Investigating Menu Discoverability on a Digital Tabletop in a Public Setting

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ABSTRACT

A common challenge to the design of digital tabletops for public settings is how to effectively invite and guide passersby—who often have no prior experience with such technology—to interact using unfamiliar interaction methods and interfaces. We characterize such enticement from the system interface as the system's *discoverability*. A particular challenge to modern surface interfaces is the discoverability of system functionality: *does the system require gestures? are there system menus? if so, how are they invoked?* This research focuses on the discoverability of system menus on digital tabletops designed for public settings. An observational study of menu invocation methods in a museum setting is reported. Study findings suggest that discernible and recognizable interface elements, such as buttons, supported by the use of animation, can effectively attract and guide the discovery of menus. Design recommendations for improving menu discoverability are also presented.

Author Keywords

Digital tabletops; interactive surfaces; menu design; public setting; field study.

ACM Classification Keywords

H.5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces. H.5.3 Group and Organization Interfaces: Computer Supported Collaborative Work.

INTRODUCTION

As large, interactive surfaces such as digital walls and tables become more feasible, they have begun to appear in public settings such as museums, airports, malls, and tourist centers. Studies examining the use of interactive surfaces in such public settings highlight the importance of a self-explanatory, 'walk-up-and-use' system that requires no prior training [7, 9, 10, 13-15, 18, 21, 24]. Such an experience requires "immediate apprehendability" [14, p. 124]. People need to experience success early, and quickly discover how to interact with the system [14, 18]. Thus, high *discoverability* of the system is important in public interactive displays. This discoverability includes attracting people to the system and informing them that the system is interactive. Attraction plays an important role in discoverability because, to interact with the system, one must first notice the system and then be enticed to interact with it.

To date, little interactive surface research has focused directly on designing for discoverability. Some commercial systems have integrated interaction design and visualization components to entice and encourage interaction, such as the water waves used on the Microsoft Surface. However, to our knowledge, the effectiveness of these techniques has not been empirically studied. A notable exception is Wigdor et al.'s [26] Ripples visualization, which provides feedback while touching a surface to help minimize ambiguity related to the success or errors of touch interactions. This approach helps to discover that a surface is interactive upon first touching, an important aspect of the overall discoverability problem. However, it does not address the initial enticement issue, nor does it help to discover the available system features (e.g., what gestures are possible or what system menus are available).

As a first step toward designing for discoverability of system features in interactive public surfaces, this research focuses on discovering system menus. As a key mechanism for accessing system functionality, menus have been the focus of considerable research for both traditional desktop computing and digital tabletops [e.g. 8, 17]. Although menus are a common graphical user interface (GUI) element, their use on digital tables is highly varied and non-standardized, creating challenges for discoverability.

This research examines how to improve the discoverability of menus designed for digital tables in public settings. More specifically, this paper presents a comparative study of several proposed menu invocation designs, conducted in a public setting. To set the context for this study, the relevant background on designing for discoverability on digital tabletops is first discussed. The proposed menu invocation designs are then presented. Next, the study method and analysis are described, and the results are presented. Finally, the implications of the study results are discussed.

BACKGROUND

Our research sits at the cross section of two streams of research in the literature: discoverability of novel technology in public settings and menu design on interactive surfaces.

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Discoverability in Public Settings

In a public setting, people tend to be unfamiliar with novel interactive devices. Unlike in a private setting, people are neither able to practice nor be explicitly instructed how to use the system. Discoverability is therefore of great importance when designing a digital tabletop for public use. In a study of a tabletop application in a public tourist centre, Marshall et al. [18] found that "visitors approached the tabletop quite tentatively…[and thus] designers need to grab their attention immediately to communicate its purpose and mechanisms of interaction" (p. 3041).

One approach to assist discoverability on public displays is to explicitly provide written instructions near the display to inform people of the purpose of the display and instruct them how to interact with the system [e.g. 9, 24]. Although this method provides an unambiguous approach to discoverability, Gaver et al. [11] argue that ambiguity in design can be used to initially draw people into interaction. This approach is echoed by Agamanolis [1] who found that ambiguity, or mystery, can entice users' natural curiosity and therefore more deeply engage them in interaction.

Gradual discovery with public displays is encouraged so as to not overwhelm users with instructions or a multitude of unfamiliar interactions [15]. Scaffolding is a gradual discovery method that breaks down larger activities into smaller steps on which to focus [27]. For example, the interface may only reveal a few elements at a time, therefore guiding the user through the exploration process.

Animation can also assist with discoverability. Previous public displays studies have used subtle movement of objects to inform users that they could manipulate these objects [e.g. 14]. The appearance and disappearance of objects has also been used to draw attention and invite interaction to these objects [e.g. 13, 14].

Discoverability of touch gestures is a particular challenge for interactive surface designers as no visible controls are typically presented for manipulation [22]. Self-revealing gestures [5, 27] use a combination of animation and visual affordances to scaffold user learning of gesture possibilities in a given interface context. This research applies similar animation and affordance techniques to improve the discoverability of individual interface elements such as menus.

Menu Design on Interactive Surfaces

Since the use of WIMP (Windows, Icons, Menus, Pointers) interfaces in the 1970's, graphical menus have been a common interface element. While many interactive surfaces utilize only gesture-based interaction, many surface applications include graphical menus to provide access to application functionality. For example, the X-Menu [3] and Occlusion-Aware Menu [6] are contextual, radial-style menus designed for digital tabletops that require people to tap the screen to invoke the menu. These designs, along with other touch-based contextual menu designs [e.g. 2, 16, 17], offer no visual indications that afford menu invocation.

While contextual menus can be invoked anywhere in the interface, other tabletop interfaces have employed edge-based menus, such as the adapted linear menu used in the Personal Digital Historian (PDH) application [25] and the semi-circular Stacked Half-Pie Menu [12]. The PDH menu was invocated from a visible control panel that could be moved anywhere along the perimeter of the table. This provided a highly visible design. The Stacked Half-Pie Menu could be invoked by tapping on a button at the edge of the table. The menu invocation button is always visible and clearly labeled with interaction instructions. This design uses a constant visual element, a button, on the display to indicate the presence and invocation method of the menu.

These evaluations have primarily focused on menu performance, particularly efficiency. Some studies also evaluated menu usability through standardized questionnaires. Although controlled studies are effective at assessing menu efficiency, particularly for user-trained scenarios, they do not assess *menu discoverability* and none of these evaluations were centred on the invocation stage. This research focuses on designing menus for digital tabletops with respect to a discoverable menu invocation experience.

DISCOVERING TABLETOP MENUS IN PUBLIC SPACES

To investigate menu discoverability, two menu invocation methods were designed: a button-based method, which leverages a conventional design concept, and an edge-based method, which uses a tabletop-specific design element. In addition to examining the effectiveness of the invocation method in fostering menu discoverability, we also explored the potential of animation to assist in menu discoverability, as suggested by the literature. Thus, we design both a proactive animation to entice and guide passersby, and a responsive animation to react to touch interaction on the table, as well as a glowing animation to highlight the invocation elements on the digital table. The menu invocation methods and animation designs are described below.

Buttons

Buttons are a common interface control element found on digital displays regardless of the medium. Modeled after physical push buttons, virtual buttons afford pushing (or touching). They are used with current menu designs such as drop-down menus. Similar to the invocation method used in the Stacked Half-Pie tabletop menu described above, the first invocation design is based on these tried and tested interface elements. This invocation design, shown in Figure 1 (left), allows people to invoke a menu by tapping or dwelling on triangular-shaped buttons situated along the interactive edge of the digital tabletop. A menu then opens in place of the button. The placement and quantity of the buttons can vary depending on the size of the digital table. This design helps to mitigate the chance of overlapping menus, and indicates the number of menus the digital tabletop provides. Menu invocation can be cancelled by dragging off the button before lifting one's finger.

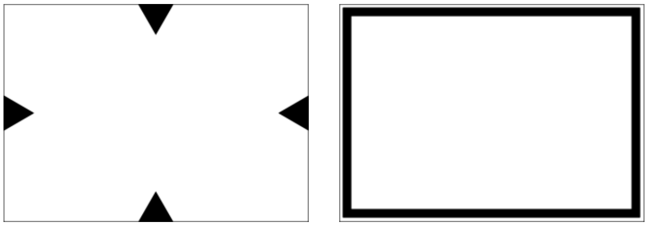

Figure 1. The two invocation type design concepts: buttons (left) and border (right).

In prior iterations of the button design, we attempted both circular and rectangular buttons, which we expected might leverage familiarity from desktop designs. However, informal user testing showed that triangular buttons were a more obvious visual element, as they bluntly protrude from the edge of table. The flat black coloring of the buttons was chosen so as not to introduce effects such as color and beveling to the observational study. Additionally, some styling effects, such as beveling a button to make it appear as though it is raised, can be misleading if viewed from an alternative orientation—a common phenomenon at a horizontal table that can be approached from any side.

Border

To provide more flexibility in positioning around the table, and in the number of menus that may be needed for a given session, an alternative invocation design was also investigated. The border design (Figure 1**,** right), allows the menu to be invoked anywhere along the interactive edge of the digital table by tapping or dwelling on the demarcated border. A menu then opens at the tapped location. Lifting the finger outside the edge will again cancel menu invocation.

Menu placement is particularly important to consider for shared tabletop and public settings, especially a walk-up and use setting, as investigated here. In this setting, people are free to approach the table from different directions, and position themselves as desired. It is also difficult to predict how many people may wish to use the table at once. Providing greater flexibility in where, and potentially how many, menus can be invoked may help to address these issues.

Animation

In public settings, many stimuli can compete for one's attention [20]. Sudden appearance of moving and/or luminous objects appeals to one's behavioral sense that the stimulus may be urgent information and thus attracts attention [4]. Therefore, animation was paired with the two invocation designs discussed above to attract passersby to the table and direct their attention to the appropriate invocation elements.

Floating Images

The first animation provided a proactive approach to attracting attention. It was designed to entice passersby to approach the table and to suggest the table contained interactive content. This animation consisted of non-interactive, translucent, floating images of the content available in the menus. The images spawned from the center of the table, enlarged as if rising, and then randomly drifted into the interactive edges of the digital tabletop (see Figure 2, left). This animation appeared whenever the table was in its "attract" state, that is, when no content was open. The images were designed to drift to the edges so as to direct people to the location of the menus. The images were also made non-interactive for the purposes of the study, as interactive floating images may have detracted from the discovery of the menus, and therefore may have affected our results. To help communicate to people that the floating images were non-interactive they were made translucent.

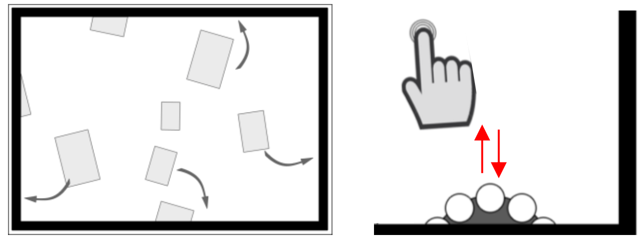

Figure 2. Design concepts for floating images animation (left) and pop-up menu animation (right).

Pop-up Menu Hints

The second animation provided a more reactive approach to indicating how to invoke a menu. When the digital tabletop was in the attract state and a person touched anywhere on the interface (other than the invocation elements), a pop-up animation would appear consisting of a partial menu coming rapidly out and then back into the edge of the table at the location of an invocation element (see Figure 2, right). This animation design was based on a self-revealing gesture to help teach people how to invoke a menu. The intention was to indicate the existence of a system menu, as well as to direct attention to the menu's location. The swift timing and movement of the animation was based on research showing that motion is effective at attracting attention, particularly if it occurs in a person's peripheral view [23].

Glow

To attract attention to the invocation elements and to indicate their interactivity, a glow effect was applied to each button and each edge. A pulsating blue gradient animation emanated from each element. The glow effect was designed so as to draw the attention of those who have not yet discovered the buttons, but not be too distracting to people already interacting with the digital tabletop. This effect only appeared on buttons and edges with no active menus, and thus also served the added purpose of indicating which sides of the table could still support additional menus.

STUDY

The goal of the study was to compare the discoverability of the different menu invocation designs for a public-use context. Thus, a realistic walk-up-and-use situation was incorporated into the study design: an observational study was conducted in a local children's museum.

Study Design

An observation-based field experiment was conducted, in which our proposed menu invocation designed were tested in a realistic setting. The study used a 2 (invocation type) × 2 (animation) between-participants factorial design.

The two invocation types were the *border* and *buttons* invocation designs. Both invocation designs invoked a system menu, described below. For the second factor, the floating images and pop-up menu hints animations were either both turned on (*animation*) or both turned off (*no animation*); however, the glow animation was kept on for all conditions.

The study was conducted across four consecutive days. Each day, observations were taken for a five hour period from approximately 10 AM to 3 PM. To ensure all four menu invocation designs obtained similar exposure to visitor traffic, the four conditions were counterbalanced using a Latin Square across the four days. To minimize disruption to participant interactions, breaks between conditions were chosen based on logical breaks in museum traffic flow, as determined by the experimenter. Conditions were presented for an average of 80 minutes per day.

Participants

Over the four-day observational period, 226 groups interacted with the digital table. Interaction times ranged from one second (e.g., a passing tap) to 20 minutes (e.g., opening and interacting with several menus and media items). Museum visitors included children aged 4 to 12[1], adolescents aged 13-18, and adults aged 25 to 75, including males and females of varying ethnic backgrounds. Visitors interacted with the table as individuals, and groups ranging from 2 to 8 people. Each visitor group typically consisted of one adult with multiple children, with the exception of kids' camp and daycare groups. In these cases, groups of only children were in the majority.

Equipment and Setting

The study took place at a local museum in August 2011. An observational area and the experimental equipment were set up on the second floor. Surrounding exhibits were primarily geared towards children. Directly across from the observational area was a motion-activated digital wall.

Within the observational area, a SMART Table[2] was set up to run our application. This table provides a child-friendly form factor (91.5×74×65.4 cm) and has a 71.5 cm (diagonal) interactive touch screen with 1024x768 pixel display resolution. The observation area also contained two small (non-digital) tables with two to three chairs situated nearby on either side of the SMART Table. The researcher sat at one of these tables to record field notes.

[1] All age classifications are the judgment of the researcher; no personal information was collected from the participants.

[2] http://smarttech.com

Figure 3: Media browsing application screenshot.

Experimental Application

To demonstrate the four study conditions, a media browsing digital tabletop application was developed. The application allowed up to four hierarchical, crescent-style menus (see Figure 3) to be opened (one on each edge of the table), from which a collection of videos and images could be opened. Multiple, replicated menus were provided based on Morris et al.'s [19] research that suggested they would better support multiple people, while reducing the discomfort and aversion of co-touching. Particularly in a museum setting, these were important factors to account for as museum visitors may not know one another.

The content in the media browsing application included images and videos representing interpretations of the fables by the author Aesop (e.g. The Tortoise and the Hare), created by local digital arts students. This content was selected for the study as it was appropriate for a broad audience (particularly children) and could be displayed as a standalone exhibit in a museum. The hierarchical organization of the crescent-style menu was leveraged to organize the content such that level 1 displayed the various fables, and level 2 displayed content pertaining to the selected fable. Text was avoided when possible for both the menu and the images to minimize orientation and display resolution issues. Figure 3 shows a snapshot of the application with two open system menus and two open content items. The application was developed in C#, .NET 4, and XAML.

Procedure

Although participants were not informed of any particular order of interaction with the SMART Table, a typical interaction consisted of the following events:

1. Noticing the SMART Table
2. Approaching the SMART Table
3. Interacting with the touch sensitive area of the table
4. Opening a system menu
5. Navigating through the menu
6. Selecting an item from the menu to open
7. Manipulating the open item

Figure 4: View from the above-the-table camera.

Participants were free to interact with the table for as short or long as desired. To help maintain the realism of a museum exhibit, a non-intrusive method of participant consent was used. A large sign posted directly behind the table informed museum visitors that by interacting with the table, they were implicitly consenting to study participation.

Data Collection

Three forms of data collection were used: field notes, computer logs, and video recording. Field notes were recorded from a nearby table. Observations focused on whether visitors noticed the table, attempted to interact with the table, successfully opened any menus, general details about their interaction with the table, and age of visitors. The experimental application automatically logged visitor's interaction with the tabletop interface. Finally, a digital camcorder was affixed directly above the table to capture a bird's eye view of the table and any interactions; audio data was captured along with the video. The video capture area extended approximately 0.5 m around the table (see Figure 4). This was useful in determining if visitors approached the digital table but did not interact with it.

Data Analysis

Visitors tended to interact with the digital tabletop in groups; therefore all analysis was conducted treating each group as one unit. Furthermore, as the focus of the study was discoverability, it was assumed that each individual in a group may be influenced by seeing other group members' interactions. Thus, the criterion used to differentiate groups was that there was no overlap in time between interacters from one group to the next.

Both quantitative and qualitative data analyses were performed. To validate the collected data, the video, log, and field data were amalgamated, verified against one another, and then sorted based on participant groups and study conditions. This data processing was conducted in conjunction with a multi-pass strategy for the video data and an open coding approach to identify behavior trends.

RESULTS

The data analysis revealed that discoverability of the system and of the system menu typically occurred in several phases. First, people noticed and approached the system, and then they began to explore the system and its interface. Finally, they began to discover the features of the system and of what the system was capable. The following sections describe how the tested invocation designs impacted discoverability through these different phases.

Initial Approach and System Use

When visitors first approached the digital tabletop, they either glanced around the system and surroundings prior to taking action or took action immediately. Actions included interacting with the system or leaving without interaction. Delay of action was often caused by people looking around the physical table (for example, looking for a physical 'start' button) or reading the consent signage. In some cases, visitors were deterred by the consent signage and left without interaction. System interaction was characterized as a person intentionally making contact with the table; this included looking around the physical tabletop and trying to find a button or tapping on the interactive surface of the digital tabletop. With a small number of groups, people interacted with the digital tabletop thinking it controlled the motion wall situated immediately across from the table. To compare the menu invocation conditions during this initial system interaction, the location of participant groups' first touches with the interactive screen was examined.

First Touches

Figure 5 shows the first tabletop interaction of each participant group across all menu invocation conditions. Each point represents the location of the first touch point of each group. Four categories of first touches were observed: invocation element, floating image, open space, and passing tap. 'Invocation element' points represent groups who first tapped on the invocation element (border or button). 'Floating image' points are only relevant for conditions with animation present as they represent groups who first tapped on a floating image (these elements were non-interactive). 'Open space' points represent groups who tapped in areas of the screen that contained no invocation elements or floating images. The last category, 'passing taps' is not shown, but represents groups who tapped on the table while walking or running by and did not stop or focus their attention to the table. Most first touches categorized as passing taps were children running by the table while dragging a hand across the surface. Often these interactions were too quick to be recognized by the system; all had no subsequent interaction. 42 groups were identified with 'passing taps' first touches. These interactions were omitted from the analysis; subsequent analysis was based on the remaining 145 groups.

As Figure 5 shows, most first touch points were located near where visitors first approached the table from the main corridor. Although this finding is likely influenced by the position of the table with respect to the visitor traffic, it suggests that people tended to first interact with the system interface within immediate reach.

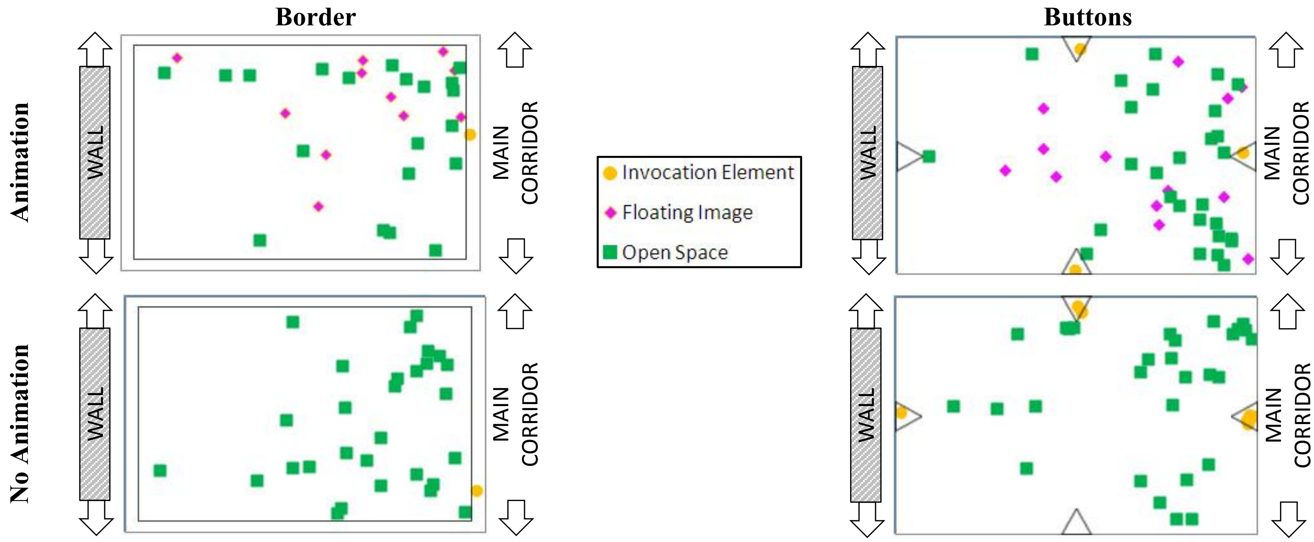

Figure 5: Location of participant groups' first touches.

In all conditions, the majority of the groups' first touches were located in the open space of the interface (107 out of 145 groups). During their initial explorations, the primary activity was to determine the purpose or use of the system. Observations suggest that people first tapped the screen to test if the digital tabletop was interactive. A difference was observed between how adults and children first interacted with the system. Adults tended to cautiously tap the table with one finger and paused for a response from the system. In contrast, most children were much less cautious and interacted with the table with their full palm (and sometimes two hands) while rubbing or hitting around randomly. Participants' explorations are presented in more detail next.

System Exploration

Timeline visualizations (Figure 6) were created for the three phases of discovery (*approach*, *explore*, and *discover*) for each group and condition to better understand these phases. Analysis of these timelines found that overall, groups with shorter *explore* times successfully transitioned to the *discover* phase. This suggests that groups with longer *explore* times often "gave up" and ceased interaction with the digital tabletop, possibly because they could not determine its purpose or find interactive content.

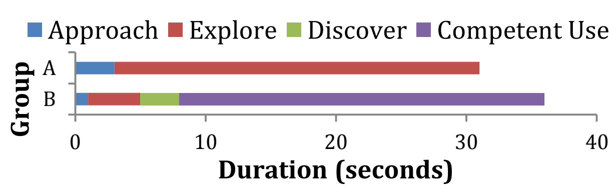

Figure 6. An example of the generated timeline visualizations.

While in the *explore* phase, many participants pondered out loud, "*what does this do?"*or *"does this thing do anything?"* If sufficiently intrigued, they continued to explore the table by continuing to tap on the screen until they either discovered something (i.e. invoked the system menu) or left. Some groups paused in this phase to read or re-read the consent and informational signage, perhaps seeking instructions on how to use the digital tabletop. Others called over other people to join in their interaction.

In exploring the digital tabletop, people either randomly tapped on the table without obvious direction or interacted with the displayed interface elements, such as tapping the floating images. Of those who interacted randomly without obvious direction, some notable interactions included a child who "hugged" the table and another one who rubbed his hands in the motion of windshield wipers.

In these random interactions, people appeared to be trying to determine the purpose of the system. If these people invoked a menu, they would often end their explorations with one person exclaiming "*oh I found something!"* to other group members. Some people's interactions appeared primarily guided by the interface elements; their interactions comprised tapping or trying to drag the floating images and, when displayed, trying to interact with the pop-up animation. These interactions are discussed in more detail below.

In the buttons condition, regardless of animation condition, many people tried to drag the buttons towards the center of the table. This behavior suggests that people may have interpreted the triangular button as an arrow pointing inward, suggesting dragging inward. Consistent with the groups' "first touch" interactions discussed above, exploratory interactions with the invocation element were not as common in the border condition.

Interactions with Animation

Groups' exploratory interactions included interaction with the floating images and the pop-up menu animations. The following statistical analysis of these interactions includes only the animation present conditions, including both the border and buttons invocation conditions.

Floating Images Animation. Overall, 51.3% of groups interacted with the floating images by tapping or trying to

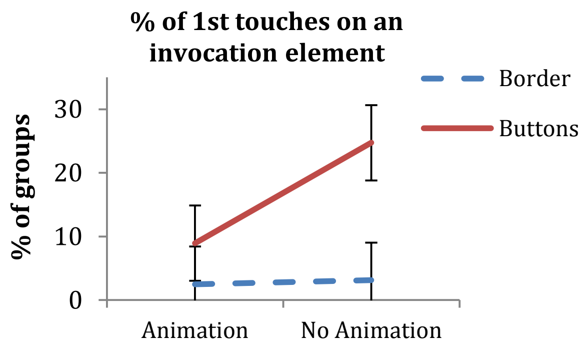

Figure 7: Percentage of groups whose 1st touch was on an invocation element (error bars based on standard error)

drag the images. This finding suggests that many people assumed that the floating images were interactive. The original intent of this animation was to provide a hint that the table contained interactive content, which could be accessed at the table's edge. However, observed interaction behavior suggests that this animation may have inadvertently distracted people by instead inviting interaction with the floating images. A t-test comparing interaction occurrences with floating images across menu invocation conditions found no significant difference (t(6)=0.51, p=.63, *n.s.*).

Pop-up Menu Animation. Of the 64 groups whose first touch triggered the pop-up animation[3], 42.2% interacted with the pop-up animation. These interactions included tapping or dragging on or near the pop-up. Of the groups that interacted with the pop-up, 51.9% of them successfully invoked a menu from their interactions. Thus, for those who noticed and were persuaded to interact with the pop-up animation, it appeared to help people successful discover and invoke the system menu. A t-test found that groups interacted with the pop-up animation significantly more often in the buttons condition (M=56.3%, SD=13.8%) than in the border condition (M=30.0%, SD=13.5%), (t(6)=2.72, p=.04). Thus, the pop-up animation appeared to be more attractive to system interaction in the buttons condition.

Feature Discovery

As groups explored the system, they began to discover the system features, including the system menu and the image and video content it invoked. To compare the effectiveness of the menu invocation conditions in this discovery process, the percentage of groups that invoked at least one menu per group and accompanying scenarios were examined.

Menu Invocations

Participants that first tapped the invocation element immediately transitioned into the *discover* phase. Figure 7 summarizes the percentage of groups whose first touch coincided with an invocation element by condition. A two-way ANOVA comparing invocation types found that the groups' first touches coincided with an invocation element significantly more often with the buttons (M=14.0%, SD=14.6%) than with the border (M=2.8%, SD=5.3%; F(1,12)=4.89, p=.047). This finding suggests that the buttons design initially attracted interaction more effectively than the border design for menu invocation. There was no significant difference found across animation conditions (F(1,12)=2.42, p=.15, *n.s.*) nor was there a significant interaction (F(1,12)=2.05, p=.18, *n.s.*).

Although no significant interaction was found, Figure 7 shows a trend for groups to first touch an invocation element in the buttons condition less often when animations were present. As the intention of including animation was to improve menu discoverability, this result suggests that animation may have actually impeded or distracted menu invocation in the buttons condition. This is further discussed below.

The video analysis revealed interesting observations of *how* participants interacted with the invocation elements. In the experimental application, a menu was invoked when a participant tapped on an invocation element. The video data revealed that some participants performed a variety of other gestures to try to invoke a menu. The most common alternative actions were to drag or dwell (i.e. touching and holding for a few seconds) on the invocation element.

Intentional Menu Invocation

Closer examination of *how* participants invoked menus revealed that there was a distinction between intentional and unintentional menu invocations. Intentional menu invocations were identified as invocations as a result of purposeful interaction while the participant's focus of attention was on the invocation element being interacted with. Unintentional menu invocations were identified as invocations as a result of an interaction when the participant's focus of attention was *not* on the invocation element being interacted with or as a result of an interaction intended for another item. Examples of interactions resulting in unintentional menu invocations are a participant resting or leaning his/her elbow/arm on the surface of the table, and a participant dragging an open image (menu content) around the screen.

Figure 8 shows the percentage of groups in which the first menu was intentionally invoked, of those that actually invoked a menu. The *first* menu is specified because it is the first menu per group that is invoked that demonstrates discoverability. Subsequent menu invocations are influenced by learning effects. A two-way ANOVA comparing these data across conditions found a significant difference across both invocation types (F(1,12)=41.06, p<.01) and animation (F(1,12)=7.86, p=.02). There was also a marginally significant interaction between invocation type and animation (F(1,12)=4.58, p=.054). Examination of the data reveals that across the invocation condition, significantly more

[3] Due to technical limitations, not all touch interactions were properly detected. Thus, not all first touches triggered a pop-up animation. Analysis of pop-up animation interactions was accordingly adjusted to include groups who successfully triggered a pop-up animation (64 of 78 groups).

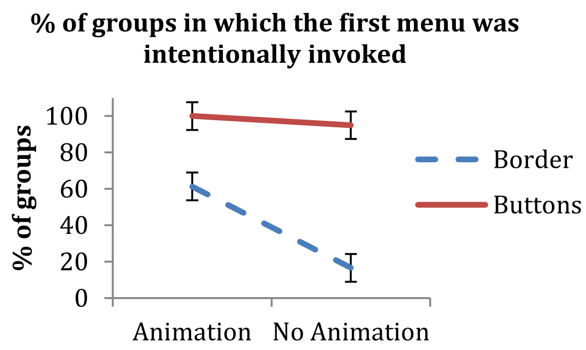

Figure 8: Percentage of groups in which the first menu was intentionally invoked (error bars based on standard error).

groups intentionally invoked a menu in the buttons condition (M=97.2%, SD=7.9%) in comparison to the border condition (M=43.6%, SD=30.3%). As Figure 8 shows, on average in the buttons condition, if a group invoked a menu, the first menu was intentionally invoked more than 90% of the time. Additionally across the animation condition, significantly more groups intentionally invoked a menu with the presence of animation (M=82.1%, SD=26.2%) than without (M=56.7%, SD=40.3%).

Further investigation of the marginally significant interaction was conducted for each invocation type across animation. An independent sample t-test comparing intentional menu invocation with the border condition found a significant difference across animation conditions (t(6)=2.62, p=.04). No difference was found for the buttons condition (t(6)=1.00, p=.36, *n.s.*). These results indicate animation had a greater impact with the border condition than with buttons; more groups in the border condition intentionally invoked a menu when animation was present (M=64.3%, SD=27.4%) than without (M=22.9%, SD=15.8%).

DISCUSSION

Invocation type and animation were introduced as two factors potentially influencing discoverability of system menus. The effectiveness of these factors are discussed below.

Invocation Type

The buttons invocation type design represented a familiar desktop-like interface element while the border design proposed an invocation method tailored to the horizontal orientation of digital tabletops.

Analysis of first touch interactions revealed that the majority of first touches coincided with open spaces or floating images, with a small percentage coinciding with the invocation elements. This finding suggests that most people were not initially drawn to the border or buttons. Of those who first interacted with invocation elements, significantly more were drawn to the buttons than the border. Since the same color and glow effect was applied to both the border and buttons, the results suggest that people recognized the buttons as an interactive interface element more easily than the border element. Each button distinctly protruded from the edge of the table, which appeared to be more effective at attracting and guiding interactions. The border design on the other hand was consistent all around the table and may have visually blended into the table edge, potentially making it difficult to distinguish as an interactive GUI element.

The examination of *intentional* versus *unintentional* menu invocation, revealed that significantly more groups intentionally invoked a menu with the buttons condition than with the border condition. These findings suggest that the buttons design was more discoverable for menu invocation. This result was likely due to the visual protrusion of the buttons, or the familiarity of most people with buttons as a GUI element. In contrast, a border is typically used to demarcate space on an interface and is not as commonly viewed as interactive. The higher frequency of border menu invocations in the raw data (though not statistically significant) was likely due to opportunistic accidents such as leaning on the table or random explorative gestures.

Although a simple aesthetic design for invocation conditions (black with blue glow) was used in the study for consistency across conditions and to control for possible confounding factors, it may have impacted recognition of the graphical elements. A flat aesthetic design (no shading or shadows) was applied to the buttons used in this study. This is unlike the classic design of buttons that mimics the physical button design, by using shading to make it appear 3D. The 3D effect is typically applied to a GUI button to imply the affordance of pushing. It is notable, that with the rise of touch interfaces, flat aesthetic designs are becoming more common, for example, as used in the Microsoft Windows Phone[4] interface. Due to the flat coloring of the buttons used in this study, it therefore cannot be definitively concluded whether the buttons design was the more discoverable design due to the use of a common interface element – a button – or, due to its more distinctive visual shape on the screen compared to the border design. Some people may not have initially recognized the triangular shape of the button as a GUI button, but instead just recognized it as a distinguishing and noticeable element on the screen. Further studies are warranted to separate these variables.

The border design appeared to be less recognizable as an interactive element, perhaps due to its classic use as a space divider. With the rise of mobile computing that uses border-based interactions (e.g. BlackBerry PlayBook[5]), people's experiences and perceptions of the GUI elements may change and thereby influence how they discover and interact with interactive systems. The design of affordances would need to account for these experiences. To better understand the impact of differing experiences on discoverability, further studies are warranted.

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[4] http://www.windowsphone.com

[5] http://ca.blackberry.com/playbook-tablet

Animation

The data analysis showed that the groups' first tabletop interactions typically were attempts to determine whether the table was interactive; they often tapped or rubbed the table and then paused for a response. When animation was present, a small subset of groups first tried to interact with the floating images. More often, groups would attempt to interact with the floating images animation during further explorations on the table. However, this animation did not appear to be effective at guiding people to the system menus, as intended; no evidence was found that people noticed the trail of the floating images into menu invocation location (i.e. into the buttons or the border).

A trend was also found in the study indicating that groups' first touch event corresponded with the buttons invocation element less often when animation was present. As a proactive animation, only the floating images animation was visible prior to any system interaction. Thus, this trend indicates that the floating images animation may have distracted people from noticing the invocation element, despite its intention of assisting menu discoverability.

The study results showed that, of the groups that did trigger a pop-up animation, some tried to interact with it. This indicates that the pop-up animation did attract some attention. Moreover, it appeared to attract more attention, and was more persuasive at inviting interaction, in the buttons condition. This may have been the case due to the fact that the pop-up appeared at the button, which already attracted attention due to its distinctive shape. It is important to note that only the number of groups that *interacted* with the pop-up was measured. It is possible that others *noticed* the pop-up, but did not interact with it. A significant number of groups who interacted with the pop-up also successfully invoked a menu across invocation conditions. This suggests that when the pop-up animation was noticed and interacted with, it was effective in supporting menu discovery.

The analysis of intentional and unintentional menu invocation revealed that significantly more groups intentionally invoked a menu with the presence of animation. Moreover, the analysis revealed that the animation had a greater positive influence in the border condition. These findings suggest that animation is helpful for menu discoverability; however, they do not distinguish between the influence of the floating images and pop-up animation.

The study results suggest that the two animations, floating images and pop-up, served different purposes. The floating images animation was proactive – it appeared before any interaction was detected, and was unaffected by interaction (until a menu was invoked). This proactive nature appeared to help entice people to approach and engage with the system. In contrast, the pop-up animation only appeared in response to interaction. The feedback it provided appeared to make it more suitable for guiding interaction during the exploration and feature discovery phases. As the two animations were evaluated together in this research, further studies are needed to determine their individual influence on overall menu discoverability.

DESIGN RECOMMENDATIONS

The comparisons of the menu invocation designs evaluated in this research provided several implications for the design of future menu invocation techniques, as discussed below.

Immediate feedback to exploratory interactions. People's first interactions with the digital tabletop were often to test if it was interactive – tapping or rubbing the table and then pausing for a response. When available, people also tried to interact with the floating images animation. It is therefore recommended that in addition to using animation to draw attention, these animations should support interaction and respond to interaction to engage people into further action.

Use of discernible interface elements. The study results revealed the buttons design to be significantly more discoverable than the border design. It is posited to be due to its distinguishable shape in the interface and use of a common GUI element – a button. This finding suggests that the use of more universal GUI elements, such as the button which is already perceived to afford interaction, particularly one that has high visible contrast, facilitates discoverability. This finding is particularly important for public settings where people are typically novices. Special attention should be made, however, to ensure these elements are designed so as not to diverge so much from their original design that they become unrecognizable, while still taking heed to the digital tabletop interface considerations, such as orientation.

Animation as a guide. The study results also revealed that animation, especially the pop-up animation, was effective at guiding interaction. Animation is therefore recommended for assisting people to discover new interactions, or even to reinforce existing ones. This recommendation is consistent with the purpose and use of self-revealing gestures [5, 27].

CONCLUSION

This paper presented an exploratory study investigating the effectiveness of two menu invocation designs, border and buttons, and of the use of animation, to facilitate the discoverability of the system menus in a digital tabletop interface. As discussed, discoverability of the system features of a digital tabletop encompasses a number of phased interaction steps, beginning with the most basic step of first recognizing that the digital tabletop is interactive.

The study revealed that buttons with the use of animation was the most discoverable menu invocation design. Overall, buttons were found to be more discoverable than the border. The buttons design was based on a common GUI element and also used a more visually distinguishable design, which likely provided more affordance for interaction than the border design. As a result, more people intentionally invoked a menu with the buttons design.

The results regarding animation from this research are consistent with findings from previous research of the positive correlation between animation and attention [4, 23]. When discovered, the pop-up animation helped to guide a person's actions towards invoking a menu. The floating images animation was useful for attracting attention and interaction; however, results suggest that it may have also distracted from locating the invocation element. Further research is warranted on these different animation designs, specifically to better understanding how proactive and responsive animations can facilitate different phases of discoverability.

Overall, this was a first step toward understanding how to facilitate discoverability of tabletop menus in a public setting. Further studies are needed to clarify how to support the different phases of discovery, from attracting people to the table, enticing then to begin interacting with it, and to their eventual discovery of what the table has to offer.

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