Using a Tangible Versus a Multi-touch Graphical User Interface to Support Data Exploration at a Museum Exhibit

Joyce Ma [1] **Lisa Sindorf** [1] **Isaac Liao** [2] **Jennifer Frazier** [1]

[1] Exploratorium, Pier 15, San Francisco, CA 94111, USA

[2] Visualization & Interface Design Innovation, UC Davis, 2063 Kemper Hall, One Shields Avenue, Davis, CA 94720, USA

{jma, lsindorf}@exploratorium.edu, iliao@ucdavis.edu, jfrazier@exploratorium.edu

ABSTRACT

We describe a study comparing the behavior of museum visitors at an interactive exhibit that used physical versus virtual objects to explore a large scientific dataset. The exhibit visualized the distribution of phytoplankton in the world's oceans on a multi-touch table. In one version, visitors used physical rings to look at the type and proportion of phytoplankton in different areas of the oceans, and in the other version they used virtual rings. The findings suggest that the physical rings better afforded touching and manipulations, which were prerequisites to further exploration, and attracted more groups, thereby providing opportunities for people to talk and share. However, the comparison did not detect any measurable differences in the thoroughness of visitors' interactions, the questions they asked, or on-topic talk with others at the exhibit. These results should help museum professionals and interaction designers better weigh the costs and benefits of tangible user interfaces.

Author Keywords

Tangible; multi-touch; informal learning; tabletop; user interaction; museums; information visualization; TUI.

ACM Classification Keywords

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

INTRODUCTION

Researchers posit that interactive tabletops with Tangible User Interfaces (TUIs) hold great promise in supporting learning. They theorize that unlike technologies such as purely multi-touch surfaces, large projections, or individual display devices, TUIs enable direct, hands-on interaction with physical objects. This technology can thereby provide novices with familiar physical objects and actions to manipulate and make sense of more abstract and less familiar digital representations [8, 14, 9, 15]. In addition to aiding usability, these physical objects may make interactions appear more playful, thereby promoting use and engagement [24, 17]. Furthermore, with TUIs, multiple users can manipulate an interactive simultaneously and see each other's activities, a valuable means for establishing referential anchors critical to collaborative learning [7, 11, 26].

With these properties, tabletops with TUIs seem particularly well suited to fostering the type of learning that happens in museums, science centers, and other informal learning venues. These environments have a long tradition of engaging visitors with hands-on interactions to promote visitor-driven inquiry [1, 5, 18] in a highly social environment where learning happens with each other and not just individually [5, 4]. With advances in TUI technology, tangible interfaces are becoming an increasingly viable and attractive option in the design of engaging, hands-on, social exhibits to foster learning.

Despite the theoretical promises of TUIs, empirical evidence for using TUIs to support learning has yielded mixed results. For example, in a study by Horn et al. [13] comparing a virtual to a tangible version of a programmable robots exhibit, the version with the tangible interface attracted more visitors and was more effective at fostering child-centered activities. However, the same study failed to find any differences in visitors' engagement, comprehension, or programming skill. In a study on individual learning with physical versus graphical materials, Marshall, Chen and Luckin [20] found no measurable differences in learning. In contrast, Fails et al. [10] found higher interest, engagement, and understanding when children used the tangible version, versus its graphical counterpart, of a game about environmental health hazards. Although physical objects are presumed to afford more natural interactions, Hornecker and Dünser [16] found that physical objects can suggest unanticipated and, therefore, unsupported uses, resulting in learner confusion. Marshall et al. [21] alternatively point out that a tangible interface can make the interaction so effortless as to precipitate short and superficial engagement with the contents of the interaction.

The field is continuing to construct a coherent framework to explain the strengths and weaknesses of using TUIs

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versus multi-touch GUIs and to inform the design and use of TUIs in learning [3, 15, 23]. Part of this larger effort involves studying TUIs, which are still largely custom-built for particular applications, across their many different manifestations and contexts of use. This work also requires conducting more comparative studies on TUIs and multi-touch GUIs. As noted by Zaman et al. [28], without these comparative studies, it is difficult to attribute TUIs with promoting learning interactions, especially social interactions, since many of the design affordances for collaboration are shared by both types of interfaces on interactive tabletops. In more recent years, the few comparative studies that have looked at interactive tabletops with TUIs versus multi-touch GUIs have focused on task efficiency [19, 27] or have been conducted with learners in laboratory settings [2, 26]. Although these studies add to our general understanding of interactive tabletops with TUIs, efficiency studies shed little light on TUIs in the museum setting, where their ability to attract, engage and support learning are more important indicators of their value. Likewise, the highly social, free-choice learning environment of a museum elicits different behaviors than a laboratory. Understanding how an interactive tabletop with a TUI versus a touch-only GUI attracts, engages, and promotes learning would require talking with and observing visitors *in situ*.

PURPOSE

The comparative study described in this paper sought to answer the question: What affordances does an interactive tabletop with a TUI provide in the informal learning environment of a museum? More specifically,

- Do TUIs attract a different demographic of users?
- Are visitors more engaged with TUIs? That is, do they stay at the exhibit longer? Do they use an exhibit with a TUI more thoroughly?
- Are TUIs better at fostering inquiry at an exhibit?
- Do TUIs better afford social interaction?

This work examined these questions by taking a close look at two versions of an interactive tabletop exhibit, one that used physical objects for the main interaction, supplemented by touchscreen interactions, and one that used only interactive graphical elements with touch points. Both versions were implemented on the same platform.

This study contributes to the larger effort underway in Human Computer Interaction (HCI) to more clearly identify the strengths and weaknesses of tangible interfaces for tabletop interactions. Findings also inform researchers and practitioners in the informal learning field about how to use TUIs in tabletop exhibits.

THE PLANKTON POPULATION EXHIBIT

Plankton Population is an exhibit developed at the Exploratorium in collaboration with the Visualization Interface & Design Innovation (ViDi) group at the University of California, Davis and the Darwin Project at the Massachusetts Institute of Technology. The exhibit aims to actively engage visitors, eight years old and older, with emerging research about the ocean's microbes by providing visitors with an interactive visualization that allows them to explore data about ocean microbes and the environment.

The interactive visualization shows the distribution of four different types of phytoplankton in the ocean as they change over the months of a year. See Figure 1 for a screenshot.

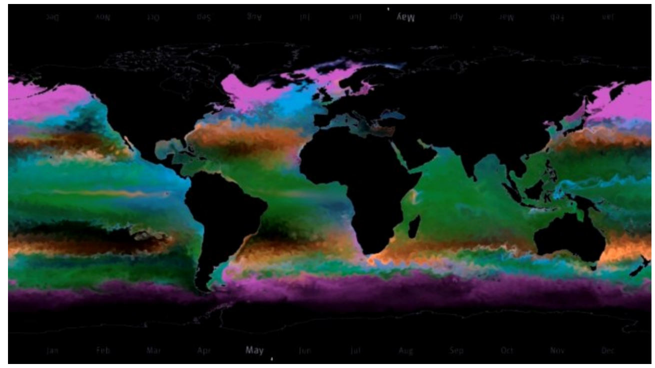

Figure 1: Screenshot of the visualization.

The visualization of the swirling patterns of colors, each representing a different phytoplankton type, is dynamic and plays continuously; visitors cannot pause or otherwise control the visualization's timeline. Instead, visitors can investigate different areas of the ocean with any of the three lenses available. The lenses are designed to connote magnifying glasses, a familiar cultural tool used to examine the very small.

When a lens is placed at a location in the ocean for one second or more, the portion of the global map under the lens fades out while icons representing the different phytoplankton types appear as shown in Figure 2.

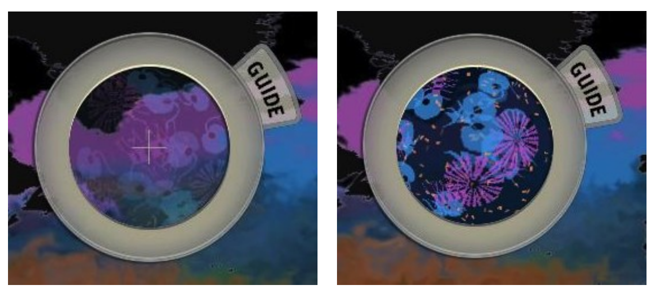

Figure 2: Close-up of a virtual ring with icons transparent (left) and opaque (right).

These icons convey the morphology of the different plankton as well as relative size. The proportion of different icons that appear in the lens reflects the distribution of the represented types at that location. A tab on the side of the lens allows visitors to access a guide that describes, in text, the four different phytoplankton types including the environmental conditions that favor their survival.

The interactive visualization runs on a Dell OptiPlex 990 with an Intel Core i5-2400 and a GeForce GTX 560, and a MultiTaction™ Cell, capable of detecting both fiducial markers and multiple finger touches on its surface. A custom built table houses the 55-inch MultiTaction™ Cell, positioned horizontally like a tabletop, as shown in Figure 3. The Dell OptiPlex 990 sits in a secured box underneath the Cell.

Figure 3: MultiTaction™ Cell and custom-built table.

The exhibit is designed to give visitors access to a real scientific dataset and, more importantly, to allow and encourage them to explore the dataset and to ask and answer their own questions with the data.

The TUI Version – Physical Rings
In the TUI version used in this study, the three lenses were implemented as physical rings shown in Figure 4. An infrared-reflective fiducial marker was embedded in the glass of the ring so that an individual could see through the invisible fiducial and glass; yet, the MultiTaction™ Cell could still detect and distinguish each fiducial marker.

Figure 4: One of the physical rings.

The Multi-touch, GUI Version – Virtual Rings
The comparable version of the exhibit with a multi-touch interface and only graphical elements was similar to the TUI version in every regard except that the three physical rings were replaced with three virtual rings of the same size and shape. The application developer went so far as to mimic the magnification effect of the lens in the virtual rings so that the multi-touch GUI version would also play up the metaphor of a magnifying glass. Like the physical rings, the virtual rings were always present, and users could move them around the table by dragging them with their fingers. See Figure 2 for a screenshot of a virtual ring.

Heeding Zaman et al.'s call to guard ecological validity [28], we sought to design a multi-touch GUI version that would be an exhibit in its own right and not just a 'damaged' counterpart. Toward this end, the exhibit with the virtual rings was reviewed and approved by exhibit developers and the gallery's curator who decided that the multi-touch GUI version could be a part of the museum collection, regardless of the research study, and would be used when the physical rings were not available.

METHOD
We used a mixed method design to understand the strengths and weaknesses of a TUI versus a multi-touch GUI. For each version of the exhibit, we collected two sets of data. First, we collected observation data of the naturalistic behavior of visitors who self-selected to approach and use Plankton Population. Second, we recruited dyads to use the exhibit and speak with us about their experience. For the dyads, we used a think aloud protocol to capture visitors' thinking as they used Plankton Population.

Observation Data
Using overhead cameras, wireless microphones attached to the rim of the exhibit table, and a screen capture application, we recorded 24 hours of observation data over the course of four weekdays and two weekend days in August, 2013. Following the procedure outlined by Gutwill [12], we cordoned off the area around Plankton Population and posted signs informing visitors that they would be audio and videotaped in that area. This procedure allowed us to secure informed consent for recording visitors' naturalistic behavior. We switched between the two versions of the exhibit once each day so that the twelve hours we collected for the physical rings were matched in time and type of day with the twelve hours captured for the virtual rings.

The two video recordings, one from the overhead camera and one from the screen capture of the interactive visualization, were synchronized in post-processing, with each other and with the audio, to produce a composite picture-in-picture video. See Figure 5.

Using this set of videos, we systematically sampled every sixth visitor who approached and stopped at the exhibit for more than five seconds. At the end of this process, our observation data corpus consisted of recordings of the behavior of 253 visitors, 128 using the physical ring and 125 using the virtual ring version of the exhibit.

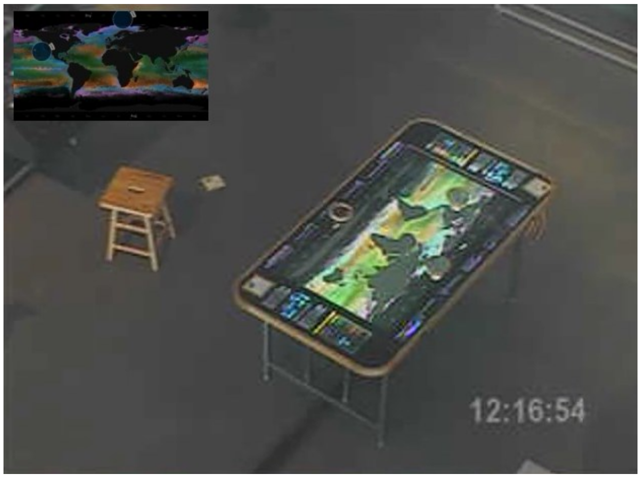

Figure 5: Screenshot of composite picture-in-picture.

Think Aloud Data from Recruited Dyads

To recruit dyads for the think aloud protocol, we approached every third visitor who appeared 8 years or older (our target demographic), who was with one other person, and who crossed a predetermined imaginary line near Plankton Population; we asked this person if s/he and one other person in her/his group would be willing to participate in our study. We intentionally selected dyads since most people come to the museum with others and because we believed that visitors would have an easier time articulating and sharing their thoughts with a person they came with.

Once both visitors consented, we turned on the microphones and asked the dyad to think aloud, articulating their thoughts with each other as they used the exhibit. Each dyad saw only one version of the exhibit. We alternated between the physical and the virtual rings with each pair recruited.

In total, we collected think aloud data from 75 dyads, 36 for the physical rings and 39 for the virtual rings. (Three of the recordings for the physical ring version were either lost due to technical issues during recording or inaudible and dropped from the corpus.) These participants' demographic breakdown is shown in Table 1 and Table 2.

Ring Version	Female & Female	Male & Male	Female & Male
Physical $n = 36$	12	9	15
Virtual $n = 39$	7	5	27
Total $N = 75$	19	14	42

Table 1: Gender of think aloud participants.

Ring Version	Child & Child	Child & Teen	Child & Adult	Teen & Adult	Adult & Adult
Physical $n = 36$	2	4	7	7	16
Virtual $n = 39$	6	0	8	4	21
Total $N = 75$	8	4	15	11	37

Table 2: Age group of think aloud participants.

RESULTS

Did TUIs attract a different demographic of users?

To answer this question, we looked at the observation data and coded each observed visitor by gender and age group (under 8 years old, child between eight and twelve, teenager, and adult). The results are shown in Table 3 and Table 4.

Ring Version	Female	Male
Physical $n = 128$	67 (52%)	61 (48%)
Virtual $n = 125$	52 (42%)	73 (58%)
Total $N = 253$	119 (47%)	134 (53%)

Table 3: Gender of visitors observed at the exhibit for physical and virtual rings. The percentage of the total number of observed visitors for each version is in parentheses.

Ring Version	Under 8	Child	Teen	Adult
Physical $n = 128$	18 (14%)	8 (6%)	41 (32%)	61 (48%)
Virtual $n = 125$	21 (17%)	15 (12%)	32 (26%)	57 (46%)
Total $N = 253$	39 (15%)	23 (9%)	73 (29%)	118 (47%)

Table 4: Age group of visitors observed at the exhibit for physical and virtual rings. The percentage of the total number of observed visitors for each version is in parentheses.

A chi-square test found no significant difference in the gender of the visitors the physical versus the virtual rings attracted; $\chi^2(1, N = 253) = 2.51, p > 0.05$. Similarly, the analysis detected no statistically significant difference in the age group of the visitors who stopped at the exhibit for the two versions. $\chi^2(3, N = 253) = 3.57, p > 0.05$.

Were visitors more engaged with TUIs?

Did they stay at the exhibit longer?

Holding time, the amount of time a visitor spends at an exhibit, is a commonly accepted metric for engagement or interest in museum research [25]. Its validity derives from the fact that museums and science centers are free-choice learning environments, where visitors themselves choose what to attend to and for how long, based on their personal interests, rather than a set curriculum that characterizes formal education settings. A comparison of the holding times between the physical and virtual rings, therefore, is one way of assessing if one interface is more engaging than the other. We used the observation data of visitors' naturalist behavior to measure holding time at the exhibit.

The holding time data were subject to a log transformation to normalize the distribution before statistical analysis. A Welch's t-test on the log-transformed data showed that visitors who stopped at the exhibit with the physical rings stayed longer (M = 92.4, SD = 82.0) than the visitors who stopped at Plankton Population with the virtual rings (M = 73.0, SD = 65.3); $t(250) = 2.21$, $p = 0.028$.

We took a closer look at the video to determine the nature of visitors' engagement with the rings, and found a higher percentage of visitors touched the physical (113 out of 128, 88%) versus the virtual rings (97 out of 125, 78%); $\chi^2(1, N = 253) = 4.39$, $p = 0.036$. (We checked to see if a ring was available at some point during each observed visitor's exhibit visit and found that in all cases, a visitor could use a ring at some point during her/his visit if s/he chose to.)

When the visitors who did not touch any ring were eliminated from the sample, we found no statistically significant difference between the log- transformed holding times for visitors who touched and used a physical (M = 98.2, SD = 84.3) versus a virtual ring (M = 85.4, SD = 67.5), $t(207) = 0.77$, $p > 0.05$. In other words, the physical rings better afforded touching and manipulation, the first step to further explorations at the exhibit.

Did visitors use the exhibit more thoroughly?

To understand the nature of their explorations with the rings, we looked at two types of data: observation data from self-selected visitors and think aloud data from recruited dyads.

Results from the observation data.

The synchronized video recordings, from the screen capture and the overhead exhibit camera, were analyzed to derive the number of times a visitor moved a ring and stopped on a location on the visualized map. A pause counted as a stop if it lasted one second or more, enough time for the map under the lens to fade out and for the icons of the phytoplankton to appear within the physical or virtual lens (Figure 2). The analysis distinguished between a stop on land, where a "No plankton on land" label would appear inside the ring, and a stop in the ocean, where icons of phytoplankton would appear.

Considering only those visitors who touched a ring, we compared the log(x+1) transform of the number of stops visitors made with the physical rings (M = 6.28, SD = 6.56) versus the virtual rings (M = 6.68, SD = 6.20) and found no significant difference, $t(206) = -0.79$, $p > 0.05$. Nor was there a statistical difference in the number of stops visitors made on land with the physical (M = 0.95, SD = 1.65) versus the virtual rings (M = 0.61, SD = 1.17); $t(208) = 1.63$, $p > 0.05$. This suggests that visitors with the physical rings explored the oceans no more or less than the visitors with the virtual rings.

We then plotted the distribution of stops to determine the coverage afforded by the physical versus the virtual rings. The resulting plots, Figure 6 and Figure 7, indicate that the stops visitors made with the virtual rings were more tightly clustered. This is borne out in a comparison between the log-transformed median search radius for each visitor's stops; visitors used the physical rings (M = 325, SD = 178) in a larger area on the interactive map than the virtual rings (M = 256, SD = 150); $t(171) = 2.93$, $p = 0.0038$. That is, the TUI better enabled broader exploration of the data in the map visualization.

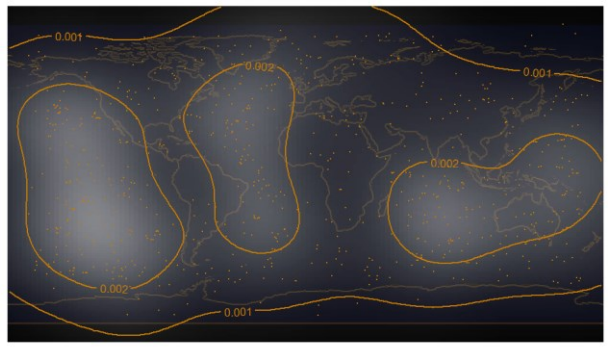

Figure 6. Density map of stops visitors made with the physical rings. Brightness denotes stops per pixel.

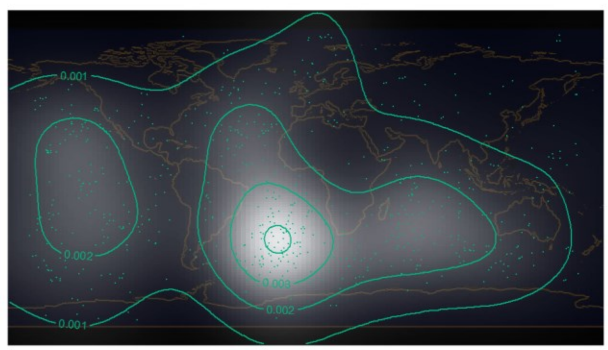

Figure 7. Density map of stops visitors made with the virtual rings. Brightness denotes stops per pixel.

Results from the think aloud data.

The think aloud data gave us an opportunity to learn about what visitors were thinking while they were using the rings to explore the data. To analyze these data, two data coders listened to the audiotaped think alouds and independently coded for absence or presence of each of five data variables visualized at the exhibit (listed in Table 5) in each dyad's talk. Sixteen randomly selected think alouds were coded by both coders to assess inter-rater reliability with the Cohen's Kappa statistic. A comparison between physical and virtual rings detected no difference for any of these data variables. The statistics for these tests are summarized in Table 5.

Data Variable	χ^2(1, *N*=75)	Kappa
Prochlorococcus	1.51	0.85+++
Synechococcus	0.21	0.86+++
Diatom	1	0.50+
Dinoflagellate	0	0.85+++
Time	0.04	0.71++

* $p < 0.05$
\+ moderate agreement
++ substantial agreement
+++ almost perfect agreement

Table 5: Chi-square test statistics comparing the number of dyads who noted a data variable with the physical versus the virtual rings. The Cohen's Kappa inter-rater score provides the reliability of each code.

Were TUIs better at fostering inquiry at the exhibit?

Looking at the think aloud data, two independent coders listened for instances of visitors posing questions that were answerable with the data visualized and for instances of visitors answering their own questions. The inter-rater reliability for 16 randomly selected dyads, coded by both raters independently, was ICC(A,1) = 0.78 for questions answerable with the data visualized and was ICC(A,1) = 0.70 for visitors answering questions using the data in front of them. These inter-rater statistics are considered excellent and good, respectively [6].

We found that dyads using the physical rings (M = 2.39, SD = 2.45) did not generate more or less questions about the data than those dyads who used the virtual rings (M = 3.05, SD = 2.95); $t(72.3) = 1.06$, $p > 0.05$. Furthermore, the visitors who did pose questions were no better at answering their questions between the physical (M = 2.21, SD = 1.70) and virtual (M = 2.33, SD = 1.81) versions; $t(48.8) = -0.24$, $p > 0.05$.

Did TUIs better afford social interaction?

We considered three behaviors in the observation data: Were visitors at the exhibit with other visitors? Were their conversations on-task? Were there instances of sharing rings?

We found that a large majority of the visitors were at the table with other visitors, 126 out of 128 visitors (98%) for the physical rings and 113 out of 125 visitors (90%) for the virtual rings. Statistically, visitors were more often at the exhibit with other people in the physical versus the virtual version; $\chi^2(1, N = 253) = 6.35$, $p = 0.012$.

Assuming that a visitor could participate in conversation as either a listener or speaker, we listened for any talk about the data visualized from anyone at the table during the time an observed visitor was at the exhibit. Looking only at those visitors who were at the exhibit with others, we found no significant difference in the number of visitors who participated in on-task talk between the two ring versions, $\chi^2(1, N = 239) = 1.67$, $p > 0.05$.

We further looked through the observation videotapes and coded instances of ring sharing (when multiple visitors have their hands on the same ring). In both versions, about a quarter of the visitors, who were at the table with others and who touched a ring, shared a ring: 29 out of 112 (26%) for the physical rings and 22 out of 91 (24%) for the virtual rings. A comparison found no difference in the number of visitors sharing; $\chi^2(1, N = 203) = 0.014$, $p > 0.05$.

DISCUSSION

In this study, we found that the TUI did not attract a different demographic of visitors to stop at the exhibit, compared to its GUI only counterpart. That is, we found no difference in the proportion of females to males or the distribution of children (under or above 8 years), teenagers, and adults who stopped at the exhibit with the physical versus the virtual rings. This was a little surprising since prior studies emphasized the appeal of tangibles to children [24, 13]. A possible explanation for this null finding may lie in the physical construction of the table. Sitting 80cm high, the MultiTaction™ Cell and the physical rings were difficult for small children to see unless they were already at the table and standing on a stool. In fact, this design better serves the exhibit's target age group, visitors 8-years and older. This null result points to the importance of the overall design of an exhibit, in which a TUI is used, in attracting the target demographic.

However, when we looked at the visitors who did stop, we found that the physical rings better afforded touch and manipulation compared to the virtual rings. Touching a ring was a critical precursor to continued engagement with the exhibit; we found that those people who touched a ring stayed longer at the exhibit, regardless of whether the ring was a physical or a virtual ring. In other words, the physical rings were better at encouraging the initial interaction necessary for continued engagement. This difference may be because the physical rings appeared to be a graspable object. Manipulable objects like the physical rings are common and even expected within the context of a hands-on museum.

Hornecker and Buur have also suggested that because TUIs can be directly manipulated, they may invite users to interact with the interface in specific ways [15]. In our case, the physical rings easily moved from one end of the tabletop to the other because they could be grasped and picked up. In contrast, the virtual rings had to be dragged across the table to explore different parts of the visualized map. The physical rings, therefore, afforded the exploration of a larger area of the map, an advantage for this particular exhibit, which sought to engage visitors with the exploration of a large scientific dataset.

O'Malley and Fraser have posited that a strong metaphorical mapping between a TUI object and its real-world counterpart may cue learners to the device's intended use [23]. In this case, the physical rings' similarity to a familiar object—a magnifying glass—may have helped visitors see them as a portal to the visualized representation of the microscopic world of phytoplankton. However, the graphical design of the virtual rings also strongly connoted magnifying lenses. This may partially explain why we found no measurable differences in how visitors engaged with the contents of the exhibit once they touched a ring, including the thoroughness of their data exploration, the number of questions they asked that were answerable with the data, and the number of those questions they tried to answer by exploring the exhibit.

O'Malley and Fraser have further suggested that in cases where learners are expected to make inferences from the representation, 'direct manipulation' may draw focus on the physical object (the physical rings) rather than the symbolic one (the distribution of plankton and the environmental factors related to that distribution) [23]. Although we did not find any quantitative evidence that the physical rings detracted from the content represented, we note that a few visitors were interested particularly in the technology behind the physical rings. On the videotapes, we noticed these visitors picking up the ring, peering through the glass and talking about possible enabling technologies. Likewise, a few participants in the think aloud study asked the interviewer afterwards for more information about the rings' underlying technology. As TUIs become more prevalent, their novelty may diminish along with their initial attractiveness for some individuals.

Findings from prior studies suggest that tangible technologies may support increased social interaction [e.g. 15, 23]. Our look into the social affordances of the TUI and multi-touch GUI detected only one difference: the TUI attracted more groups. One possible explanation for this finding may lie in the fact that the virtual rings were hard to see unless a visitor was already on top of the exhibit. In contrast, the physical rings were more noticeable from further away, especially when there was already another visitor at the table holding a ring. The physical rings themselves may have also appeared more novel than a touchscreen. We postulate that the combination of visibility and novelty attracted additional visitors to join visitors already at the exhibit. However, we note that the multi-touch GUI version was also highly popular with groups, suggesting that large multi-touch surfaces also provide opportunities for social interaction. Although a significantly higher proportion of visitors used the TUI with others, the physical rings did not elicit more on-topic talk about the exhibit's content (i.e., plankton distributions) or encourage more sharing of the tools (i.e., the rings) with which to explore that content.

CONCLUSIONS AND NEXT STEPS

The results of this study suggest that there is an advantage to using TUIs in interactive exhibits. Practitioners looking to develop tabletop exhibits may consider using TUIs to foster manipulation or encourage group use. As we work to improve the robustness of the technology, the maintenance cost should diminish making the choice of TUIs, as compared to multi-touch GUIs, a more attractive option in informal learning contexts.

However, several findings from this study merit further investigation. Hornecker and Buur have suggested that tangible objects may help focus conversation and reflection [15]. This study took a narrow look at the discussions engendered by the physical and virtual rings, focusing on visitor inquiry. Future studies might look for qualitative and quantitative differences in broader categories of talk. For example, a comparison of talk about the tool (i.e., ring) versus the content visualized might better characterize the discussions that occur and the differences in those conversations at the TUI versus the multi-touch GUI versions of this exhibit.

Similarly, the nature of collaboration at the TUI version can be better elucidated. For example, Marshall has argued that tangible interfaces may give access to views of others' activity, which may assist learning [22]. Alternately, Price et al. have suggested that shared surfaces may engender conflict, which in turn may lead to collaboration [24]. In this study, visitors did not differ in the ways they shared the rings, but future studies might investigate other ways visitors share investigations, and whether a physical or virtual object affects the nature of that collaboration. Understanding more about the quality of users' experiences with tangible interfaces will help to inform future decisions about whether they are the appropriate choice to support learning in museum settings. This study is a part in a series of steps to that better understanding.

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