Towards Understanding Interactions with Multi-Touch Spherical Displays

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ABSTRACT

Interactive spherical displays offer unique educational and entertainment opportunities for both children and adults in public spaces. However, designing interfaces for spherical displays remains difficult because we do not yet fully understand how users naturally interact with and collaborate around spherical displays. This paper reports current progress on a project to understand how children (ages 8 to 13) and adults interact with spherical displays in a real-world setting. Our initial data gathering includes an exploratory study in which children and adults interacted with a prototype application on a spherical display in small groups in a public setting. We observed that child groups tended to interact more independently around the spherical display, whereas adult groups interacted with the sphere in a driver-navigator mode and did not tend to walk around the sphere. This work will lay the groundwork for future research into designing interactive applications for spherical displays tailored towards users of all age groups.

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KEYWORDS

Interactive Spherical Displays; Child-Computer Interaction; Touchscreen Interactions; Group Interactions; Collaboration

(a) 

(b) 

Figure 1: (a) Typical deployment of non-touch spherical displays requiring remote interaction to manipulate the display. Hatfield Marine Science Center, courtesy K. Stofer. (b) Touch-driven spherical displays enable more direct, hands-on interaction with the physical display. PufferTouch display prototype, courtesy Pufferfish, Ltd.

INTRODUCTION

Interactive spherical displays offer unique affordances for numerous entertainment and educational opportunities in public spaces for multi-generational users [3,12]. The physical attributes of a spherical display create a unique experience, allowing for interfaces that play with content visibility and body orientation [12]. In contrast to flat displays, spherical displays are borderless with no front or center, so, users can approach and explore the content from multiple directions [3]. Also, the entire content of the display cannot be viewed from any given perspective, since spherical displays offer each viewer a limited viewport, depending on the user's head position, height, and angle toward the display. These physical attributes of spherical displays pose challenges for interaction but can also be exploited to create unique user experiences.

Non-touch-enabled spherical displays have been installed in museums and schools [14], but they are deployed either with no interactivity or interaction only via flat screen monitor (Figure 1-a) [5]. In 2008, Benko et al. [3] developed the first touch-enabled spherical display and described how touch interactions, e.g., drag and flick, could be implemented on the sphere to support interactivity. The authors also discussed how the spherical form factor of the display could afford new interaction styles which are not commonly seen with horizontal displays; they contrasted a horizontal display, which acts as a window into the larger digital world, to spherical displays, which show the entire digital world in a continuous fashion. Bolton et al. [4] explored the collaborative potential of interactive spherical displays in a lab-based study by developing multiple software-based "peeking" techniques to allow users to see the other parts of the display.

Since interactive spherical displays have only recently become commercially available (Figure 1-b) [15] and are yet not in widespread use, most previous work has been in lab-based studies. A notable exception is an in-the-wild study conducted by Williamson et al. [12] that examined how supporting different types of interactions affected dwell times at a spherical display installed at a university campus. They found that offering more interactive options increased dwell times as users tended to explore more of the features. There is clearly a need to continue to investigate interaction with these spherical displays in the context of real-world settings with multiple users collaborating naturally. Furthermore, all work so far involving spherical displays has been conducted with *adult* users; *children's* interaction with touch-enabled spherical displays has not yet been studied. This gap is important to address because prior work has shown that the results from touchscreen studies with adults do not always apply to children, who have different motor and cognitive capabilities [1]. Our project focuses on investigating how adults and children (ages 8 to 13) naturally interact with spherical displays by understanding users' gestural patterns and group interactions around the sphere. This paper is the first step towards exploring this topic. In our preliminary results, we discuss similarities and differences between children's and adults' general interaction patterns and mental models concerning interaction around a sphere in a public setting. We saw that child groups tended to interact more independently and explored new interaction opportunities offered by the sphere as compared to adults. Our next steps include iterative development of a prototype application for the spherical display, and public deployment and evaluation of the prototype in a science museum.

Figure 2: The sphere prototype application used during our exploratory study, showing Earth's ocean temperature patterns.

Table 1: Demographics make up of our groups of children (ages 8 to 13) and adults.

	Adults	Children
Group 1	1F, 4M	2F, 2M
Group 2	1F, 5M	2F
Group 3	4F, 1M	2F, 1M
Total	16 adults	9 children

EXPLORATORY STUDY

To better understand how children and adults collaborate and explore content on an interactive spherical display, we conducted an exploratory design probe study. During the study, participants interacted with a prototype application that allowed them to explore data visualizations of the Earth's ocean temperature system on the sphere (Figure 2). Our prototype is a part of a broader project to design better touch-enabled learning experiences, and the tabletop version of this prototype has been previously evaluated with multi-generational family groups [9]. The participants were recruited via an email sent to a faculty list and flyers distributed at a local science museum and library asking them to participate in a focus group held at a public library about their knowledge, interests, and experiences with the ocean for the larger project goals. The exploratory sphere study took place at the end of the focus group in an open-ended structure. A total of 25 participants in six groups participated in our study. Each group (max group size: six) consisted solely of adults or of children ages 8 to 13 (Table 1). Each session lasted for approximately 6 to 8 minutes, during which the groups of children and adults were asked to use the think-aloud protocol [6] to talk out loud about what they were seeing or doing on the sphere while exploring the prototype. The main goal of the design probe study was to see how people naturally interacted with the spherical display in small groups, and we did not constrain them or assign them tasks. All participants were given a $10 grocery store gift card for participating in both the focus group and the sphere session. The participants were also asked to fill out a short demographic questionnaire. From this data, we determined that the participants visited museums and science centers multiple times a year. We video recorded participants while they interacted with the prototype using two cameras, one placed at a side angle and another which was hand-held by an experimenter to cover all the interactions around the sphere. Touch interactions were also logged by the prototype application running on the sphere. Our study protocol was approved by our Institutional Review Board.

Prototype Application

Our prototype application was developed using XML and C# to run on the PufferTouch [15], a 24" diameter commercially available interactive spherical display from Pufferfish, Ltd., with a resolution of up to 1600x1600 pixels (34 ppi). The display is 1475 mm tall (58 in). We used two map views with color scaffolding designed by NASA [16]. The first visualization used a pink-to-purple color scale that showed *baseline ocean temperatures*, and the second visualization used a red-to-blue color scale to represent the extremes of the *temperature difference from baseline*. Each map visualization contained six continent hotspots that, when tapped, would pop-up an information box with content about El Niño, an ocean phenomenon affected by temperature. In the prototype, users could rotate the sphere by dragging to explore the entire globe. To enable participants to observe temperature changes over a year, our prototype contained a "calendar" (circular yellow widget in Figure 2). The user could observe the temperature changes by month by tapping on the arrows to change the month shown.

(a)

(b)

Figure 3: (a) Children performing long-hold gestures using both hands. (b) Adults interacting with the spherical display using one- and multi-finger tap gestures.

OBSERVATIONS

Novelty and First Impressions of Interactive Spherical Displays. As the spherical display is a new form factor, we observed that both children and adults experienced an initial novelty effect and were very excited during their interaction: *“This is so cool”* [adult-group 1], *“this is awesome, I will get me one of these”* [child-group 1]. While most participants tried standard touchscreen gestures (see next), we also observed that sometimes people were unsure about the interaction possibilities with the spherical display: *“Do we all interact at the same time?”* [adult-group 3], and did not always find interacting with the sphere to be very intuitive due to their unfamiliarity with the form factor: *“How do I go back to the original globe?”* [adult-group 2].

Gestures by Children and Adults. Prior work on flatscreen displays has shown that children tend to attempt unique gestures, whereas adults tend to make mostly standard touchscreen interaction gestures [2,7]. In our study, the same pattern was evident. However, with the sphere, we observed children trying a richer variety of one- and two-handed gestures using more than one finger or the whole hand. For instance, we observed a child trying to interact with the sphere by moving all five fingers in a circular motion and by performing a 5-finger long tap gesture on the sphere. We also observed children grabbing the sphere with both hands using all five fingers to stop it from rotating (Figure 3-a). In contrast, adults frequently made legacy-bias inspired touchscreen gestures (e.g., single or multi-finger tap) (Figure 3-b). It was interesting to observe children moving beyond traditional touchscreen interaction patterns and exploring new interaction opportunities offered by the spherical form factor. For example, one of the child participants said, *“Let’s see how fast the sphere can spin.”,* as he rotated the sphere using a two-handed swipe gesture.

Independent versus Collaborative Interaction (Driver and Navigator Mode). Our participant groups engaged in periods of interaction in which they were working mostly independently at separate locations around the sphere, and periods in which they were working together as a group while standing together looking at the same information on the sphere (Figure 4). The majority of the child group interactions with the sphere tended to be independent of each other, with all participants interacting at once at various locations, whereas adult groups tended to interact collaboratively with the sphere in *driver-navigator mode.* The driver and navigator group behavior, which has been observed in prior work for tabletop displays [8], involves one participant actively interacting with the interface while the rest of the group members view and discuss the information in an engaged manner. In our study, this group behavior occurred in all three adult groups and one of the three child groups (child-group 2, consisted of two female participants).

Static Locations Around the Sphere. Participant groups transitioned between independent and collaborative interaction within the same session, but in both cases we saw that participants tended to stand in one location, as opposed to moving around the sphere to view it from multiple perspectives. This tendency to stay "rooted" in one location has been noted in studies of non-interactive spherical displays in public settings as well [5]. A heatmap of touch points for an entire interaction session by a child group (child-group 2) shows that participants mainly explored the prototype by rotating the sphere while staying at the same physical location, since interaction is seen only in one quadrant (Figure 5). In some cases, when working more independently, we did ob-

(a)

(b)

Figure 4: (a) Group of children working independently in their private areas. (b) Group of children coming together to work together on one side of the sphere.

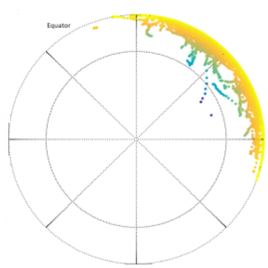

Figure 5: The touch points generated by the participants around the sphere, as viewed from above, for one child group.

serve participants calling each other over to the other side of the sphere to share information.

Interference for Gaining Control. Overall, all the groups worked well together during our study. However, considering children tended to interact more independently as compared to adults, we observed child groups sometimes exhibiting negative physical and verbal behaviors such as fighting for position and criticizing each other during their interactions to gain control of the interface elements. We did not observe this behavior in the adult groups. We also observed several instances in which a child participant was unable to read the text in an information box due to another child rotating the sphere at the same time. This ability for users' interactions to affect the entire interface could hinder group collaboration, as it gives users the ability to block what other users are trying to do. The above example suggests that the flatscreen territoriality concepts introduced by Scott et al. [10] and other negative group behaviors observed in children such as blocking access to objects and fighting for control [13] are applicable on spherical interfaces.

FUTURE WORK AND CONCLUSION

Our initial observations pave the way for future work in a number of areas related to end-user interactions around spherical displays in a public space.

Understanding users' gesture preferences. We observed that children attempted a wide range of unique gestures and moved beyond traditional touchscreen interaction patterns to explore new interaction opportunities offered by the spherical form factor, even more than in prior work on flatscreens. This observation indicates a clear need to investigate interaction with these spherical displays with users of multiple age groups. Prior work on tabletop interactions note that novel gestures that children perform during their open-ended explorations are not always supported or elegantly handled by the software, and ensuring responsiveness to these novel interactions can encourage exploration and maintain engagement [2]. A primary focus of our continuing work will be to systematically investigate users' gesture preferences with the aim of creating a gesture set for spherical displays that caters to all users and age groups.

Understanding group interactions around spherical displays. We observed different types of interaction styles that groups employed when interacting around the sphere. Overall, children tended to interact more independently around the sphere, whereas adult groups interacted with the sphere in the driver-navigator mode and did not tend to walk around the sphere. We saw a few instances of child groups exhibiting negative physical and verbal behaviors during their interaction such as fighting for position. In our future work, we will explore further how the spherical form factor influences group collaboration and develop guidelines to decrease negative collaborative behaviors. We observed groups transitioning between independent and collaborative interaction styles within the same session. This pattern indicates the collaborative potential of spherical displays for informal and open-ended environments such as museums, where the main goal is not always for all the users to emerge with a single, shared understanding [11]. Instead, this group behavior afforded by the sphere allows users to execute independent and group explorations in parallel. Future work can investigate what specific features of the spherical form factor can be exploited to support or hinder different collaboration styles.

Though there are many other open human-computer interaction questions in the area of touch interactive spherical displays, this *work-in-progress* has begun laying groundwork for future research into designing interaction for this form factor. We will conduct further work to explore the open research questions identified above and conduct a user-centered design process with target users to improve and evaluate our prototype in real-world settings with a larger sample size and broad audiences. Although, for now interactive spherical displays have limited access due to high costs, future work can explore the use of these displays for other settings, like classrooms, or other contexts, such as in biology to model the eye or in geology to model the interior of the Earth.

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