual objects?
- Which one was more effective for telling the story ? Playing with the real objects or virtual objects? Why?
- What are the differences between working with real objects and virtual objects?
- Did you have any difficulty in learning the application?
- Do you have any suggestion to improve this application?

Appendix B: The story's scripts given to the participants.

The Tortoise and the hare

One day a rabbit was boasting about how fast he could run. He was laughing at the turtle for being so slow.
Much to the rabbit's surprise, the turtle challenged him to a race.
The rabbit thought this was a good joke and accepted the challenge.
They decided to start a race. As the race began, the rabbit raced way ahead of the turtle, just like everyone thought. The rabbit got to the halfway point and could not see the turtle anywhere. He was hot and tired and decided to stop and take a short nap. Even if the turtle passed him, he would be able to race to the finish line ahead of him.
All this time the turtle kept walking step by step by step. He never quit no matter how hot or tired he got. He just kept going.
However, the rabbit slept longer than he had thought and woke up. He could not see the turtle anywhere! He went at full-speed to the finish line but found the turtle there waiting for him while dancing and being very cheerful.
The rabbit became sad. Then he became angry because he had underestimated his rival.
The turtle told him to not boast anymore. He apologized and so promise to not to be selfish and make fun of others anymore.

Appendix C: Ethics approval

Dear Researcher:

The recommended revisions/additional information requested in the ethics review of your ORE application:

Title: Supporting sandtray therapy on an interactive tabletop
ORE #: 18082
Faculty Supervisor: Mark Hancock (mark.hancock@uwaterloo.ca)
Student Investigator: Mehrnaz Mostafapour (m3mostaf@uwaterloo.ca)

have been reviewed and are considered acceptable. As a result, your application now has received full ethics clearance.

A signed copy of the Notification of Full Ethics Clearance will be sent to the Principal Investigator or Faculty Supervisor in the case of student research.

****

Note 1: This ethics clearance from the Office of Research Ethics (ORE) is valid for one year from the date shown on the certificate and is renewable annually, for four consecutive years. Renewal is through completion and ethics clearance of the Annual Progress Report for Continuing Research (ORE Form 105). A new ORE Form 101 application must be submitted for a project continuing beyond five years.

Note 2: This project must be conducted according to the application description and revised materials for which ethics clearance has been granted. All subsequent modifications to the project also must receive prior ethics clearance (i.e., Request for Ethics Clearance of a Modification, ORE Form 104) through the Office of Research Ethics and must not begin until notification has been received by the investigators.

Note 3: Researchers must submit a Progress Report on Continuing Human Research Projects (ORE Form 105) annually for all ongoing research projects or on the completion of the project. The Office of Research Ethics sends the ORE Form 105 for a project to the Principal Investigator or Faculty Supervisor for completion. If ethics clearance of an ongoing project is not renewed and consequently expires, the Office of Research Ethics may be obliged to notify Research Finance for their action in accordance with university and funding agency regulations.

Note 4: Any unanticipated event involving a participant that adversely affected the participant(s) must be reported immediately (i.e., within 1 business day of becoming aware of the event) to the ORE using ORE Form 106.

Best wishes for success with this study.