Stages of Social Interaction on Large Multi-touch and Tangible Interfaces

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ABSTRACT

Large interfaces not only offer a large screen real estate but also the possibility of multiple users working simultaneously on a shared workspace. Several studies and research have shown how to build these systems that foster performance and accuracy, both quantitatively and qualitatively. However, few studies have explored the aspect of social interaction between its users while using these systems. In this paper, we present a taxonomy of already existing large multi-touch and tangible interfaces. We then divide the process of social interaction in four stages and present a comparative study of each of those stages w.r.t tangibles and multi-touch surfaces. In conclusion, we propose design guidelines by summarizing the existing body of research.

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation (e.g. HCI): User Interfaces; See http://acm.org/about/class/1998/ for the full list of ACM classifiers. This section is required.

Author Keywords

Large displays, multi-touch displays, tangibles, social interaction.

INTRODUCTION

Large interfaces are a topic that has received a lot of academic attention over the years. Multiple research papers have shown their use in various contexts. These range from public information displays like the CityWall [19], collaborative teaching tools in a semi public context like the SynergyNet project [23] to a more private context such as a biologist doing a lab experiment on the eLabBench [24]. In this paper we want to have a look at one of the lesser explored areas of this wide topic: the social interactions that occur between users while they interact with such an interface and how the design of the interface affects these social interactions.

In order to do this, we have decided to divide the process of interaction with large interfaces into four parts. The main benefit of this is being able to study and analyze the otherwise large body of existing research. Although these four stages are not always distinguishable, we think this is a good starting point for understanding social interaction with large interfaces. We also observed some common patterns of interaction in the existing literature. However, there does not exist a text with consolidation of different stages. We aim to bridge this gap by connecting the dots between these stages

In the first part, we will look at how the user approaches the interface. We will see how users react to seeing an interface and how a system can entice users to interact with the interface. This is a very important stage not only to break the ice for the first-time user but to entice other prospective users as well. We will see the techniques of physical and social engagement around a large interface, the common challenges and ways to overcome them.

In the second part, we will describe the interaction between the user and the interface and how one user's action can affect social interaction of other users of the system. Can large displays facilitate increased social interaction between people? If so, how to achieve this? We will also see how the introduction of Tangible objects can increase awareness of other user's action.

In the third part we will have a look at social conflicts that can arise between users while using a collaborative interface and how to resolve them. For example, the design decision of an interface and how it may lead to conflict between users. We will also see how conflicts can sometime contribute to increased verbal communication between users.

In the final part we will focus on the final and largely unexplored area of the interaction process, the Disengagement. There has been very little research on how users end the interaction and the effect of this stage on the overall user experience of the system. We will also see some of the main reasons for users leaving the system without finishing their interaction.

For each of these stages, we will start with a short general introduction and then talk specifically about how large Multi-touch interfaces and Tangibles work in these contexts. At the end of each chapter we will talk about how the use of Tangible User Interface might change the way these social interactions take place, or if using Tangible User Interfaces changes it at all.

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LARGE INTERFACES

Multi-touch displays

Multi-touch displays are a prominent area of focus in Human-Computer-Interaction research. At the same time, large companies such as Panasonic, LG or Microsoft have created commercial multi-touch displays, mostly in the form of large screens or table surfaces. These displays differ in size, price point and intended use case.

Several studies [2, 20, 29] have been performed to provide insight as to whether multi-touch displays are a feasible alternative to more traditional solutions such as traditional desktop setups in different environments. These environments range from public interactive wall displays to information stations in museums or tourist centers. However, a good portion of commercial products like Microsoft's Surface Hub or Panasonic's Multi-Touch LED Displays seem to focus mostly on corporate office environments.

Many papers also try to put multi-touch displays in the context of education [3, 23]. Since group tasks are common in classroom environments, displays that can be used by multiple users at the same time can provide a more collaborative environment than the use of traditional single user desktop setups. Smart boards [26] and other interactive white boards , that are used in classrooms today, also classify as large multi-touch displays. These displays however are meant to replace the traditional blackboard and as such are mostly meant to be used by one person (e.g. the teacher) at a time.

Tangibles

Tangibles or Tangible User Interfaces (previously known as Graspable User Interface) are interfaces which facilitates interaction with digital systems in the form of physical objects and materials. They may also allow physical control and representation of information of the digital system. One distinct property of TUIs is that tangible input devices can be attached to different functions, each independently accessible. This property is known as space-multiplexing [15]. This is unlike the properties of the mouse (in a conventional desktop setup), which is used for controlling different functions at different times (time-multiplexing) [10].

The research on Tangibles dates back to the 90s. At CHI 1997, Ishii et al. [13] presented 'Tangible Bits' with the goal of making computing "truly ubiquitous and invisible" by establishing a new form of human computer interaction. They defined "Tangible User Interfaces" (TUIs) as user interfaces that "augment the real physical world by coupling digital information to everyday physical objects and environments".

Tangibles offer the affordances of grasping and manipulation. In addition, it may also offer the natural properties of the physical input device. This may include size, shape, surface texture of the object itself. Tangibles have shown to improve learning [11], gaming [27] and performing logistics work [21] in recent studies.

At the same time, tangibles have limitations associated with the limitation of the physical property of the object (e.g. rigidity, weight etc.). Ishii and colleagues used the metaphor 'atoms' to describe tangibles; unlike changeable 'bits' in a conventional graphical display system. Tangibles cannot always morph according to the underlying digital representation (in a more recent study, Ishii and colleagues introduced the concept of 'Radical Atoms' [12] which overcomes this phenomena). In addition to that, tangibles have a lower information bandwidth compared to GUI or voice interfaces. Ergonomics might also be a constraining factor in the design of systems or applications [5].

What is social interaction?

According to sociologist Georg Simmel, social interaction is "a common set of symbols and understandings possessed by people in a group" [22]. Clearly, social interaction is a very complex and broad topic to define. For the sake of brevity we have decided to look at three characteristics of social interaction. The first characteristic being *Communication*, the exchange of information between two or more people. In a social interaction there is often *Conflict* or social disagreement. However, in order to achieve shared goals there usually is some level of *Cooperation*. The lack of which can lead to abrupt end of the interaction.

Figure 1. Social interaction in a Digital Pandemic board game [6]

Like real life, there are a variety of different social interactions that can occur on collaborative interfaces like multi-touch surfaces, depending largely on the context that the interface is used. In a public setting, like when observing a city-center display [19], different interactions take place than while observing a semi-public multi-touch table in a tourist information center [17] or in a school environment [23]. Figure 1 shows one example of social interaction between players of a board game on a large interface by Chang et al. [6].

STAGES OF SOCIAL INTERACTION

Large multi-touch displays and tangibles on a large surface affords usage by multiple users. Often the systems and the applications are built in a way to make it easy for multiple users to collaborate. It is obvious, that the social interaction between participants is crucial for the productivity of the users. The forms of social interaction may not be limited through the use of the intermediate system but can also be direct forms of communication (e.g. verbal, finger pointing). In the following sections we divide and investigate social interaction in four stages.

A) Approaching/engaging the interface

B) Interacting with the interface

C) (Social) Conflicts and resolution

D) Disengagement from the interface.

It is to be noted here that some or all of the phases might occur more than once depending on the (system) design and especially the application specific tasks the users are given to perform. Though all the phases might not be distinct, consequential or clearly distinguishable, we think this division of phases will provide us with a good starting point on analyzing social behavior of the users.

In the following sub-sections we also provide a description of the social interaction with multi-touch surfaces and tangibles for different environments and existing systems. we mainly focus on the points below for each phase of the interaction stages:

1) Interaction between the users.

2) Challenges between the users and the system.

3) Role of affordances and feedback to overcome those challenges.

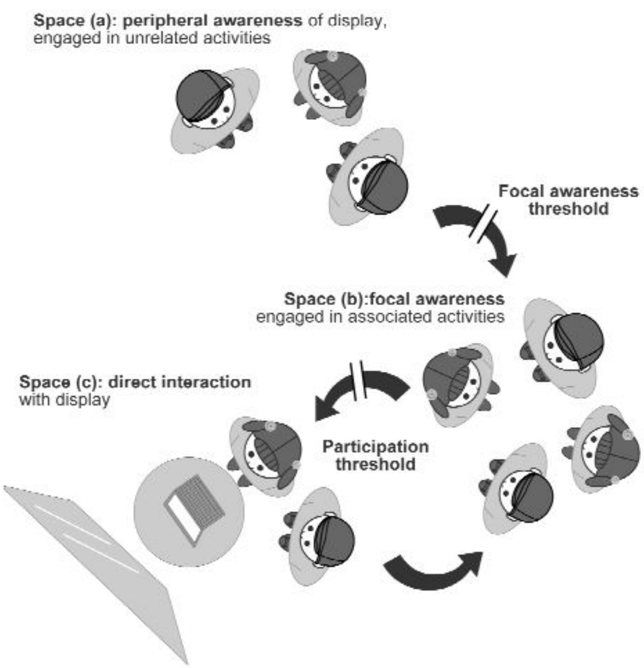

Figure 2. Public Interaction Flow model by Brignull et al. [4]

We expand upon the "Public Interaction Flow Model" [4] by Brignull et al. and "Framework for Interaction Phases" by Vogel et al. [28].

APPROACHING/ENGAGING AN INTERFACE

The user approaching and engaging with the interface is a crucial part of any interaction process. We will see how users react to seeing an interface and how a system can entice users to interact with it. This stage is important to break the ice for the first-time users and consequently attracting more users to interact with system. Brignull et al. divides the interaction process into three *Spaces* (figure 2). The challenges for users to transition from *Peripheral Awareness Space* to *Focal Awareness Space* is crossing the *Focal Awareness Threshold*. Further, they need to cross the *Participation Threshold* to transition to *Direct Interaction Space*. They suggest using affordances and feedback to make it easier for the user to transition through these spaces.

Multi-Touch Displays

Getting users to approach a multi-touch interface is a problem that is most prominent in public settings, because most users of these types of interfaces are random passer-by, that have no experience using the interface and will most likely only use it once. They might not even expect to run into any sort of user interface at all, which means that designers have to make it overtly obvious to users that they are looking at an interactive interface and not just a passive display and the utility of the interface has to be made clear as well.

Figure 3. The Honeypot effect: People noticing a person making uncommon gestures, and positioning themselves [18]

There are some approaches that we found that address the issue of making users aware of interactivity. Brignull et al. [4] talks about the Honeypot effect (figure 3), the phenomenon that users interacting with a public interface create a 'Social Buzz' that brings more users into the sphere of the interface, where they might engage passively in activities associated with the interface and even transition into using the interface directly.

This effect however still requires a string of early users to kick start some form of interaction and attract new users. One way to attract people is to use directly mirrored representations of users in the interface. Several studies [1, 16, 18, 25] have been conducted to investigate the effects of different kinds of user representations.

Ackard et al. [1] compared two different ways to represent users in large public displays. The first approach was to display their entire silhouette while they were walking by, acting as a mirror. The other approach they investigated was to display a rendered skeletal representation of the users as they walk by. They found that while the silhouette representation "facilitates more serious interaction", the skeletal representation "facilitates more play" and "causes people to stay longer" [1].

Müller et al. [18] did a similar study between using no representation at all, a silhouette based representation (similar to the previously mentioned study) and an image based representation that works similar to the silhouette based one, but that shows all of the details of the user, instead of just his/her outline, thus acting like an actual mirror. They also observed a version of their interface that featured a call-to-action, which was a string of characters in the attract loop featuring the words "Step Close to Play", versus a version of their interface with no call-to-action. They found that the image based representation seemed to lead to a higher number of interactions than the silhouette based one, which in turn had a higher number of interactions than using no representation at all. Surprisingly, using a call-to-action seemed to lower the number of interactions significantly when using user representations. With the image representation the number of interactions was almost halved when using the textual invitation compared to when no call-to-action was present.

Figure 4. Landing effect by Müller et al. [18]

Müller et al. [18] also observed an interesting social phenomenon that they called the Landing effect (figure 4), which refers to the situation in which passer-by notice the interactivity of the interface. Many users were walking right past the interface while the user representations were mirrored on the display. Instead of stopping as soon as they see the representation of themselves, they seemed to stop later, when they had already crossed the interface. They then proceeded to walk back because the user representation had caught their attention. This effect seemed to happen to groups of people in particular, where a variety of small conflicts within the group can arise from it. When people walked in groups and a person in the front of the group stopped because he noticed the interface, people would occasionally collide with the person in front of them, surprised by their sudden stop. On the other hand, if people in the back discovered the interface latter and walked back, the other group members would have a hard time noticing it, because they were not looking backwards. They would keep walking forward for a while before they realizing someone in the group had stopped. This situation especially led to conflicts because either the entire group had to stop walking and join the interacting person at the interface, or they would walk ahead, forcing the lone person to cut their interaction short in order to avoid getting left behind by their group.

It has to be addressed however, that most of the studies we have discussed so far were done with gesture-based large displays instead of multi-touch. Since mid-air gesture-based interfaces need to have some sort of camera system built to recognize gestures, it is easy for such a system to generate user representations directly from their visual input. Multi-touch systems on the other hand do not usually possess any visual input capabilities. However, Loesch et al. performed some research [16] on how to integrate user representations into multi-touch systems in order to make them more enticing for passing users.

Loesch et al. [16] have done a study on using user representations with a touch-based interface. They utilized multiple projection spaces on movable walls in combination with a separate touch display for user input. Projectors behind the movable walls are connected to Kinect cameras, which record users' silhouettes, which in turn are projected on the walls from the back. While only the touch-based display is interactive, the projected walls can serve as a sort of buffer zone to offset the Landing effect. By giving people more space to notice the user representations, they might not have to walk back once they notice it and they might just happen to stop right at the interactive part of the interface.

While Loesch et al. [16] utilized a simple and not explicitly multi-touch interface in conjunction with multiple non-interactive displays, it would stand to reason that, using the aforementioned cameras, one could create real-time user representations on a real public multi-touch display to entice people similar to gesture-based public displays.

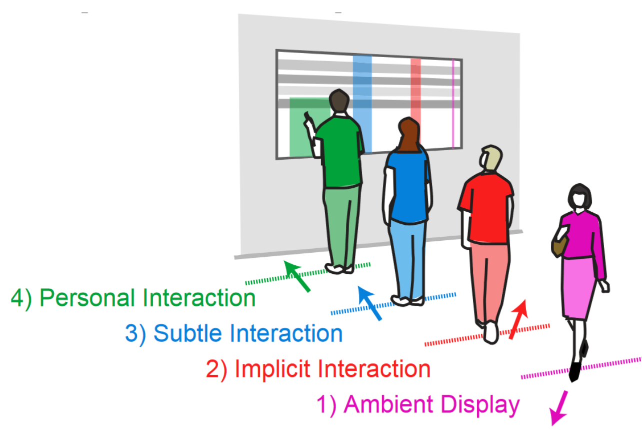

Figure 5. Framework for Interaction Phases by Vogel et al. [28]

Vogel et al. [28] proposed a framework for Interaction Phases for large, public displays. Their framework consists of four suggested stages of interaction that the interface should support with a variety of functions: Ambient Display, Implicit Interaction, Subtle Interaction, and Personal Interaction. Figure 5 shows a visual representation of the stages and users' stances toward the interface in each stage. *Ambient Display* is the proposed default state of the system, where information is displayed depending on the utility of the display, with updates occurring slowly. The *Implicit Interaction Phase* of the system should start once it senses a user in its periphery. This is the phase where the interface entices the user to come closer with user representations. The *Subtle Interaction Phase* begins when the user steps close enough and gives an implicit signal such as stopping for a moment or performing a subtle gesture. In this stage information items are displayed and the user can really interact with the interface for the first time by selecting an information item. This phase is intended to be short, Vogel et al. suggest a duration of about one minute. By selecting something, the user puts the system into its last stage, the *Personal Interaction*. Here the user can browse the information that the display provides them with. This information could also be personalized in some way, hence the name of the phase. The user should also be able to leave the interaction at any point just by physically walking away from the screen. The system should then return to its default state.

Tangibles

When it comes to signifying interactivity in a public setting, multi-touch displays have the issue of just looking like a passive display. Designers have to make efforts to entice users with their interfaces and to make sure users actually understand the utility and intent of the system. When using tangibles, the interactivity is often very clearly visible to the user due to affordances provided by the Tangible interface itself.

Issues can arise however since many tangible user interfaces rely on some sort of graspable input device that might be physically separate from the display, but which communicates with the application on the display in some meaningful way. When using these separate tangible devices in a public setting, users might take these items with them when they leave, intentional or not, and make interaction impossible for following users. This makes it hard to make use of all of the advantages tangible interfaces have to offer in a public setting like a wall display.

In non-public contexts however, tangibles can make it easy for users to identify their corresponding system as interactive. Because designers are free to design their own tangible hardware instead of just building an application on the given hardware of a multi-touch display or table surface, they are less constrained by the previously discussed limitations of interfaces that look like passive displays.

From our literature review we think that techniques (like the Honeypot effect, the Public Interaction Flow model) to entice users to a Tangible interface will be similar to the techniques for their multi-touch counterparts. However, we did not come across research specifically on Tangibles to entice users to the interface.

INTERACTING WITH THE INTERFACE

In the last chapter we had a look at how people can be enticed to interact with public interface through the use of social phenomena like the honey pot effect, and the landing effect can be a source of conflict in approaching an interface. In this chapter the focus will be on the actual interaction itself, and what kind of social interactions can occur between users here.

Working on large displays often involves collaborative aspects, seeing as how the interactive screen can be so large, that one standing person typically can not reach the entire space without moving. As such large, commercial multi-touch systems like Microsoft's Surface Hub are marketed to be used as collaborative interfaces that teams can use for a variety of tasks in an office environment, like presenting ideas, brainstorming or holding conference calls.

In this chapter we will focus mainly on systems in a semi-public context, systems that are designed for environments where the users interact not only once but in a regular fashion. This is in contrast to the last chapter where we focused mostly on public systems and how they could be designed to attract users, by designing around some key social interactions like the Landing effect. Here we will have a look at the actual interaction. Users interacting with the system and with each other for prolonged periods of time. Systems that were designed for environments like schools or offices provide these kinds of prolonged, collaborative interactions, as both in schools as well as in office environments, people are used to working together in groups on common tasks. It is also reasonable to assume that people in these contexts know each other to effectively work together.

Multi-Touch Displays

When looking at collaborative multi-touch displays and the social interactions that can occur during interaction, the effect of "social learning" and "group learning" are very interesting concepts. We have already seen some examples of social learning in the last chapter. When observing other people using a public interface, users learn that the observed system is interactive, as well as its utility and how to interact with it. This learning by copying might happen because users are interested enough to want to use the system themselves, but they want to avoid the social embarrassment of appearing incompetent when using the interface in the wrong way in front of other people.

This kind of learning success is often sufficient for public contexts, as they help users overcome the barrier of entry to using the system. In educational contexts however, systems need to provide more learning opportunities, as most of the time there is a specific educational goal that students should reach, like learning how to draw connections between separate information snippets in order to reconstruct a large, logical time line of events [23] or learning how to organize and optimize the layouts of warehouses in a logistics context [21], just to name a few examples that we came across in our literature review. Here, the multi-touch system is a tool or a platform that should help students learn. To reach this goal the multi-touch system should not be hard to use or difficult to get into, as this would make it an obstacle that would require more unnecessary learning from students instead of helping them work towards educational goals.

Higgins et al. [23] provided a comparative study done with 10 to 11 year old children in a classroom setting (figure 6). The children were provided with a variety of different text snippets, that each gave some information relating to a mining accident in the 18th century. Together in small groups they were instructed to look at the snippets and to come to a conclusion about who was responsible for the accident. While one group was given paper snippets, the other group was instructed to work with a multi-touch table, where digital snippets had been prepared, that could be moved, resized and rotated by the students as they saw fit. Higgins et al. measured the level

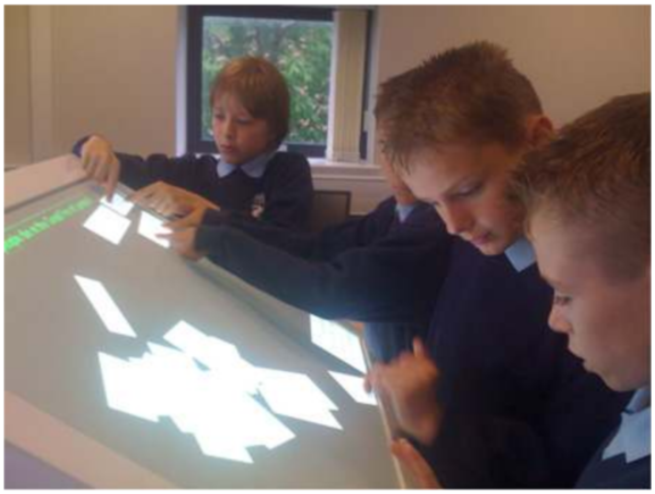

Figure 6. Students using Multi-touch Table by Higgins et al. [23]

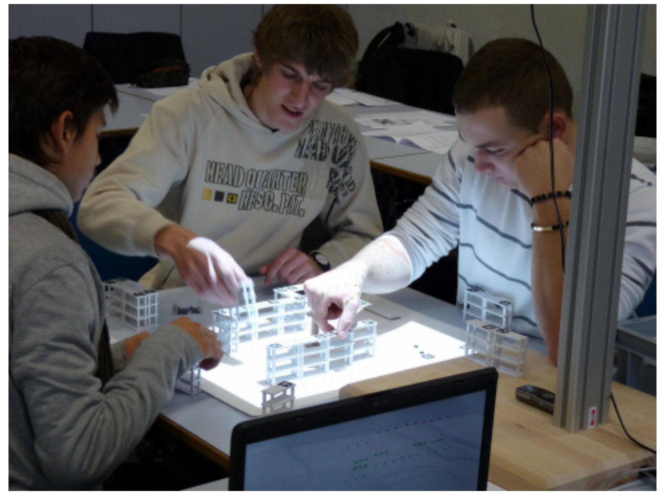

Figure 7. TinkerLamp by Do-Lenh et al. [8]

of reasoning and the time taken in all of the groups across both conditions. They conclude in their paper that while there was "no statistically significant difference in the length of time taken, examining means indicates that the groups in this multi-touch condition took almost 25% less time than groups in the paper-based condition" [23]. The level of reasoning displayed by student groups across both conditions seemed to be at about the same level, so multi-touch using students got to a similar quality of conclusion but they were faster. Higgins et al. also offer some possible explanations for these results.

According to Higgins et al., students with the multi-touch condition were able to establish better starting strategies with the opportunities that the multi-touch interface provided. A particular student group decided on size and position conventions based on the importance of the digital snippets. When snippets of information were deemed irrelevant they were downsized and put to the side of the interface. They also saved time reading, as by enlarging the snippets, all of the students could read the text at once, which in turn led to a better shared understanding of the contents and to faster, more efficient discussions, as they had established a base of understanding together. But the most interesting finding from this study for us is the four-fold increase in number of groups of "Shared view, read aloud" compared to the paper based solution.

Tangibles

While multi-touch surfaces seem to be helpful in educational context, by creating a more collaborative environment and also by providing usability through functions like zooming or free movement of information across the screen, there are some research results that seem to suggest that tangible user interfaces might provide even better learning environments for students in certain environments.

Do-Lenh et al. [8] provided a comparative study similar to the one done by Higgins et al. [23], where they measured both the task performance as well as the learning outcomes of student groups. The students were apprentices in the logistics sector, and they were supposed to learn about the proper layout and optimization of warehouses in the task that was observed. 2 classes of 15 students each would work with a tangible user interface called the "tinker lamp" (figure 7), while another class of 15 students as well as an additional class of 16 would work on the same task but on paper and without using the tinker lamp.

The "tinker lamp" system consisted of an overhead projector in combination with several paper-based sheets and a multitude of miniature models of warehouse shelves. One of the sheets has the layout of the fictional warehouse printed on it while the other sheet can be used to change parameters of the warehouse. Students would place the miniature shelves on the sheet with the layout while the projector remains over the sheet, gathering information about the state of the system via visual input from a camera. While students placed the shelves on the sheet the system would process this information and give visual feedback about the system state. The system would measure distance between shelves and project green dots onto a miniature shelf, if it is far enough away from other shelves, so that forklifts could reach it. Unreachable shelves were indicated by a red dot, so there was instant feedback on the placement of shelves.

They found that the groups working with the tangible tinker lamp system found significantly more alternative solutions to the layouting task than groups in the paper condition, while also having a higher quality in their final solution that they turned in. Quality in this case was measured by the number of shelves placed, so they were able to use the space more efficiently than the paper condition groups. This could be due to the iterative nature of the tangible interface. It is easier to prototype a solution and to change single shelves around for optimization of space usage than in the paper condition, where the shelves had to be drawn and then erased and redrawn if they wanted to iterate on a solution. The instant feedback of the tinker lamp as well as the rapid iteration possibilities that the system offered led to the groups spending less time on tedious and time intensive tasks such as drawing.

Another observation was that while the task performance was indeed significantly better in the tangible condition, the learning outcomes they measured were not significantly different between both conditions. These results are similar to the results of Higgins et al. [23] in the multi-touch context. In both cases student groups came to results faster or explored more alternatives in the same timespan and it both cases there appeared to be no significantly deeper understanding of the subject matter of the students.

In a follow-up study by Schneider et al. [21] consisting of some of the same authors as well as using the same tinker lamp system, provided a similar study comparing the tangible condition of the same task to a condition using a multi-touch table instead of a paper-based approach. The study again looked at both performance as well as learning gain as the dependent variables.

They found that again, tangibility led to better performance in terms of shelves placed and efficiency of the resulting simulated warehouse. But this time they found a small but statistically significant increase in learning gain for the tangible condition.

Over both of the studies they definitely found that performance of the task was enhanced by using Tangible User Interface system over both a paper-based approach and an approach using a multi-touch table. They attribute this increase in performance to easier exploration of the solution space, more collaboration and increased playfulness of the task in the tangible condition. They also provided some analysis that suggests that none of these factors contributed to the increased learning gain in the second study.

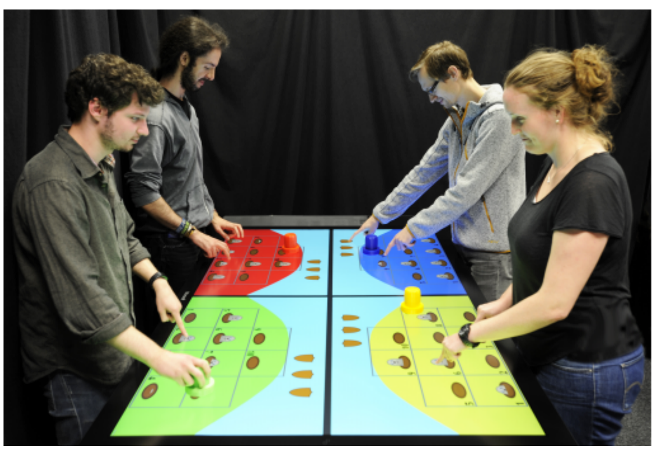

Figure 8. Whac-A-Mole with 3D printed barrel by Cherek et al. [7]

In a recent study, Cherek et al. [7] investigated the role of Tangibles in awareness of other user's action in collocated group work. Groups of 2-4 users played multi-player version of the Whac-A-Mole game on a large Tabletop interface (figure 8). They introduced new rules where each user needed to be aware of other users' actions to defend attacks in addition to the primary goal of the game: catching the moles. They found increased awareness of other player's when they introduced a 3D printed Tangible barrel (the interface element to cast attack) compared to a virtual on screen barrel. They attributed this phenomena to the physical properties of the Tangible UI element. Also, through user interviews and questionnaires they encountered another interesting observation. Some user reported that the auditory feedback of moving the tangible on the Tabletop surface made them more aware of other users' actions. Although the role of auditory feedback for Tangible UI elements was not goal of this research and hence is open to future studies.

Another study by Xambo et al [31] looked at the people using a previously developed artifact called the ReacTable [14]. The ReacTable is a musical instrument that produces electronic music similar to a synthesizer. It was developed by Jorda et al. and since then has been a popular installation at museums as well as conferences and festivals. The ReacTable features a tangible user interface, where small physical boxes are placed on a round multi-touch table, which recognizes these boxes as input and provides additional digital controls around the boxes once placed on the table. All of these boxes provide different musical output that can be altered via physical manipulation of the boxes or by interacting with their surrounding controls. The boxes could also be connected and chained to use the output of one box as the input for the next one.

Xambo et al. [31] did an observational study with the ReacTable, where they looked at several different aspects of social interactions within a 35 to 45 minute collaborative "jam session" with the system and 3 to 4 users in a group setting. They found, amongst other things, that users did some form of exploration of the interface by testing its limits. In the case of the reacTable this was done by placing all of the available boxes on the table at once. Some users had exploration strategies that were specific to the tangible features of the system. For example one user placed his phone on the table, obviously to no effect. Another user took a cylindrical input box and rolled it around the table until it eventually fell off. So when designing a tangible user interface, people will play with it and experiment with it based on the affordances of the system.

Xambo et al also investigated how users learned to use the interface. Exploration is one part of this investigation, another part is looking at social interactions between users. One such social interaction they call *mimicking*, which means that one user discovers an interaction with the system, for example how to use a certain box, and other users imitate their actions and iterate on them, discovering other techniques, which are again copied and expanded upon by other users. Another social interaction they investigated was verbal communication during the session. They discovered that verbal communication occurred mostly at the beginning and the end of these sessions and less often in the middle of them. Users were not just having group discussions but often verbalized their thoughts by thinking aloud or by announcing discoveries they had made. This also contributed to the peer learning of everybody in the group, as new members of groups were instructed by more experienced members, who showed them the different manipulation techniques they had learned earlier, thus passing on their experience with the system.

In conclusion it seems that tangible user interfaces can lead to increased performance in group tasks due to their intuitiveness and the ease and speed of their usage. In terms of increasing the depth of understanding of students however, the results seem similar to the results of Higgins et al. [23], where depth of understanding was not significantly different between conditions. It seems that tangibles mostly speed up tasks, even faster than multi-touch systems could, as shown by Schneider et al. [21], but while they can deepen understanding somewhat, it is still unclear which property of the interaction with tangible interfaces leads to this small increase in learning gain.

SOCIAL CONFLICTS AND RESOLUTION

When looking at public or semi-public interfaces that are potentially used in groups, looking at conflicts between users is an interesting topic. Even though conflicts and disagreements can occur between users, sometimes the cause of the conflict can be traced back to the design of the system they used instead of their interpersonal differences. Understanding how conflicts arise from design can help in avoiding conflicts that can lead to unsatisfactory user experiences due to inadequate expectations of the interaction with a system. Recovery from conflicts is also very important for a successful continuation of the shared task.

In this chapter we will have a look at some examples of social conflicts that we found described in different papers and attempt to understand why they occurred and which combination of design decisions could have caused it.

Multi-Touch Displays

Multi-Touch interfaces are often used in collaborative contexts, seeing as how large displays can be so large that a single user can't reach every corner of it without moving around the interface. But wherever people work together, there can always be conflicts between people caused by a variety of things.

When it comes to multi-touch displays conflicts can arise from bad interaction design for example. Marshall et al. [17] provided an observational study in their paper, which dedicated a whole sub chapter to "tension between strangers". They set up a large multi-touch table in a tourist information center in Cambridge and watched people interacting both with the table and each other for five weeks.

The conflicts that they observed however seemed to mostly stem from the interaction design of the application running on the multi-touch table. The table was offering a collaborative interaction, where users could plan their trip through Cambridge by scrolling through virtual cards with information about popular tourist attractions on them. However the interaction was split into two parts: In the first part of the interaction up to users would be looking through the cards in parallel. Each user would have one quarter of the screen for them and their own stack of cards in their part of the interface. The second part of the interaction would be initiated by any user pressing the "next step" button in the middle of the interface, upon which a pop-up was displayed for each active user, asking them if they're finished choosing the cards. Once all the users confirm the pop-up, the second part of the interaction would start. All of the selected cards would move to one side of the interface where users could gather and discuss their individual choices with each other.

As is apparent the system was designed for groups of people that were traveling together. Conflicts mostly arose from people who did not know each other, but who were using the interface together. Since the first part of the interaction does not suggest collaborative work, these people were confused as soon as they tried to move on to the second part of the interaction. It is also interesting to see how the conflicts

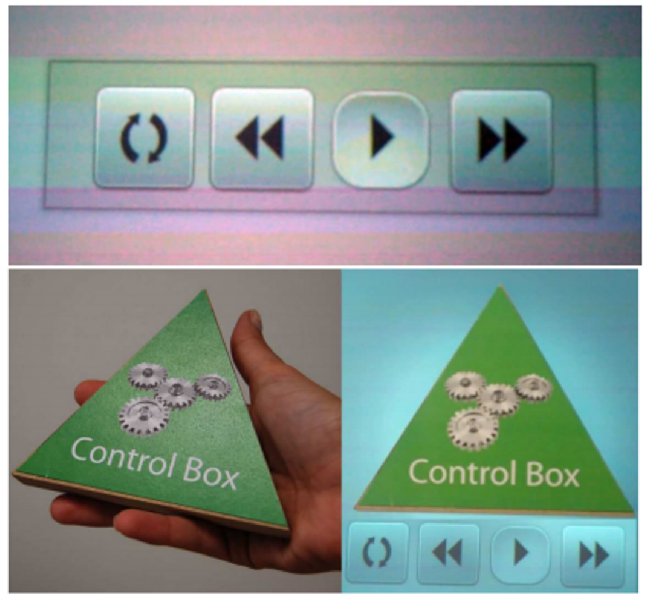

Figure 9. a.Graphical Toolbar Widget (top) b.Tangible Toolbar Token (bottom) by Olsen et al. [9]

were resolved. Marshall et al. identified multiple ways users resolved their conflicts with each other. The first way they observed was people leaving the interface as soon as a stranger joined them at the interface, which leads to avoiding conflicts altogether. The second way was for two users to be interaction with the system simultaneously but because they didn't realize that they were in fact taking part in a collaboratively designed interaction, one of them got increasingly frustrated with the system and then proceeded to leave, ending the conflict. The final way that conflicts got resolved int their observations was through discussion between users. As these users were strangers however, this typically caused some awkwardness and discomfort for everybody involved.

To sum up, the observed kinds of conflict resolution were either uncomfortable for the involved users or led directly to users leaving the system and not getting to complete their interactions. As such conflicts should be avoided through design if possible. If an interface is collaborative, it should signify that immediately and as clear as possible. It also seems like a bad idea to mix collaborative tasks with non-collaborative tasks in the same interface, especially if users encounter the non-collaborative task first, as it leads to false expectations of the system that can then subverted in a confusing manner.

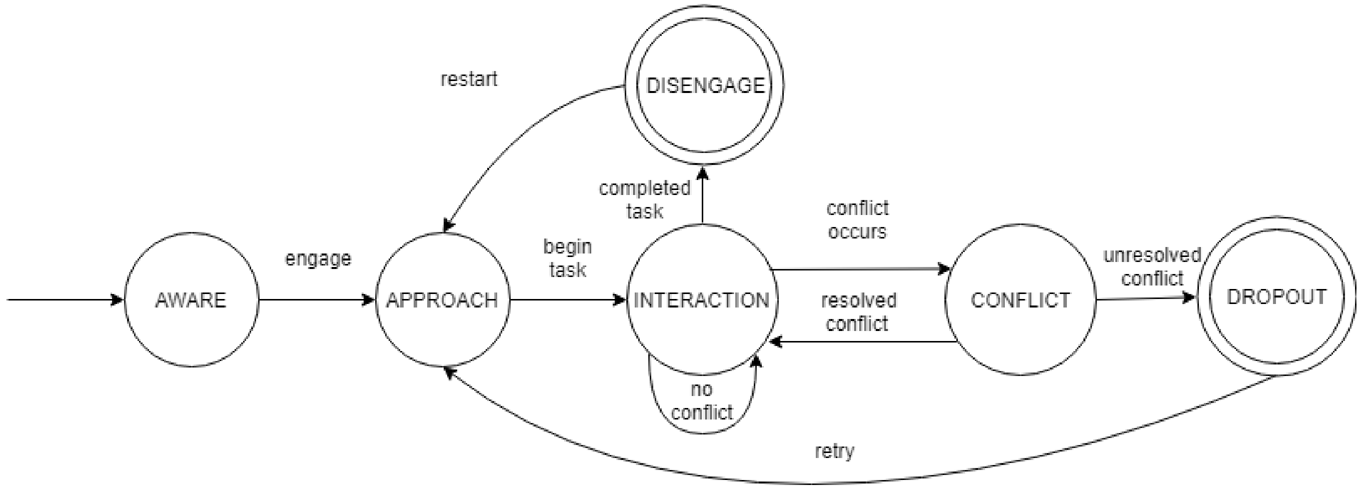

Figure 10. State diagram of various Stages of Social Interaction

Tangibles

In the following section we will see how introduction of Tangible objects can help to deal with conflicts (when compared to multi-touch counterpart) and in turn increase social interaction between the participants of a large interface.

In 2016, Olsen et al. conducted a case study of children's collaborative behavior around a multi-touch tabletop interface [9]. Four children participated in this study over a period of four weeks. They particularly observed conflicts between the children relating to a graphical toolbar that the children could drag around the screen on a Tabletop (figure 9a). In the following week, they slightly changed the interface design. Children first needed to place a Tangible wooden block on the screen (figure 9b) in order to make the toolbar appear on screen, and to get hold of it. Not only this resulted in a much shorter completion time (5 minutes, 24 seconds vs. 18 minutes, 7 seconds) compared to the previous session with the graphical toolbar on the Tabletop, they observed increased social interaction between the children. The tangible block facilitated to resolve conflict and to promote spontaneous turn taking behavior among the children. There were less verbal complaint, reach over, blocking and increased passing and tucking among the participants. In discussion, they attributed the increase in turn-taking behavior to affordance of removal of the Tangible control from the table thus "separating control of the interface element from the tabletop territories".

DISENGAGEMENT FROM THE INTERFACE

In this chapter we will discuss about the last and often final stage of the interaction phase, Disengagement. This is a very important but often overlooked phase in the interaction cycle. Disengagement from the interface may also mean disengagement from the system and/or completion of the task. Thus, it is very important in conveying to the users the state of the system through proper feedback. In addition the system might need to be prepared for the next user (engagement). For multi-touch displays this could be resetting the application to it's start state. For tangibles things get more complex. If physical objects were moved from it's start state by it's users should they be put back in order to be usable by the next user or should the application adjust itself accordingly? Could the application force the users to place the tangibles in order finish one interaction and consequently make itself ready for the next cycle? Most of these answers depend on the particular system and/or it's applications and also on the design choices by the makers of the systems.

Unfortunately, there is not a lot of research specifically focused on disengagement phase of the interaction cycle and the role it plays in social communication between the users of the system. However, a recent study by Wouters et al. sheds some light on 'Transitioning out of Engagement' [30]. They use the term "Dropping Out" to for both complete and incomplete interaction. In this paper we use the term Disengagement for successfully completed interaction. This means the user was able completed the task. Wouters observes the reason of *Completion* as "participants have progressed through the complete narrative of the interactive system, or conclude that they have depleted all possible, expected or interesting interaction possibilities".

The also observe various reasons for *Dropping Out* after an unsuccessful interaction with an interactive system. Namely these are unwillingness, disappointment, discomfort and withdrawal. Unwillingness occurs before any interaction actually has a chance to start. Users might not be interested in the system at all, or they immediately experience some surrounding issue like loudness or a long queue, the negative aspects of which outweigh the interest they have in the system. Disappointment can be caused by false affordances or other usability issues. It happens when there is a difference between the user's expectation of a system and their actual experience with it. Discomfort occurs when users are experiencing social fears that the system doesn't help enough to overcome. Wouters et al. provide the example of an interface that requires large, sweeping gestures as input, which users might perceive as awkward in a public space. Finally, withdrawal is when users drop out of a system after interacting with it for a while. This might be because of exhaustion or due to the interface being crowded with potential users. They suggest "Interactive systems need to be designed to avoid dropouts for external reasons, like limited usability or insufficient enjoyment. Systems should integrate gentle ways to abandon engagement and allow for different degrees of commitment with a system".

It is to be noted that Wouters et al. does not distinguish between the positive or negative reasons of Dropping Out. In our literature we reserve the term Disengagement for a successful end to the interaction.

CONCLUSION

Figure 10 is a representation of state diagram of the above mentioned four stages. This is also a summary of different stages and the transition from one stage to other. It is observed that the user might engage again after dropping out from the interaction, but it is more the exception than the rule. We found multiple design implications and guidelines associated with different research on this topic. It is naive to propose one set of guidelines for all large interfaces due to the fact that this is such a wide area of research. Depending on the application design, context, users the design guidelines can vary immensely. However, almost all research seems to have few common guidelines when designing a novel large interface. We conclude below three guidelines for designers or makers of large interfaces.

Make it easy to cross Thresholds: Make it easy for the user to transition between the different levels of interaction [4, 28] while approaching or engaging with the system.

Design with Conflicts in mind: Social conflicts are likely to occur between users. Design to avoid conflicts. Use affordances and feedbacks to inform the user about the system state. If conflict occurs, provide ways to recover from them.

Aim for Disengagement, not Dropout: Drop Outs contributes to negative user experience. Aim for Disengagement from the interaction.

We think there is a need of future research to find out if Tangibles can make approaching the interface easier, the role of conflicts in social interaction as well as the Disengagement stage of the interaction process.

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