Social Activities with offline tangibles at an interactive painting exhibit in a children's cultural centre

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ABSTRACT
This paper describes an empirical study of a tangible interactive painting installation at a children's cultural centre. The study focuses on how social interactions are related to features of the interactive installation. The findings concern awareness and communication within groups, mediation of control through physical objects, how groups used tangibles outside of their turn with the installation to plan, negotiate and build up anticipation of their engagement with the exhibit. Interactions within groups as well as between the active 'operator' at an exhibit and the rest of the group are presented providing insights as to how the exhibit relates to the social context. Finally, we discuss how the findings could be used for future design of group interactive exhibits that aim to (1) support social engagement such as planning, sharing experiences and discussions, (2) engage children with the exhibit topic outside of their interaction with the system and (3) foster children's anticipation of their interaction with the exhibit. Providing offline tangibles was found to extend engagement with the exhibit and support social interactions.

Categories and Subject Descriptors
• Human-centered computing~Human computer interaction (HCI)~Empirical studies in HCI • Human-centered computing~Interaction design • Human-centered computing

Keywords
Social interaction, museum, public interactive exhibits, offline tangibles

1. INTRODUCTION
Interactive exhibits that require hands-on tangible interaction are becoming commonplace in public spaces such as museum and cultural centres to enhance interactivity [10]. A lot of research in this area focuses on the active users but there is a lack of attention on the rest of the group before and after interaction. This work questions how features of an exhibit influence social interactions and engagement. Although interactive exhibits offer benefits for visitor experience there are still concerns as to whether they support or hinder visitor activities that align with visitor goals of 1) spending time together and sharing experiences, consolidating bonds and 2) being interested and engaged with exhibits in a public space [3]. A large proportion of museum visits are orientated around doing something together [3, 22]. People often visit in groups and it is important for people to swap between individual and group experiences to enable them to connect to stories, artefacts and each other [3]. Often, when people go to a museum they will have a social agenda to spend quality time with loved ones and to consolidate bonds [3, 10]. Interactive installations have been criticized for creating barriers to communication [10, 21], particularly because the social context is an integral element to the museum experience and children generally attend museums in a group with family, friends or school [10, 22].

In the area of tangible interaction it has been noted that tangible objects that can be physically and digitally detached from the system are often linked to people's actions in the larger social setting [4, 6, 7]. We investigate how these design features support social interactions and engage visitors specifically in the context of museums and public spaces.

The paper describes an evaluation study and findings of an interactive installation in a children's cultural centre. The installation (Figure 1 & 2) was a painting installation with a tangible paintbrush, wooden tokens, tabletop screen and wall projection aimed at children approximately 3 to 6 years old. It was designed as part of an exhibition for children aged 2-12 years, school groups and families. The installation consists of a projection and a table with a screen embedded in it. There was a range of wooden cards to select an animal to colour in, with the user painting on a screen using a physical electronic paintbrush and paint pots.

Findings are presented from interactional analysis of 5 volunteer video-recorded groups and observations of the general public. The study consisted of 133 children and 91 adults. The analysis

Figure 1: Installation in the Ark Cultural Centre for Children, Dublin, Ireland

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specifically focuses on how features of the exhibit relate to social engagement. The paper discusses three themes; (1) how interactions around the exhibit contribute to awareness and communication within groups, (2) the mediation of control through physical objects, (3) how the installation's physical and tangible design supported activities outside of using the interactive exhibit, which included social interactions, planning future interaction with the installation, negotiation in groups and active anticipation of one's turn.

2. Background

Museums, cultural and science centres recognize the need for interactive installations to deliver experiential value [16], evoke emotional reactions, and not only support hands-on, but also 'minds-on' interaction [1]. Social interaction in museums heavily influences the overall experience [5, 20]. In addition museum visits tend to be group activities with a purpose of spending time together. Prior work indicates the challenges that public interactives face when trying to support collaboration and social interactions [10, 13, 20, 22]. Digital interactive exhibits can impact the social ecology of a group. Vom Lehn gives an example of this from studies they ran with various high-tech immersive VR installations [21]. They found that although the installations increased participation between the exhibit and visitors, there was impoverished opportunities for discussion, collaboration and interaction between visitors. Typically, single user exhibits lack active engagement from the rest of the visiting group on a personal level [22]. Understanding how to create exhibits that support communication and shared experiences is thus very important. The presence of others may disturb or enhance the experience. There is a growing awareness of issues that exist for groups and onlookers when interactives are designed for single users (cf. [10, 12, 20]). When individuals are using single user interactive exhibits their companions become witnesses to the users' actions and are limited in their participation *"with the surrounding ecology of the exhibit"* [9, p.5]. The rest of the group cannot always see the actions of the user or what information is presented [9]. In some cases with children, situations where companions do try to co-participate in the users activity the main user becomes irritated and tries to keep away others or parents keep them away [9]. However, relatively little research investigates non-active group members' interactions [10, 20], group negotiations, planning and handling of conflicts [12, 15]. These elements are the focus of this research, in particular, how tangible objects relate to non-active group members' experiences by facilitating physical interaction with the exhibit outside of core interaction.

Interacting with tangible objects outside of core interaction has previously been defined as 'offline' tangible interaction (cf. [4, 6, 7]). Offline tangible interaction refers to interactions that occur with tangible controllers or 'tokens' that are not registered by the system (cf. [4, 6, 7]). In the case of the interactive exhibit designed and evaluated for this research, "offline" means physical interactions with tangible features of the exhibit that do not change the digital content. Esteves and Fernaus, amongst others, have pointed to some design criteria of tangibles that have proven to support and encourage social activities [4, 6]. Their work indicates the ability of tangibles to support offline activities may be one of the strongest benefits of tangible interaction [4, 7]. Prior related research has focused on systems that are designed for collaborative and/or task-orientated interactions. The systems used have detachable tangibles that represent several different actions with varying outcomes. Esteves examined offline tangibles in terms of users' performance, task complexity, problem solving and the offloading of cognitive workload [2]. Whereas Fernaus et al's [2006] research examined offline tangibles in the context of a tangible programming space for school groups. They found that offline tangibles fostered socially-orientated actions such as physically sharing resources and developing a sense of shared activity.

Various digital painting systems have previously been developed, using real paintbrushes on tabletop interfaces [19], haptic devices such as the phantom [14] or mouse input [12]. This prior research emphasized the lack of natural intuitive interfaces [14]. In addition, tangible interfaces are recognised as possessing qualities that support social activities, can be used as tools for communication [6, 11], resources for action[6] and are associated with affective experiences [7]. This gave reason to design and evaluate a system which required physical interaction with tangible objects.

Snibbe & Raffle's research investigates socially immersive media relating to camera-based interactives, tangible interfaces, interactive games and interactive art [17]. Primarily, they work with the idea of performance and narratives around camera tracking systems and large wall projections. They argue that socially immersive media should be, among other things, *'socially balanced'*, where interaction should equally emphasize *"a user's awareness of herself, other users, and the media itself"* [17. p.1449]. Their work achieves this by facilitating users to jump between roles such as a performer or viewer of the interaction. This aligns with Debenedetti's argument to provide both introspective and shared experiences in museums in order to connect with stories on a deeper introspective level or to fulfill social agendas [3].

We can draw upon design strategies for interactive systems from these projects, strategies that aim to support social interaction such as: providing controllers that can be detached physically and digitally from the system and that facilitate users jumping between the performer and viewer roles. The previous research discussed above, was based on examining multi-user input systems and/or group orientated tasks. However, in our study we analysed the social interactions at and around a system that was designed for single user input that has similar design features such as detachable controllers, a large screen projection and situations where visitors are the viewer or performer. The research is situated in the context of public interactive exhibits in order to understand the relationship between features of the exhibit and visitors' communication and social interactions.

3. The Installation

The installation that we designed and evaluated was part of a 3 month exhibition about exploring nature and biodiversity at the Ark, a cultural centre for children in Dublin, Ireland. The installation was developed for the exhibition, in order to investigate in a real museum-type environment the user experience at an interactive exhibit involving tangible interaction. The exhibition was aimed at children aged: 2-12 years. School groups and families were the target audience. The centre aims to introduce children to the joy, wonder and creativity of arts, presenting high-quality engagement and rich experiences. Children are encouraged to be makers and doers as well as lookers and listeners. The painting installations target audience was children approximately aged 3-6 years, but potentially all visitors could use it. An integral part of the design was to engage children in tactile exploration and interaction with the installation. An iterative design process was adopted in the development of the

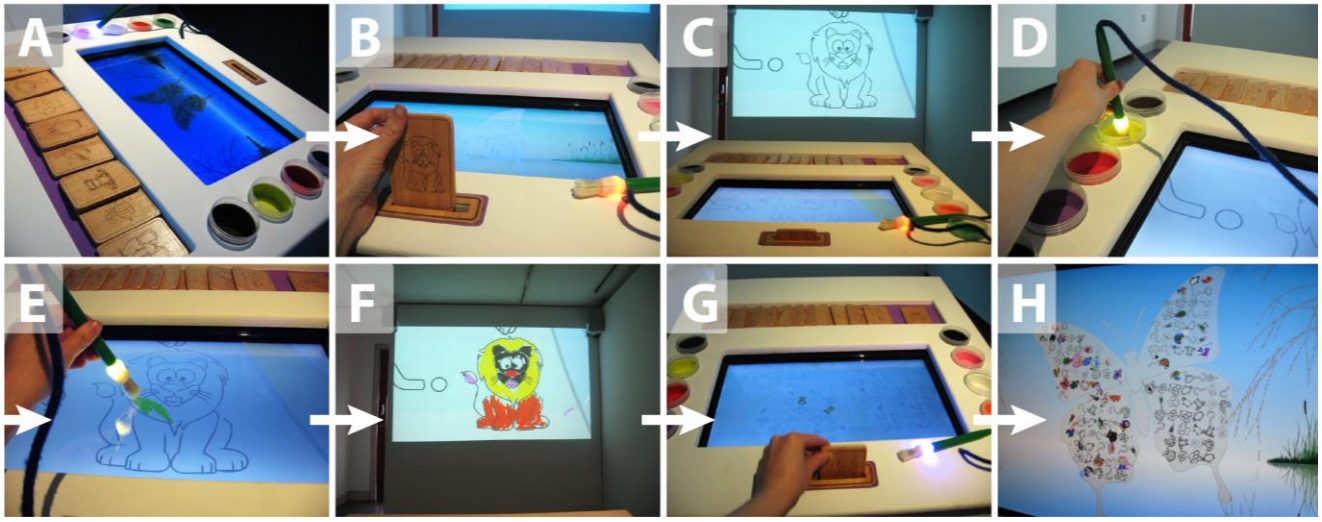

Figure 2:Interaction Flow

exhibit by using paper prototype and Wizard of Oz prototypes to test out designs, guiding the design before final implementation.

The system *Painting Patterns For Nature* (PPFN) was about the topic of biodiversity. The system uses visitor-created content. The concept for the installation is that children colour in various animals, which then become part of a giant butterfly image, similar to mosaic pieces that make up an overall picture. This collectively involves visitors in the creation of a new species from smaller user-generated paintings. The activity aimed to raise awareness of how people's actions affect other living organisms and how different species affect the larger ecosystem.

Figure 2 shows the story of the typical interaction using the installation. Children approach a table placed in front of a large screen (figure 1). At the table, they choose an animal/organism to paint from a selection of wooden cards engraved with outline images (part A of figure 2). On inserting this into a slot at the front of the table, an outline image appears on the table and on the projected screen (part B and C). Children then paint, using a physical paintbrush and "paint pots" (parts D, E and F). When finished, they remove the wooden card from the slot (part G). Their painting is added to previous visitors' paintings to make up the wing pattern of a butterfly on the projected and screen image (part H).

3.1 The System

The installation (figures 1 & 2) consists of a screen projection, an interactive touch screen both synchronized to show the same visuals, embedded in a tilted wooden desk, as well as a physical paintbrush on a leash, 10 physical paint pots, a tangible card slot at the lower end of the table, tangible wooden cards and an ambient audio track of wildlife sounds.

The cards have laser-inscribed drawings representing animals/organisms. The slot and cards were created to have a similar aesthetic appearance, using the same materials, colours and laser etching, to indicate their connection. An RFID reader inside the table recognizes an inserted card via the tag embedded in each card. Painting is done with the brush, which has a real brush tip, on an HP touchsmart screen. The paint pots are fitted with pulsating IR LEDs, each pulsating in a different pattern, which are detected by an IR sensor in the tip of the brush. When the system detects that the paintbrush is in a pot, the paint strokes' colour is altered. The paintbrush itself lights up in the chosen colour to provide direct visual feedback by means of an LED inside the brush, simulating the paint on a real paintbrush.

4. Research Approach

4.1 Research Focus

The research focuses on how social interactions are related to features of an interactive exhibit. Prior research in the areas of tangible interaction and 'socially immersive media' has also investigated the social context but concentrated on multi-user input systems. Moreover, there is limited research investigating non-active group members' interactions [10, 20] at systems that are intended for single user input. This is the focus of the study. In particular we investigate how tangible objects support non-active group member's experience by allowing physical interaction with the exhibit outside of core interaction, meaning the manual interactions with the exhibit that are not registered by the system. An understanding of the relationship between features of the exhibit, visitor communication and social interactions can be gained from this research. As such the work is placed in the context of public interactive exhibits.

4.2 Study Overview and Setup

During the exhibition an in-situ evaluation of the installation with was carried out with the general public. The study consisted of ethnographic style observations and was documented with notes and hand-drawn sketches, screen captures of drawings, and 6 video and audio data recorded sessions.

62 family groups were observed, consisting of 133 children of various ages and 91 adults during public opening times. 115 children painted while 11 adults took part in painting, even if only for a moment. In addition, 5 volunteer groups participated in 6 video-recorded sessions that consisted of 18 children and 9 adults in total (see table 1). Participants were asked to interact with the exhibit as they normally would and were free to come and go as they pleased. All 18 children painted, and 13 had more than one turn at painting an image. During video recordings, the exhibit was closed off from the public, to ensure that the cultural centre's child protection policies were adhered to.

Groups	Adults	Children
1	Mum (35)	Siblings: Millie (8) Ann (5) Siblings: Sarah (8) Henry (5)
1 Revisit	Child minder (30)	Siblings: Millie (8) Ann (5)
2	Gran (70)	Boys: Stuart (13) Miles (11) Niall (7)
3	Mum (27) Female Friend (26)	Son: Tod (6), and friend of Tods, Girl: Ali((7)
4	Mum 1 (35) Mum 2 (36)	3 girls & 4 boys: Siblings: Felix (110 Zara (4) Siblings: Lilly (8) Ted (8) Mary (11) Anthony (11)
5	Mum (32) Dad (34)	Sibling boys: Robert (8) Colin (10)

Table 1. Overview of video-recorded groups

Video and observational data was iteratively reviewed by two researchers to develop themes. The process involved open coding, transcription, developing concepts from the data and clustering prominent behaviours into themes that are grounded in the data. The analysis involved studying the relationship between people's activities and the exhibit's spatial and physical attributes. Group social interactions and how these related to the features of the exhibit were investigated by identifying and recording the following situations: moments of social interaction, communication, wooden card interactions, paintbrush handovers, negotiations, holding onto cards, planning, who was in the space. Through open-ended video interaction analysis, specific patterns of interaction were observed repeatedly, resulting in themes grounded in the data. The following themes developed from the analysis: (1) awareness and communication within groups, (2) mediation of control through physical objects and (3) the role of tangible resources outside of a user's turn as tools for communication and for planning.

5. Findings

This section describes the social interactions within 5 video recorded groups which include discussions, negotiations and activities with the tangible elements of the exhibit such as the wooden cards, paintbrush and paint pots. We have broken these findings into the themes that emerged from the analysis, described previously in section 3. Study overview and setup. A reflection on these findings linking them to the research questions, will be covered in the Discussion section. We present and discuss vignettes to illustrate our findings (based on analysis of the video data from all 5 groups) and mostly feature one extended family group. The vignettes represent interaction patterns observed across all groups. Using vignettes from one group gives a sense of the extended conversation within a group and simplifies descriptions of 'who's who'. Fictitious names are used throughout the data.

Within a group we identify three positions at the exhibit that people move between: the painter, bystander and observer (figure 3). The *painter* has the paintbrush, and is located at the table. *Bystanders* are close to the painter, and might be overlooking the activity, closely working with the painter or playing with the exhibit (cards or paint pots). *Observers* are further away, usually sitting on a bench roughly a meter away, where they can see the projected image and painters' actions but are in more of a passive role. Throughout an individual's time at the exhibit, they shift between these positions. Both observational data of the general public and video-recorded data showed children within the same group as the painter moved between all positions.

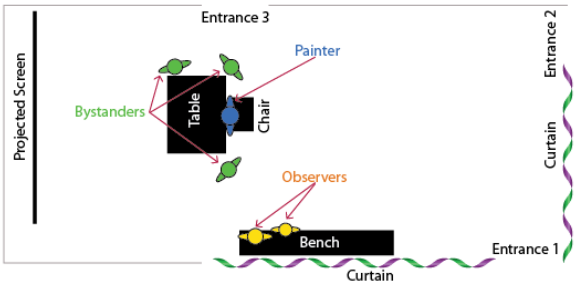

Figure 3: Plan view of the exhibit layout and the positions visitors may be in.

5.1 Awareness & Communication within a Group

In this section, we focus on data relating to social encounters and awareness within groups. We narrow the focus to analyse social engagement within individual groups as opposed to interactions between different groups of visitors. There were 3 dominant situations where people demonstrated awareness of the actions, thoughts and intentions of others. Firstly, we noted situations of awareness when people explicitly drew the attention of others to what they were focusing on. Secondly, we saw an awareness of the actions of those painting, which led to discussions. The third situation observed was an understanding of bystanders' intentions.

5.1.1 Explicitly drawing attention to a train of thought

People explicitly drew others' attention to objects verbally and or physically pointing them out. This happened in all groups but was very frequent in the groups that had more than 2 children and the groups that stayed at the exhibit while others painted. The following vignette describes a situation from group 1 illustrating how a resource is used to draw attention to their train of thought and to start a conversation. Here, Henry notices that a newly created painting on the overall butterfly is right next to the one he had just made.

> **Vignette 1:** Mum is on the bench with a friend while Henry, Millie and Sarah are around the table. Ann inserts the ladybird card into the slot. When it zooms in Sarah says: "*there ya go*".
>
> Henry notices: "*It's right beside mine*", jumping up and down. He turns to the bench and then back to the girls at the table. He repeats: "*it's right beside mine, Ann....* " points at the big screen (figure 4B) "*look....mine's right there*" Ann looks towards the projection, then back to put the brush into the pink paint pot.

Millie points at the big screen and Sarah remarks "*Henry you forgot to do **your** feet*" (as the animal's feet are not painted). Ann starts painting the ladybird. Henry looks up: "*ah damn it"*, and pretends to hit the side of his head.

Henry physically points to the projected screen (see figure 4B), and verbally emphasizes what he is interested in at that moment, drawing the attention of others. The sequence of events opens up social interaction. First, Henry relates the content to himself and what is happening at that moment. He expresses his thoughts verbally. He draws the attention of others to a resource that helps them to understand what he is thinking about, including them in his train of thought. This opens up a situation where others can relate to what he is thinking and can respond to this. Without the visibility of the main screen it is questionable if he would have been able to draw the attention of others to this or even to see it himself. The conversation was orientated around a visually accessible resource for the whole group.

A further situation where people drew others' awareness to their thoughts was when people made a resource visible to others by physically re-orientating and manipulating the wooden cards to show to another person. Figure 5 shows Millie re-orientating a card to show somebody else, creating awareness of what Millie is focusing on. Vignette 2 described another one of these situations.

Vignette 2: Mum suggests painting something together. Millie and Henry start to discuss. Henry moves to the table and starts to browse through the cards. He slides them one over another while Millie suggests doing a penguin. Henry holds the lion card in his right hand while continuing to move the others with his left.

He says: *"look a jellyfish"*, and picks up the jellyfish card. Ann, the painter echoes his words. Henry holds the card up in the air, twists it towards Millie and the others at the bench. Millie responds: *"I think maybe...."* Henry puts the card back: *"maybe I'll do a lion and you could do the head."* Millie walks towards the table: *" we could like aaaah ....a penguin maybe..."* gesturing out to her sides *"....coz like there's loads of big spaces in it"*

Henry, a bystander, moved and re-orientated a key element of the exhibit, sharing information with others, making a resource visibly accessible to another person and actively including another person. It is possible to move the point of focus (the card) around in 3D space to enable others to view and access the same information without the receiver being required to move location. In contrast, if images would be selected on a touch screen affixed to the table or the cards were fixed to the table, observers would very likely have struggled to see the object of reference without relocating so as to have a better view of the screen.

Figure 4: Visibility & access to common resources

5.1.2 Awareness of the painters' actions

Secondly, we found people were aware of the painters' actions, commenting or discussing the colours selected by the painter with each other or with the painter. Across groups, awareness and visibility of the painters' actions lead to discussions. This was the most regular topic of conversation even if it was only a brief comment, other than discussing what children planned to paint or could try out. When painters chose a colour, moving the brush towards a pot and swirled or dipped the brush into a pot, onlookers would often comment or make suggestions for colour choices. The action and use of the brush and paint pot was visible for others to see. Vignette 3 describes a situation where this occurred.

Vignette 3: Millie (age 8) is near the end of her painting. Her friend Sarah comments, while placing her hand in each pot: *" so let's check, you've done green, orange"*. Millie agrees: *"yeah"*, holding the brush in both hands, while watching Sarah's' hand going into the pots. Sarah suggests*:"you haven't done white"* and places her hand in the white pot. Millie (the painter) responds: *"white"* as she places the paintbrush in the white pot.

The children did this together as a collaborative activity, going through the possible options, physically referring to the paint pots as a reference to further support their conversation.

5.2 Control, Negotiation, Planning and Anticipation

This section looks at the activities people carried out with the tangible elements of the exhibit such as the paint pots, wooden cards and paintbrush. We discuss these activities in two sections. Firstly, how the tangible elements of the exhibit mediated control and secondly what others in a group were doing with the wooden cards, in preparing for and building up anticipation of their turn to paint.

5.2.1 Negotiation of Control

There were two key situations for participants in relation to control. Firstly, the painter maintaining control during painting and secondly handing over control to the next painter.

Across all groups we observed that painters were able to maintain control with little effort while other children physically explored the exhibit. While a child was painting, if the card was taken out of the slot, both screens would zoom out from the image being painted and show the overall butterfly, stopping the painter mid-painting. The card slot was located between the painter and the table screen. Its location supported the painter in maintaining control. Painters' bodies often leant over the card slot or an arm was rested across it, creating a barrier for others, even if unintentional. It was very rare that a bystander would take out the card from the slot during painting (figure 2G). The video-data revealed that in only 4.84% of painting interactions, the painter had to prevent a sibling/friend from removing a card from the slot. While this was not common, some painters placed their hands

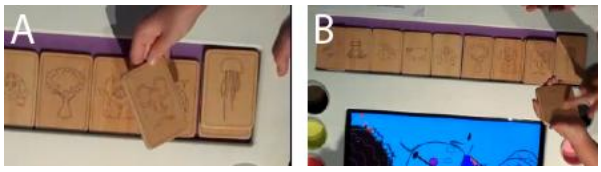

Figure 5: Picking up and showing a card to collaborator as a suggestion for what to paint next

over the slot when others approached the table.

We observed bystanders playing with the paint pots, putting their fingers systematically into each paint pot or trying to select colours with their fingers. As the only way to select a colour was by putting the paintbrush in a paint pot, bystanders touching the pots didn't change the colour for the current painter or disrupt them.

We now describe how people handed over control to the next painter. Handing over control to the next painter was observed repeatedly across all groups except when there was not another child waiting for their turn at the table. When children handed over the brush, it was directly handed to the next person rather than left on the table to be picked up. In handing over the brush to a sibling or friend, sometimes children walked towards the next painter with the brush as far as the leash allowed. This seemed to prevent fights over who was painting next at the point of handover, since the handover was very explicit. In effect, the paintbrush acted as an explicit mediator of control [cf.11].

The cards, physical paintbrush, and pots combined with the technical set up of sensors and actuators, enabled painters to maintain control of painting while bystanders manually explored the exhibit's tangible elements. Bystanders and the painter were able to carry out their activities in parallel without interrupting each other's tasks. This highlights how the physical constraints, affordances and pairing of sensor areas with specific input controllers of the exhibit enabled painters to maintain control without much effort, resulting in little conflict during parallel activities.

5.2.2 Offline Activities - Bystanders & Observers Activities

Throughout the video recorded group activities, children within the same group as the painter interacted with the wooden cards and paint pots before or after their own turn. We use the term 'offline' from prior research to refer to the activities with tangibles that do not manipulate or control the digital content and outside of the main painting activity [4,6,7]. The three main offline activities bystanders from the same group as the painter carried out were (1) browsing, touching, moving, playing with the cards at the table, (2) showing others card/s while discussing their intentions (what to paint) and (3) taking a card away holding onto it until their turn.

Browsing, touching, moving and playing with the wooden cards at the table was performed by all groups and was the most common activity carried out by bystanders who interacted with the exhibit. Both individually and together, children from the same group as the painter browsed through the wooden cards laid out along the top of the table (Figure 4A) and moved them around independently of the table (Figure 2A). Typically this occurred while bystanders waited for their turn. The video data showed that for one third of the time a child was painting, at least one other child from the same group was interacting with the cards. Bystanders often browsed through the wooden cards, sliding them over each other, discussing what to paint while standing at the table or bringing the wooden card to others at the bench to discuss.

Both painter and bystander were physically interacting with the exhibit in parallel. Bystanders were manually interacting with representations and controllers without being tracked by the system. This allowed people to engage in social activities together without disrupting the users' engagement with the exhibit.

Showing a card to others while discussing their intentions was observed in 4 groups. This happened in the groups who didn't split up to look at other exhibits and waited at the exhibit for their turn. If they were in the space, they spent time playing with the cards, planning their turn or commenting on the painter's actions. Many discussions around planning what to paint happened while showing others the wooden cards. Children used the cards to orient discussion, as physical and visual references, and to communicate their intentions, as illustrated by vignettes 2, 4 and the below vignette, 6. This vignette describes Millie and Sarah discussing what to paint together, referring repeatedly and with detail to the wooden cards as they move and re-orientate them.

> **Vignette 6:** Henry is at the bench discussing with Mum and a staff member the number of owls on the butterfly. He has the penguin card in his hands and is waiting for his turn. While Ann paints, Millie and Sarah have been standing at the table, discussing what to paint and browsing through the cards. Sarah holds onto the mushroom card behind her back. Millie, lifting the cards up, says: *"maybe we could do an elephant.....or a tree....?"* Sarah: *"no "* Millie suggests*: "maybe a mushroom",* looking a Sarah. Sarah brings the mushroom card from behind her back for a moment and says: *"here"*, before putting it behind her back again. Sarah brings the mushroom card back in front of her, showing Millie: "*maybe a multicoloured mushroom, like all the spots with different colours",* moving her fingers around the mushroom image on the card as she says this, (see figure 5B).

Millie lifts up cards as she verbally suggests painting the image. Sarah re-orientates the mushroom card so Millie can see it. Sarah changes the card from visually inaccessible to Millie to being accessible while still maintaining possession. Sarah then runs her finger over the card while showing it to Millie, (Figure 5B), using it as a reference for the conversation. Sarah and Millie use the cards as references to support the discussion and planning. Both re-orientate the card to suit the context of the situation, the topic of conversation and allow another person to see the card, actively including them.

In interacting with the cards, bystanders physically and mentally prepared for their turn in an active way, both individually and collaboratively. The previous sections describe the activities with the wooden cards that relate to planning what to paint. In addition, we found children were able to go further than solely planning to actively putting their plan into action outside of their turn, by holding onto cards until their turn. We observed numerous occasions where bystanders held onto cards until their turn or for long periods of time.

Holding onto a card intermittently and until their turn was an extremely common behavior. This happened with all except for group 3. Group 3 consisted of 2 children and they were often not at the exhibit at the same time. Vignette 6, as well as vignettes 2 and 4, show bystanders preparing for their painting activity by browsing through the cards, discussing options, their intentions, and securing their plan by holding onto a card. Regularly, children (similar to Henry in vignette 4, who stresses: "*I'm gonna do a penguin"*) took cards away from the table and held onto cards until their turn, keeping it away from others. This served to protect what they wanted to paint from others as well as allowing them to mentally prepare for their turn painting, investing energy and thought into the possible activity ahead of them. Children could carry out the first step in the overall interaction, selecting a card, before they began painting. In this way, children engaged

with their future painting activity before it happened and built up anticipation by connecting with the content outside of their turn.

6. Discussion

The discussion reflects upon the findings relating them to the research focus examining the relationship between features of the exhibit and visitors' communication and social interactions. Supporting social interactions in the museum is a highly valuable but challenging task [10, 16, 20, 22]. In the study, situations arose where children used features of the exhibit as tools for communication within groups, for negotiating, planning and observing others in order to make meaning.

The findings suggest a link between actively planning and preparing for one's turn before interaction by extended engagement with the exhibition. Pre-interactions built up anticipation that was further encouraged by the ability to hold onto a card. The cards thus acted as a stepping stone for action and as a representation of future action, providing a physical reminder of plans. We therefore suggest that a design implication from this finding is that offline tangibles could be used to prepare people for interaction, extending engagement outside of core interaction, creating investment in their future activity, and enabling them to plan ahead.

Building on Fernaeus's research [6], we found that the inclusion of tangibles for interaction allowed children to act individually and collectively, arranging cards, passing them to each other, and drawing on each other's attention by manipulating the artefacts and reorienting them. Supporting these behaviours can foster situations where children can act at their own pace to step in and out of social activities, such as discussions, negotiations and planning. This is valuable to develop independent thinking as well as collaborative skills.

Facilitating other group members to explore the cards and paint pots while the painter painted supported activities to run in parallel with each other. On a temporal level, this meant that individuals engaged with the exhibit content before and after their turn, thus extending engagement that one has with the exhibit. These activities were often entwined with social interactions, emphasising how enabling physical exploration of an exhibit outside one's own turn can foster social activities. This is particularly important in the museum context as both individual and shared group experiences are important for people to connect engage with each other and with stories on different levels [3, 10, 22]. Furthermore, this is a novel contribution as prior research in the area of offline tangible interaction has not explicitly indicated the presence of expanding one's engagement beyond core interaction to before and after online interaction.

Online and offline experiences can be equally important. Varying social and introspective experiences influences how we relate to exhibits [5]. Providing diverse visitor activities and experiences is important in order to maintain interest throughout the visit [8, 3]. The activities involving removable tangibles enabled onlookers from the same social group to remain active and to engage with the topic on a personal and social level while waiting, beyond simply observing the active user (as commonly occurs at museum exhibits) [3, 9]. Another issue using offline tangibles in public installations could address is that during groups visits *" people in the same group can often interrupt a person mid-engagement with an exhibit"* because they want to move on to something new [18]. Thus supporting multiple people's engagement around an exhibit in parallel with each other, could decrease engagement interruptions.

Individuals drew the attention of others to their train of thought or points of interest by explicitly physically referring i.e. by pointing them out features of the exhibits. People touched paint pots and re-orientated cards to show another person, creating awareness and including another person. This initiated or sustained conversations actively including others in one's thoughts. Groups were aware of the painter's actions which led to discussions with the painter or others in the group. The data analysis showed people not only were aware of other people's actions but also their intentions, for example what they planned to paint. This shows people shared experiences and engaged in social activities primarily outside of their turn with the exhibit. People were not only thinking about their own painting but were aware of that of others. Demonstrating awareness of others is important to foster the social ecology of groups. Snibbe and Raffle argue that socially immersive media should be, 'socially balanced', meaning interaction should equally emphasise *"a user's awareness of herself, other users, and the media itself"* [17. p.1449].

We propose the social ecology within groups was built upon awareness and communication, supported by features of the exhibit. Children had an understanding of what others were doing and planned to paint. The visibility and awareness of the painters action encouraged commenting on their choices. Referring back to the findings the exhibit features supported a social ecology: parallel activities and the ability to move and show cards to others in order to make references visually accessible. The findings demonstrate how powerful offline tangibles can be in supporting social interactions even when a system doesn't support multi-user input.

In relation to mediation of control, negotiation, planning and anticipation, the tangible features combined with specific sensor detection resulted in the following outcomes. Maintaining control of painting was mediated in a number of ways. Firstly, children controlled who painting by using the brush which was an explicit mediator of control, directly handing it over to the next person. Secondly the constraints of the exhibit also controlled the activities. The exhibit only allowed the painter to choose a colour with the brush, preventing others from interfering with the painting process and engagement. Furthermore, the painters body or arm usually covered the card slot, preventing others from pulling it out during painting. Easily maintaining control for the painter means parents don't have to try and mediate children interfering with each other's activities. In museums, parents can spend their time mediating children's activities in order to decreased conflicts. This can detract (or stop) group social activities and engagement in the process. Creating exhibits where groups can carry out parallel activities with the exhibit without interfering with each other means parents don't need to spend their time mediating children's actions. It also enables children to play and reflect upon the exhibit in a meaningful way to them at the time. In other words they can relate to the exhibit in their own way.

Usually 'offline interaction' only refers to interaction with non-tracked tangible objects such as tokens [4, 6, 7]. We have interpreted the term offline tangibles more broadly by referring to all manual interactions with tangibles representations and controllers that are not sensed by the system including fixed objects, referring to the paint pots in this case. This interpretation contributes to the HCI communities by expanding the understanding of tangible offline interactions to consider

interaction with any fixed location offline tangible representation and controller, beyond considering only removable tangible tokens.

Visitor studies research suggests the social element of a museum visit is possibly the most important influence on overall experience, emphasising the importance of developing exhibits that encourage social interaction, discussions and collaboration [10, 20, 21, 22]. We suggest future single user interactive installations for children could utilize offline tangibles as a means: 1) to build up children's anticipation before interaction, 2) to extend engagement outside of core interaction, 3) to support both individual and collaborative experiences in parallel and 4) to socially engage groups by sparking and prolonging conversations.

6.1 Design Implications

We use these findings to suggest future design implications for interactive exhibits that aim to (1) support social engagement such as planning, sharing experiences and discussions, (2) engage individuals with the exhibit topic outside of their interaction with the system and (3) foster anticipation of one's interaction with the exhibit.

1) using tangibles that can be physically and digitally separated from the exhibit but still **maintain** the visual representation of its digital counterpart enables consistency of meaning and retention of a meaningful reference for people use to as a reference

2) providing tangible controllers that can be handled offline (outside of the main activity and untracked by the system) enables people to plan their actions and creates investment in the future interaction by taking the first step of the interaction. Thus extending engagement and interaction by combining online and offline interaction.

3) offline tangibles can be used as tools for communication which supports social interactions at public interactive installations

4) offline tangibles can be used to keep people engaged with the exhibit while they wait for their turn

4) offline tangibles facilitate bystanders playing, manipulating, appropriating and interacting with features of the exhibit simultaneously while the operator uses the installation

5) spatial placement of key controllers and coupling sensors with controllers can ensure the activities of others group members exploring the exhibit does not interfere with the 'operator's' interaction and engagement

6) provide a balance between access to key resources (in the study: cards, pots, table) for all parties and maintaining control for the current active operator by restricting the ability of onlookers to interfere with digital input, or allowing the operator to easily restrict or allow others digital input. This can reduce conflict and supports unmediated activity by parents, parallel exploration of exhibit and active use of exhibit at the same time by different individuals

6.2 Study Limitations

While the findings are presented as a contribution to the field of hybrid interactive exhibits for children in museums we recognize there are limitations to the study.

All the exhibits on the same floor of the exhibition were curtained off due to lighting issues, which is unusual for most museum interactive and may have influenced how people behaved together.

We recorded fewer of these offline activities with the open public outside of the video recordings, when groups could mingle. We speculate that privacy or time pressure could to be a factor when other groups were present in the space. Perhaps an area that future work could address is examining offline tangibles in multi-group situations and/or where there is time pressure.

Lastly, the interactional analysis is based on video data from 5 groups. We support this with recorded observational notes of the public and interaction patterns were compared as the best possible.

6.3 Conclusion

This research investigates how features of a tangible painting installation relate to social interactions and engagement. The work focused on the relatively unstudied area of non-active group members around a system that is designed for a single user input [10, 20]. Related work focuses solely the operator of systems or on the social context of multi-user system. However, we look at the social value that features of an exhibit can offer to bystanders. The exhibit designed and evaluated was an interactive painting installation with tangible paintbrush, paint pots, wooden cards, a large screen projection and a tabletop screen. The approach involved interactional analysis considering the social, personal and physical context related to actions and user experience.

Through interaction analysis the following themes developed which were grounded in the data; (1) interactions *around* and with the exhibit showed awareness and communication within a larger social ecology, (2) physical objects and spatial setup helped in mediating control, (3) the role of 'offline activities for planning, negotiation and (4) anticipation of one's turn and engagement. Finally, the significance of the findings are discussed in relation to the area of public interactive installations.

The analysis revealed that features of the exhibit were used to actively include others by drawing their attention to a point of reference both verbally and physically via a re-orientation of cards, the pointing at and touching of cards and paint pots or by occasionally referring to the large screen.

The research presented in this paper provides insights into: (1) how tangibles are used in the context of public interactive exhibits, (2) how features of tangible objects foster social interaction in groups and (3) how tangible objects support non-active group member's experience by enabling manual interaction outside of core interaction. This builds on prior research suggesting that offline tangibles are valuable in supporting deeper social meaning in groups [7] by bringing it into the context of public interactive installations.

The work contributes to the research looking at supporting group activities in public space such as museums or cultural centres by suggesting how tangible objects can be used outside of the system's detection to encourage social engagement within a group, to further connect children to the topic and to create a level of anticipation of interaction with the system. We found that creating an exhibit where it was easy for individuals to maintain control and allowing parallel physical interactions with the exhibit for the rest of the group took the pressure off parents managing the group. This supported groups to physically interact with features of the exhibit, using them as tools for communication and as a means to engage with the exhibit, outside of their turn

4 key lessons learned from this study are: (1) understanding that the ability to carry out separate parallel activities with the exhibit takes the pressure off parents in managing several kids who are waiting for their turn, by enabling 'on-the-side' interactions that plan future action, engage children already, allow for negotiation of who does what etc. (2) easy turn taking negotiation by leaving the painter in control while still allowing for some side-action supports individual and shared experiences (3) offline tangibles are so powerful in the social context that they are effectively used as tools for communication and support social activities even when implemented at a single user exhibit and (4) offline tangibles can extend engagement beyond core interaction.

The study revealed that the most influential feature of the exhibit in relation to the social ecology of groups, was the ability to physically interact with key tangible controllers outside of an individual's turn, in other words 'offline'. People used the tangible features of the exhibit to support communication with other bystanders and the current operator, by physically referencing them or by making them visually accessible to others.

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