University of Strathclyde

Department of Computer and Information Sciences

"No, you press yours first!"

Sharing interaction and socially interacting with companions at tangible hybrid interactive museum exhibits

by
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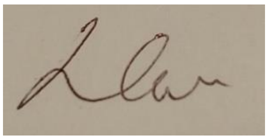
Declaration of Authenticity and Author's Rights

‘This thesis is the result of the author’s original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.’



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Abstract

Hands-on tangible interactive exhibits are prevalent in science and technology centres, and are becoming increasingly common in traditional museums which conventionally exhibit historical artefacts and classical paintings. Interactive exhibits can enhance visitors' experiences, offering museums interesting alternative ways to engage visitors and portray narratives about their collections. How interactive technologies support or encourage companions in sharing interaction with other and engaging in social interaction with each other is of particular interest to this PhD research. In this doctoral thesis, I present three case studies that focus on companions sharing social interactions at tangible hybrid interactive museum exhibits, and subsequently question variations in how control is distributed between companions. The nature of this research draws on several disciplines and as such is multi-disciplinary, in the field it draws upon, how it was conducted and in the research contributions.

Case study 1, Painting Patterns for Nature, focused on the social activities of companions before and after their interaction with the exhibit, and examined how the exhibit supported these social activities by the presence of several portable tangible controllers which are accessible (but not interactive) outside of core interaction. Case study 2, Glen Douglas and Fire Fighter, emphasised companions' social interaction stemming from an interplay between different controllers and reliance upon companions. Case study 3, Razzle Dazzle highlighted the ways in which companions share decisions before interacting, questioning equality of participation between companions interacting with the exhibit.

The research offers a unique contribution within the fields of tangible interaction and museum studies investigating interactive exhibits by conducting empirical research through a design lens. In conducting the research, a contribution has been made in developing a definition for 'tangible hybrid interactive museum exhibits' (THIMEs). Furthermore, the research makes a contribution by describing visitors' social interactions with their companions and their behaviours sharing the interaction at THIMEs. The research has identified strategies for distributed controller between companions physically (providing multiple controllers), functionally (in what the controllers do) and temporally (when people use controllers) at interactive museum exhibits which considers how to support visitors social interactions with their companions and how to share the interaction with the exhibit.

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Table of Contents

Table of Figures

Table of Vignettes

Table of Tables

Chapter 1

Introduction

Visiting a museum is inherently social. People often go to museums to spend time with close friends or family strengthening and consolidating bonds with each other (Debenedetti, 2003). Technology plays an increasing role in our everyday lives, and has increasingly become part of the landscape of museums and art galleries. Accordingly, expectations of technology have also increased. Integrating technology into exhibitions brings a number of advantages. Museums often utilise technology due to its benefits in enhancing visitors' museum experience; communicating stories relating to collections; offering immersive experiences, games on multitouch interactive surfaces, guided tours or quizzes via apps on visitors' personal mobile phones; and providing digitally enhanced replicas of artefacts, or interactive scenes which allow visitors to act out stories in role play (Dindler et al., 2011), (Taylor et al., 2015), (Hornecker and Ciolfi, 2019). Where once visitors discussed exhibits with each other, now technology plays a role in visitors experiences with each other is added to the scenario. Is it therefore important to question does technology interfere in social interactions, or does it create new opportunities for social experience? How do the shared interactions of co-visitors with each other play out at interactive exhibits? Drawing on these questions, this PhD focuses on the relationship between technology and the social activities of visitor's groups and families. Specifically, the research examines the shared social interactions and behaviours visitors carry out while using with tangible hybrid interactive museum exhibits.

Ultimately, museums aim to create exhibits that are engaging and relate to their collections. It is widely recognised that the actions of others heavily influence our interest and engagement with the resources around us in a museum setting (Vom Lehn et al., 2001), (Barriault and Pearson, 2010), (Warpas, 2014), (Hindmarsh et al., 2005), (Debenedetti, 2003). In one the most recognised models concerning museum visitors' experience, Falk and Dierking (2013) emphasise the influence of co-visitors on visitors' experience. Their model lists the social dimension as one of the three contributing contexts which influence visitor experience, alongside physical and personal context (Falk and Dierking, 2013). For example, visitors are influenced by their companions moving on when group does, or when they are beckoned to hurry up (Tolmie et al., 2014). Furthermore, in the field of education, it is widely acknowledged that social interaction directly relates to engagement and understanding (Crowley et al., 2001), (Perry, 2012), (Pekarik et al., 1999), (Falk and Dierking, 2013), (Borun et al., 1996), (Piscitelli and Weier, 2002). Thus we can see social interaction is an important aspect to consider in the process of designing engaging exhibits.

It is in the context of constantly developing and increasingly widespread technology in museum environments that this thesis examines the how adopting technology can enable visitors to connect with the stories surrounding artefacts. The intent of this thesis is to investigate how technology-based interactive museum exhibits can contribute to social context, and to examine which specific aspects of these exhibits foster social interactions and support visitors in sharing exhibit interactions with their companions.

The research addresses a question that over the past decade or decades various people have been dealing with: how to design exhibits that facilitate or engender interaction? The research has responded to the question by developing a number of design considerations relating to how control is distributed between groups at interactive installations, which are discussed throughout the thesis.

1.1 Motivation

The rationale to study social interactions is multi-faceted. Firstly, the social context of a museum visit is recognised to have a significant impact on visitor experience. Most museum visitors do not go to a museum alone, and moreover often go with the intention of spending time together. For many years, museums have been integrating technology into exhibitions in order to increase visitor engagement; provide cutting edge interactive exhibits; keep up with innovations in entertainment and expectations; and explore new interpretation techniques. However, as technological advances are integrated into the museum experience, new challenges are identified. Gamification has been criticised for focusing visitors' attention on winning and away from reflection on the narrative. Digital content can compete for visitors attention diverting their attention away from the artefacts. When museums explore new technological interpretations, usability and ease of use can be overlooked, or in tension with the exhibit's other aims. Similar to many technological devices present in everyday life (Rogers, 2014), it has been argued that certain technologies can create social barriers in museums and isolate visitors from each other (Heath et al., 2005), (Vom Lehn and Heath, 2005). Individual ear pieces to listen to audio content, audio guides, and individual controllers for an exhibit are all examples of technology which can hinder the social nature of a museum visit. This PhD research thus investigates the social interactions at interactive exhibits in order to further an understanding of how to support the social context of the museum visit.

Secondly, at present, the majority of research evaluating interactive museums exhibits has been oriented around educational values. Only a limited number of studies concern the social interactions that interactive exhibits may foster for visitors (Warpas, 2014), (Hindmarsh et al., 2005). In museum studies, some work has concentrated on the social context, but not specifically regarding interactive exhibits (Debenedetti, 2003), (Tolmie et al., 2014). Related research has criticized evaluation studies conducted by museums for ignoring the actual interactions which visitors have with exhibits, instead focusing too heavily on measures like holding power or knowledge attainment (vom Lehn and Heath, 2016).

The benefits of social interaction during a museum visit have been well established in prior research. For example, social interactions have been found to positively impact on learning (Falk and Storksdieck, 2005), (Sayre and Wetterlund, 2008). Furthermore, social interaction is not just educationally beneficial for children, but also includes parents in the activity (Crowley et al., 2001).

From the museum perspective, understanding how to support the social context of a museum visit allows museums to enhance visitor experience, and has economic relevance. Enticing new visitors and encouraging return visitors is vital to the survival of a museum. If visits to museums are based on social motivations, then supporting the social element of this visit is important not just for visitor experience, but also for the continued existence of the museum itself. Although museums ultimately remain centres for informal education, crucially if people enjoy their visit, spend quality time with companions or experience achievements in overcoming challenges, there is great value in this.

Finally, I am a very social person and with a background in industrial design, and as such I am interested in how objects can act as social tools (Simon, 2010b). Interactions with exhibits as a whole object relate to the social interactions we might have when we visit the museum.

Defining Interactive Shared Social Interaction

This research focused on situations in which museum visitors engage in social interactions and share the interaction with museum exhibits along with their companions. Interaction for the context of this PhD is understood to be when people interact with others or interact with objects such as exhibits and importantly the action triggers a response from another. For example, a person manipulating digital content through their actions. In other domains, interaction maybe understood as simply a person looking at something or somebody. Here, this PhD understands interaction to be both an action and reaction both in terms of people acting and responding to each other and an installation reacting to a person's actions or presence.

Previous research focusing on visitors' social interaction and their conduct with each other while using interactive (and non-interactive exhibits) has used the term 'co-participation' (Hindmarsh et al., 2005). Co-participation refers to ways companions participate in the activity and the *"organisation of action at the exhibit-face"* (Hindmarsh et al., 2005, p.31)*.* Co-participation specifically considers social interaction beyond verbal communication, including bodily orientation, gesture, gaze and the visible manipulation of exhibits. Hindmarsh argues that such behaviours are *"critical to the ways in which participants organise their collaborative appreciation of exhibits and constitute the sense and significance of the exhibit"* (Hindmarsh et al., 2005, p.31). Drawing on the field of Human Computer Interaction, a conceptual model known as collective action is also concerned with *"interactive technology in support close collaboration amongst co-located people"* (Peterson et al., 2017, p.69).

I developed the term: 'interactive shared social interaction' which I will refer to as the acronym SSI in this thesis. My understanding of a shared social interaction is 'not just sharing the interaction with the exhibit together but interacting socially with each other too.'

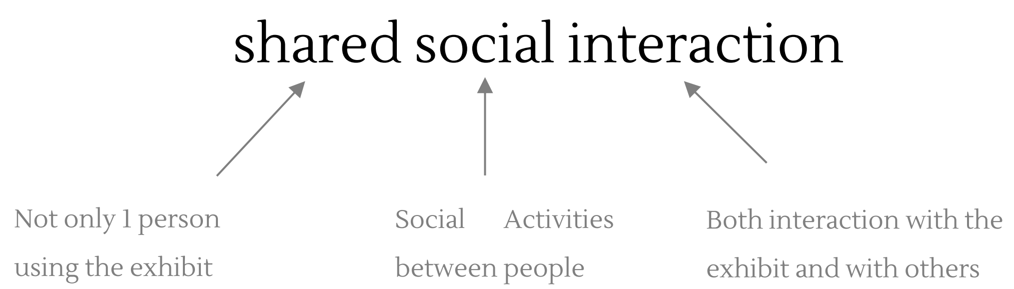


Figure 1-1: Shared Social Interaction

1.1.1 Technology in museums

Traditional museums and galleries are often places in which visitors take a slightly passive observatory role; the museum is a place in which visitors to view artefacts, rather than interact (Ramsay, 1999), (Fernández and Benlloch, 2000), (Witcomb, 2006). Following the establishment of science centres, in particular the San Francisco Exploratorium, and advancements in technology, visitors are now encouraged to take a more active role in the museum visit (Ramsay, 1999), (Humphrey and Gutwill, 2005). Subsequently, museums and science centres have developed exhibits utilising current technology to support a more "hands-on" experience for visitors as well as supporting mindful engagement with content, classified as "minds-on" (Allen and Gutwill, 2004), (Witcomb, 2006). However, there are questions as to the value of such exhibits for visitors and museums (Witcomb, 2006). Are these exhibits truly engaging visitors with content or supporting shared experiences?

Some exhibits that utilise new technology such as museum audio guides, have been known to hinder the museum experience, by isolating individuals, restricting conversations and taking away from the shared social experience of a museum journey (Bellotti et al., 2002), (Grinter et al., 2002), (Novey and Hall, 2007). Museums are rising to the challenge to entertain, often striving to produce novel meaningful interactions. In some respects, visitors and museums have conflicting agendas. Broadly speaking, museums are interested in presenting collections, telling stories around their collections and communicating information, though it should be noted that this is not the case for all museums. Furthermore, many museums are now shifting towards edutainment. Visitors often go to museums expecting to spend time together, have a day out, see something new, or out of personal interest in a topic. A visitors' agenda may not be solely be concerned with learning or new experiences, but may instead focus on undertaking activities with other visitors and consolidating bonds with companions (Debenedetti, 2003). When introducing new technology into the museum context, it is therefore important to question how this technology supports visitors in their social agenda and enables them to share interactions. While a large body of work has considered group interactions in museums, at present, questions remain as to how interactive exhibits relate to the social interactions of groups.

Why focus on this, one might ask? Currently, visitors' expectations of technology in the museum are continually growing, in part due to the pervasiveness of high quality daily interactive experiences provided by devices like the Xbox, the Nintendo Wii and other entertainment devices. The museum is under pressure to keep up with these developments, and deliver experiences that people cannot have at home. While the promised benefits of technology are numerous, designing and developing interactive exhibits that meet the goals of the museum and the agenda of visitors is an extremely challenging and complex task. Technology such as PDAs and audio guides has been criticized for diminishing the social side of the visitor experience because it can create barriers between people and isolate them (vom Lehn and Heath 2005). Furthermore, single user exhibits or multiple user exhibits which support independent parallel activities can compromise how people can share the experience together and engage in various forms of interaction with each other (Heath and Vom Lehn, 2008), (Heath and vom Lehn, 2003), (Hindmarsh et al., 2005). The notion that technology in the museum context could take away from deeper connections with artefacts is also worth considering (Debenedetti, 2003). This PhD research does not suggest that tangible hybrid interactive exhibits should be deployed for every museum narrative and artefact. Rather, the research notes that there is great value in a diversity of interpretative mediums in an exhibition. People learn in different ways, and have different interests in and preferences for different forms of interpretation. Older visitors tend to steer away from technological exhibits that look like computers, especially if these are dominated by screens, whereas younger visitors are often more attracted to such exhibits (Hornecker and Stifter, 2006). Furthermore, if all the exhibits in a museum were interactive, visitors may find this tiring or monotonous. As such, various interpretative methods can work in tandem, complementing each other to shape a balanced visitor experience. Appealing to different people and supporting their individual preferences is important for a museum.

A focus on 'Tangible Hybrid Interactive Museum Exhibits' THIMEs

Museums employ a range of interpretative materials to engage visitors such as labelling, information panels, multi-media displays and hands on interactive exhibits. The type of exhibits this PhD investigates are usually classified in the museum discipline as 'hybrid interactive exhibits' (Bitgood, 2014), (Caulton, 2006). An exhibit is understood to be 'interactive' when it *"exhibit prompts a response which changes the state of the exhibit; change is under visitors control"* (Bitgood, 2014, p.118). In other words, 'interactive' implies that visitors can manipulate the state of the exhibit but the exhibit does not necessarily have technology integrated into. The term 'hybrid' refers to the integration of technology into an exhibit and is often associated with the manipulation of digital content. The physicality and type of controllers an exhibit provides brings me to focus on the 'tangible' component of the exhibits studied. Tangible User Interfaces (TUIs) are defined as interfaces which have physical artefacts that both represent information and act as controllers of information too, and which can be manipulated by interacting with the objects (Ullmer and Ishii, 2000). In the domain of Human Computer Interaction, an extension of this is to think beyond the physical artefacts to the physical actions required by people to interact with the content (Shaer et al., 2010). The latter refers to tangible interaction whereas the former refers to TUIs (tangible user interfaces). Combining tangible interaction with a focus on hybrid interactive exhibits defines the types of exhibits investigated in this research as 'tangible hybrid interactive museum exhibits'. I'll refer to these are THIMEs for the remainder of the thesis.

1.1.2 Tangible User Interfaces

The research is driven by personal observations in museums, a passion for working within the museum organisation myself and from the insights of previous literature. For me, tangible interaction is fascinating as traditionally, developments in the technology industry often result in technology which directs users away from interacting with physical objects such as touch screen devices. Yet physical movement and contact is often required to interact with technology. Tangible interaction offers many beneficial outcomes such as appealing to sensory and affective experiences (Fernaeus et al., 2008); supporting group interaction, by enabling multiple people to interact together; and making interactions more easily observable (Shaer et al., 2010). Tangible objects can be used as resources for action (Fernaeus and Tholander, 2006) and tools for communication (Hornecker and Buur, 2006). I have chosen tangible user interfaces as a central factor due to of their ability to support social interaction Furthermore, physical objects can be the foci of attention to orientate conversations around between people (Simon, 2010a). On a personal level, owing to my industrial design background, I am always excited by physical and tangible artefacts.

Previous research concerned with social and or shared interaction in the context or museums or public spaces rarely focusses on tangible user interfaces which provide physical objects (Humphrey and Gutwill, 2005), (Wakkary et al., 2009), (Hindmarsh et al., 2005), (Taylor et al., 2015), (Fraser et al., 2003), (Ciolfi and Bannon, 2007). Typically the technology investigated in such studies make use of interactive surfaces and screen (Hinrichs, 2013), (Hornecker and Nicol, 2011) or use the body as a controller to manipulate digital content (Hindmarsh et al., 2005), (Snibbe and Raffle, 2009), (Meisner et al., 2007). At present, there is still limited insight into design considerations that focus on supporting social context for groups surrounding their interaction with tangible interactive exhibits. While design sensitivities have been developed regarding the social interaction and visitors shared actions (Hindmarsh et al., 2005), these must be built upon, questioned and expanded. This PhD research aims to contribute to an understanding of the social interactions which play out between companions while they are interacting with interactive museum exhibits involving physical tangible controllers to manipulate digital content.

1.1.3 Designing interactive museum exhibits supporting the social dimension

A number of exhibits have focused on supporting the social context of groups by supporting multiple companions interacting simultaneously, using technology such as multitouch surfaces (Peltonen et al., 2008), (Hornecker, 2008), (Block et al., 2015), (Hinrichs, 2013) stations located side by side for companions to interact alongside each other (Heath and Vom Lehn, 2008), (Dalsgaard et al., 2011), or immersive interactive mediascapes (Snibbe and Raffle, 2009). While many multi-user exhibits foster co-located action, they can present limitations in supporting social interaction. At such exhibits, several individuals interacting simultaneously can make it difficult for visitors to coordinate actions or discern when, how and what visitors are interacting alongside themselves (Hinrichs, 2013). Furthermore, visitors may focus primarily on their individual interaction, and as such, opportunities for social engagement with companions is limited (Snibbe and Raffle, 2009). From a design perspective, understanding how to support and avoid hampering visitors social and shared interactions can be quite challenging. Benford et al (2000) has defined a spectrum of the ways in which technology can be structured to support collaboration. At one end of the spectrum technology enables collaboration, at the middle of the spectrum technology encourages collaboration, and at the other end, technology enforces collaboration (Benford et al., 2000). They do on to discuss the different ways the function of controllers can be interlinked with each other to enable, encourage or enforce collaboration. Enabling collaboration allows individuals the choice to opt in or out of coordinating the use of their controllers with other people in order to manipulate content. While enforcing collaboration means controllers must be used in coordination with others to manipulate content. Hornecker et al (2007) also discuss how availability of controllers enhances shareability of interaction. In this research, I discuss and analyse the different ways control is distributed between people, and the potential role of how control is distributed plays in the social and shared interaction which play out between companions.

1.2 Research Questions

In light of the factors outlined above, and drawing on my own design background, the present research is driven by an aspiration to support the design of future tangible interactive exhibits which encourage and support companions to socially interact with one another while also sharing interactions with the exhibit. The insights and design considerations which this PhD contributions to are listed in the results chapters and the discussion chapter. To pursue this research, focused research questions have been developed which are presented in this section.

Interacting with an interactive museum exhibit while at the same time sharing the interaction with companions and engaging in social interaction can be difficult to balance. The overarching research agenda is to understand: What factors should be considered when designing tangible hybrid interactive museum exhibits concerned with supporting and fostering companions' social interactions and shared interaction with the exhibit?

In order to focus the research, three research question have been established. RQ1 and RQ2 support in answering RQ3 which is the primary question the research is concerned with. These questions define the scope of the installations this research will focus on, and serve to roughly categorize social interactions., which are key elements for RQ3. Addressing the overarching research question; RQ1 defines the exact type of exhibit the research focuses on, RQ2 identifies companions' social interactions and shared interaction with the exhibit, and RQ3 unpacks the role features of the exhibit play in companions shared social interaction, in particular the way in which control of the activity with the exhibit is distributed between companions.

Research Question 1: **What are tangible hybrid interactive museum exhibits (THIME)?**

A variety of exhibits and interpretative materials in museums and galleries have technology integrated into them. Multi-user touchscreens, hands-on interactive exhibits, hybrid exhibits and immersive interactives are generally covered by the term 'interactive exhibit'. However, the term does not portray the type of interaction that can be expected at such exhibits. Does the term interactive imply an exhibit does or doesn't use technology? It is thus necessary to more clearly define the exact type of exhibit this PhD research focuses on. A classification of the term 'tangible hybrid interactive museum exhibit' will therefore be established.

Research Question 2: **What are the range of social activities between companions and how does sharing the interaction unfold?**

RQ2 is concerned with the social and shared interactions which unfold between companions, mapping out the different ways people share the interaction and the different social activities which develop between companions. The question will investigate what social behaviours and actions companions engage in while interacting, including how companions share interactions with each other while using interactive museum exhibits. This question will therefore determine what social and shared activities are, which supports in answering RQ3.

Research Question 3: **How can social and shared interactions between companions be supported and encouraged by the way in which control is distributed?**

The final research question is the most important in terms of fulfilling the motivation to aid future design. This is a two-part question with the aim of understanding firstly how control of the exhibit is distributed between companions at THIMEs, and secondly the role that the way control is distributed plays in the social and shared interactions between companions. Considering how control is distributed focuses the research to critique an aspect of the exhibit (the distribution of control), specifically in terms of the role control plays in shaping the social and shared interaction between companions while using the exhibit.

1.3 Research Approach

The research is concerned with three main areas, which are illustrated the diagram in *Figure 1-2*. The first research area is social and shared interaction, which focuses on visitors interactions and behaviours with the exhibit and with their companions. Secondly, as the present research is grounded in the field of HCI, tangible interfaces are a key area of interest. In such interfaces, several physical objects are often used to control digital content. Finally, the third key area is the specific context of museums, considering technology and its role in the social and shared interaction between companions in the museum environment.

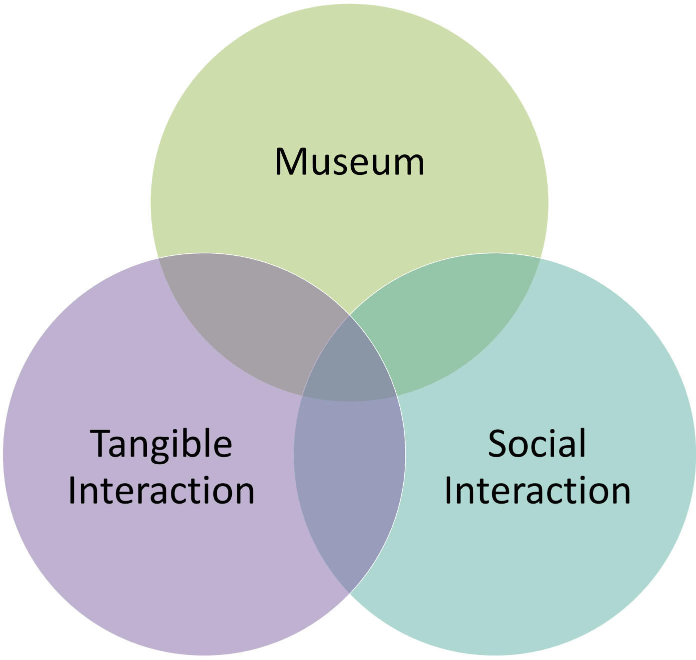


Figure 1-2: Three areas of research

An unusual characteristic of the research is the multi-disciplinary nature of the work, drawing on a number of disciplines to conduct the research such as product design, visitors research and design, human computer interaction, museum studies, psychology and social sciences. The research approach draws on product and interaction design skillset, creating and making objects in order to conduct research (research through design) but also in how the research questions are framed in terms of design considerations. Data analysis methods are called upon from psychology and social sciences such as thematic analysis and interaction analysis. The research calls upon museum and visitor studies in understanding the context of the research and in placing the key research contributions. In addition, the research has linked with the field of Human Computer Interaction. In particular research concerning tangible interaction, interaction in public spaces and heritage sites and social interactions.

Coming from an industrial design background, I am interested in understanding how features of museum installations play a role in visitors' social and shared interaction. This research employed a qualitative approach. Three empirical case studies focusing on visitor interactions with tangible hybrid interactive museum installations were undertaken. Studies 1 and 3 applied a 'research through design' process, in which artefacts were designed and fabricated in order to gain insights (Frayling, 1993); two tangible hybrid interactive installations were created to analyse visitors' interactions with THIME. Study 2 focused on existing exhibits at the Riverside Transport Museum in Glasgow. In focusing on visitors' interaction and behaviours, I drew upon the research process 'in the wild'. This refers to research conducted in real-world situations rather than lab-based studies (Taylor et al., 2013). As such, all of the studies were carried out in museum-like contexts, with the exception of study 1. Study 1 instead focused on an exhibit displayed as part of an exhibition in a cultural centre for children. With strict child protection policies in place at the cultural centre, participants needed to be explicitly invited to take part in the study while the exhibit was curtained off from the public. Thus study 1 is more closely aligned with a field study. All three studies involved carrying out video-audio-based research. Firstly, conducting video-audio recording in the museums/cultural centre captured visitors' interactions and behaviours at THIMEs. Secondly, analysing video-audio data using interaction analysis and thematic analysis. The main insights gained from this PhD research are established from video-audio based research from the three case studies.

1.4 Contributions

This research has made a number of key contributions to knowledge. Firstly, at present, several interchangeable terms are used in museums studies and human computer interaction to refer to interactive installations which involve hands on tangible interaction to manipulate digital content. Thus, a key contribution of this research is the creation of a singular term for such exhibits: THIMEs, which stands for 'Tangible Hybrid Interactive Museum Exhibit'. The creation of this term adds clarity and fixity to previously vague and mutable terminology. The definition was defined primarily from a literature review covering human computer interaction and museum and visitor studies.

Secondly, while there is a growing body of research focusing on visitors social and shared interactions at interactive museum exhibits, at present there has been limited mapping of these social behaviours outside of educational models for museum learning. Throughout the three case studies presented in this research, various social and shared interactions have been observed and mapped out. Therefore, this present research crucially contributes knowledge and understanding of the different types of social and shared behaviours that play out at exhibits with distributed controllers. Although all three studies supported this contribution, study 2 and 3 were the main contributors as study 1 focused on a single user installation, limiting the scope for shared interactions with the exhibit between companions. In addition, the research also contributes to field of museum evaluation in its use of videography as a methodology in order to consider how we evaluate the social impact of technology on museum visitors' interactions with each other and with the exhibit

Thirdly, in carrying out this research, an understanding has been developed of three main ways in which control is distributed: physically, functionally and temporally:

1. where controllers are and what they are (physical distribution of control)
2. what the controllers do (functional distribution of control)
3. when to use controllers (temporal distribution of control).

These different ways of distributing control contributes to answering RQ3 and in turn is connected to the social interactions with played out between companions (RQ2). All three studies played a role in answering RQ3 as the exhibits in question had various combinations of how control was distributed.

These three types of control can be combined in a number of different configurations. This understanding of the distribution of control aids the systematic exploration of the design space of such exhibits, and facilitates in understanding the factors contributing to how to design exhibits that support shared social interactions. Furthermore, this research contributes to our knowledge of the types of social activities companions may engage in at interactive exhibits, including before and after interactions, and social activity with bystanders who may not directly engage with the exhibit. I identify this as a design space based on how control is distributed between companions, and consider the various ways a distribution of control can be implemented in order to support and elicit shared social interaction between companions.

The research also contributes to an understanding of the processes which occur before and after groups interact. This contribution is crucial as many current coding schemes omit the before and after social activities outside of direct interaction.

This PhD research, being cross disciplinary, contributes to various disciplines, such as human computer interaction, visitor research and design, psychology, social science, product design and museum studies.

For visitors and museum studies, the PhD presents an example of how evaluations of existing exhibits can feed into future designs of interactive exhibits. A highly unusual situation as most evaluations in traditional museums are summative and for the purpose of reporting rather than of use to future exhibit designs (Davies and Heath 2013). The kind of comparative study in case study 3 is more typical for HCI (sort of AB testing), but extremely rare in visitor studies. This thesis contributes a case study for visitor studies, indicating the kind of findings and insights we can gain from such studies.

This research contributes to the field of HCI in a number of ways. The research adds to a limited body of research focusing on social interaction between people in public spaces. Particularly unusual, is the focus on people outside of their core interaction, before and after interaction. In addition, contrasting to a lot of prior research concerning interaction in public spaces, this research focuses specifically on companions, rather than strangers. Beyond contributing to research in public spaces and research in the wild, the research contributes in unpacking the different types of distributed control where previously control is viewed as directly manipulating a system through a direct input. Here different types of distributed control are unpacked contributing to HCI, museum and visitor studies, and product design.

The research contributes to the field of design in particular product and interaction design by developing a number of design considerations for future products and interactive designs which are concerned with facilitating and supporting companions' social experiences with each other when interacting with products or future technologies.

1.5 Structural Overview

This thesis has 7 chapters. Firstly, this introduction has framed the research context and posed the research questions. Following this, background related research is outlined in **Chapter 2**. This chapter provides an overview of the literature this research draws upon, primarily from the fields of human-computer interaction and museum studies.

The chapter has three main sections: 1) the museum context and museum visitors experience; 2) a social interaction section, outlining the various social interactions and ways visitors conduct their behaviours with each other; and 3) a technology section, which discusses various interactive technologies in the museums and how these can support group interaction which are relevant to the scope of this research and or imply design strategies for developing social installation. At the end of Chapter 2, I briefly define the type of exhibit this PhD focuses on (THIMEs) and re-introduce the research questions before moving on to discuss the methodology. **Chapter 3** discusses the research approach and methods applied in this research. In particular, I discuss the approach of conducting research 'in the wild', carrying out video-audio based research and the analysis of video-audio data using thematic and interaction analysis. **Chapter 4** introduces the first of three case studies, 'Painting Patterns for Nature' (PP4N), which details the study of a tangible interactive painting exhibit in a children's cultural centre. The chapter outlines how the study was conducted and how the exhibit works, before presenting findings. The chapter closes with a discussion outlining how the study responds to research questions and highlights the main insights gained. This format of discussion is adopted in all of the case study chapters (Chapters 4, 5 & 6). **Chapter 5** describes the study of two THIMEs at the Riverside Transport Museum in Glasgow, the 'Fire Fighter' installation and the 'Glen Douglas'. These were existing installations in the museum and have similar qualities, such as inviting team work, role play, and tangible interaction with distributed controllers. **Chapter 6** presents the third case study, 'Razzle Dazzle'. The chapter firstly explains the motivation for the study building upon the previous two case studies. It then goes on to outline how the study was conducted, before discussing findings. The findings are broken into three main themes: 1) group sharing decisions; 2) sharing physical interaction; and 3) dominating physical interaction with the exhibit. I then provide an interpretation of the findings, mapping out how features of the exhibit relate to the behaviours revealed during analysis. This includes some observations which lie outside the main scope of the RQs, but are felt to be highly relevant to research concerning interactive exhibits in museums and are thus briefly mentioned. **Chapter 7** discusses the main contributions of this PhD research. It returns to all three RQs, with RQ3 making up a large body of the discussion as the main question of interest. The discussion directly responds to the research questions, and responds to the key themes which have been revealed during this research. Finally, the discussion ends by detailing the research limitations, potential future work, conclusions and a personal statement.

Chapter 2

Background

2.1 Introduction

Existing research relating to this PhD spans multiple disciplines such as human computer interaction, museum visitors research, psychology, education, social sciences and product design. Museum visitor studies and human-computer interaction (HCI) being the two main fields of reference. This chapter considers a range of prior research focusing on the museum context and visitor experience. Specifically, I discuss visitors' behaviours, the social dimension of the museum visit and related models. I will also discuss the place of technology in museums, delving into both disciplines of HCI and visitor studies. This chapter will also outline the core research questions for the PhD research.

Conventionally, the field of Human-Computer interaction (HCI) has focused on the usability and functionality of computer technology. Over the last 20 years, HCI has expanded broadly to include a focus on user experience and designing for pleasure (Sharpe et al., 2007).

Similarly, in museum design, there has been a shift from focusing predominantly on collections and preservation, to broadening the focus to include learning outcomes (Hein, 2002), (Falk and Dierking, 2013). The educational focus has also developed to consider experiential aspects of museum visits, such as social interactions, fun, pleasure, novelty and physical interaction (Perry, 2012), (Pekarik et al., 1999), (Falk and Dierking, 2013). Furthermore, technology is gaining increasing prominence in museums, being used as a means of conveying content, exploring information, and enabling interactive experiences. This includes audio-guides, multitouch interactive surfaces, virtual and augmented reality, or 3d printed replicas which may have digital media embedded inside. The spread of this type of technology has raised questions about the benefits of integrating technology into exhibitions, as well as potential issues that might arise for both visitors and the museum as an organisation. Discussions around benefits and drawbacks of this technology concern its impact on the social nature of visits and the type of interactions that visitors have in the museum, both of which are key aspects of the overall visitor experience (Falk and Dierking, 2013). This research aims to understand what technology has to offer in terms of the social context of visitors' interaction with interactive museum installations.

This research is underpinned by the aim of uniting literature regarding technology, the museum context and social interaction, in order to focus on the social dimension of visitors interaction. The majority of previous research in this area has focused on engagement or educational aspects of the interaction. While a wide range of studies mention social interaction, only a limited number of these adopt this as their primary focus (vom Lehn and Heath, 2005), (Heath et al., 2005), (Heath and Vom Lehn, 2010), (Hindmarsh et al., 2005), (Heath et al., 2002). In contrast, social interaction is the primary focus of this research. For this reason, the background literature focuses on three distinct areas of research. Firstly, I discuss the museum context in order understand what comprises a visiting experience, examine expectations of a museum from various perspectives, and highlight some key points for consideration drawn from prior research about museum visitors. Secondly, I discuss the variety of social and shared interactions which museum visitors engage while visiting a museum. Finally, I discuss technology in museums and technology relating to social shared interaction.

2.2 The Museum Context

Designing for human-computer interaction in a museum context is a very challenging task, and often falls outside of the typical HCI context. Unlike most traditional HCI contexts, often museum visitors do not have a fixed task they want to pursue and a set goal they aim to achieve. Generally, the activity is not in work context or necessarily about obtaining specific information; instead, it concerns browsing material and experiencing something different or novel. As Benford et al. (2009, p.712) wrote, *"the purpose of cultural user experiences is not to reach a destination, solve a problem, or complete a task, but rather to enjoy an engaging journey"*.

A museum visit can be social (spending time with family and friends on something of shared interest), leisure oriented (seeking entertainment or simply passing the time), or learning oriented (finding out information about a specific topic, pursuing hobbyist interests). Visitors' agendas can even change over the duration of their visit. The audience may consist of various age groups. Visitor experience and engagement at installations can be extremely diverse, depending on visitors' personal interests, motivations, and who else is present and what they are doing (Falk and Dierking, 2013).

This section describes the museum context in greater detail. Firstly, I briefly discuss the various types of museum and expectations associated with these museums. Next, I discuss the visitors' experience referring to the most relevant established models or frameworks. I then go on to highlight different categories of museum visitors. Prior research has clustered certain behaviours and needs into visitor categories and noted how these visitors groups behave differently based on age, group type and background. Finally, I highlight some well-known issues regarding visitors and their agendas which museums typically face.

2.2.1 The Museum Visitor Experience

Prior research has developed a strong understanding of the 'visitor experience' in museums. Pekarik et al. (2003, p.153) summarise the main body of literature prior to 1999, addressing the core attributes of the museum experience. They conclude that there is agreement in this body of literature that a museum experience "*can be very complex, involving different dimensions of a visitor's life, including the physical, the intellectual, the social, and the emotional*". Pekarik et al. (2003, p.153) also reference Falk and Dierking's (2013) model of visitor experience, which categorizes the museum experience into three intersecting and overlapping elements: *"the personal context (visitor's interests, motivations, and concerns), the social context (visitor's companions), and the physical context (the museum)"* (see Figure 2-1).

This analysis of the museum experience from three angles - the personal context, social context and physical context - is applied in this thesis. In the case of the present research, an interactive exhibit (and its surroundings) can be understood to be "*the physical context*", as it is the source for various channels of communication between an interactive exhibit and the visitors. These contexts are deeply entwined. For example, the social context is frequently influenced by the personal and physical context. This idea at the core of this PhD research; the research studies the relationship between physical context and social context by focusing on social interactions occurring at or with tangible hybrid interactive museum exhibits (THIMEs). The physical context in this thesis refers to the exhibit, including the setup of controllers, spatial relations, and interactional qualities.

Prior researchers have developed models exploring aspects of the museum visitor experience. I will now discuss the most prominent of these models, and those which are most relevant to the PhD research.

The contextual model of Learning

The most prominent body of work outlining the attributes that influence visitors' experience was established by Falk and Dierking (2013). It is called the 'Contextual model of learning'. The model proposes that visitor experiences are founded on three contexts: the personal context, the sociocultural context, and the physical context. The model proposes that all three contexts work simultaneously overlapping, connecting and interacting together. As Falk and Dierking note, *"Whatever the visitor does focus on is filtered through the personal context, mediated by the sociocultural context, and embedded within the physical context"* (Falk and Dierking, 2013, p.30).

The model extends context to the events which take place before the visit, during the visit and after the visit. The present PhD research is primarily concerned with the context(s) *during* the visit.

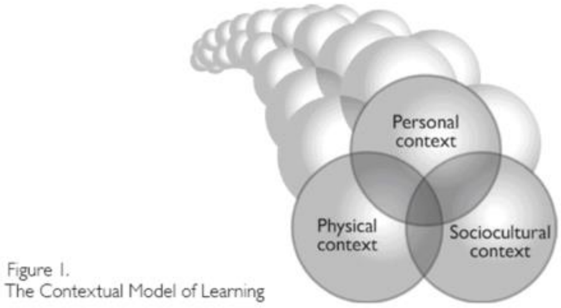


Figure 2-1: The Contextual Model of Learning (Falk and Dierking, 2013 p.26)

Personal Context

The personal context is based on identity-related motivations. These are dynamic and fluid, and change based on circumstances. Visitors have different backgrounds, interests and experiences which forms their own individual personal context of the MX[1]. Visitors will have varying experience and knowledge of the institution they are visiting, its exhibits, programs and artefacts, and, as such, knowledge and experience of the content will differ from visitor to visitor. Furthermore, visitors are at different development levels and ages, and have varying preferred modes of learning. Every visitor brings their own personal motivations, interests and attitudes to the museum. These aspects filter what visitors focus on, shape their agenda and affect how they behave. An awareness of these aspects helps to understand visitor behaviours and the lenses which these behaviours are underpinned by.

Sociocultural

The sociocultural context is made up of two factors: the social and the cultural. Visitor MX is both enriched and influenced by the social ecosystem during a visit as well as the culture of the museum itself and the individuals' cultural background. Firstly, the cultural context has a number

[1] Throughout this PhD Thesis the acronym MX refers to 'Museum Experience'

of key aspects. A visitor's beliefs, customs, values, thought processes and comprehension of different languages are formed outside of the museum, frame their MX. People's economic status, ethnicity and country of origin also shape their perceptions of the museum and their experiences. In addition, the museum institution has its own culture. This culture is based, for example, on how the museum was formed; the type of museum it is; and decisions regarding what is displayed and what is communicated to visitors. Secondly, the social context also has an impact on visitor MX. According to Falk & Dierking (2012), *"the museums experience is, first and foremost, a social one"* [p.148]. This is, in part, due to the fact that most people visit museums with other people (Falk and Dierking, 2013), (Hornecker, 2010), (Kelly et al., 2004). Even if visitors attend alone, they will encounter other visitors and museum staff. Museum experiences also vary depending on who the visitor is attending with; visits may be different when the visitor is visiting with family, friends, with an elderly person, or with children. For example, young children typically lead the way, while parents follow (Falk and Dierking, 2013). Yet children visiting a museum in either a family group or in school group may experience the same museum in a different way. Additionally, certain people in a group may be knowledgeable about the exhibits, and as such direct the rest of the group; or, conversely, group members may disengage from others in order to allow them to form their own opinions. Finally, the number of visitors attending can have an impact, as a museum experience may be calmer or more stressful, depending on whether the museum is quiet or crowded at that particular time.

Physical

While both the sociocultural and personal contexts are based on individuals, and thus different for each situation, the physical context of the museum rarely changes and remains invariant. Similar to the personal and sociocultural contexts, physical factors influence a visitor's MX. The architecture, artefacts in the museum and the 'feel' of a building influence how visitors move through it. The smell and lighting of a space can influence how long people spend there, and give it a certain ambience. These physical components of the museum space are the aspects that museum staff can alter and shape. Indeed, many exhibits are created under the assumption that the museum controls the visitors' experience, rather than the visitors themselves (Falk and Dierking, 2013 p.105). However, visitors use the available resources in the museum to create their own physical context (Falk and Dierking, 2013 p.107). Even so, physical 'affordances' and 'constraints' can limit or encourage a range of physical actions (Norman, 1988). Combining physical affordances with the perceptions, expectations and goals formed through the personal and sociocultural contexts, the outcome *"can be a channelling of behavior into a relatively few, relatively predictable trajectories"* (Falk and Dierking, 2013 p.132). In other words, visitors with similar personal and sociocultural contexts behave with predictable patterns of behaviour when put in the same physical context. Falk and Dierking (2013) found that visitors showed predictable behaviours in relation to reading labels.

Time is also a factor

Falk and Dierking also propose that time is a factor in visitors' MX (Falk and Dierking, 2013). Visitors' actions are filtered by, mediated and embedded within the three contexts over a particular period of time. During a visit, the elements of these contexts will change. For example, an individual's motivation to learn more about an artefact can dwindle when they are tired or hungry (Hanner, 2011). Or, visitors' attention may be directed towards an exhibit purely because of its aesthetics. Moreover, the MX extends beyond the time period of the museum visit itself, to what visitors do before and after their visit; the conversations they have with others about their plans for the museum before the visit, and the future plans after the visit; and how they plan their visit in advance, as enthusiasts may research beforehand.

Factors to consider

The visitor experience consists of a complex set of independent variables such as settings, design, orientation, organisation prior to a visit, and reinforcing experiences after the visit (Falk and Storksdieck, 2005). The contextual model of learning outlines a number of factors that can impact on learning which are not directly linked with educational purposes. For example, Falk & Storbieck identified 12 factors which influence the museum learning experience (Falk and Storksdieck, 2005). Five of these factors relate to the personal context: 1) visit motivation and expectations; 2) prior experiences; 3) prior knowledge; 4) choice and control; and 5) prior interests [ibid.]. The sociocultural context has two factors: 1) meditation by others outside the immediate social group; and 2) within-group social meditation. Finally, the physical context has five factors: 1) orientation to the physical space, 2) advance organizers, 3) design and exposure to exhibits and programs, 4) architecture and large-scale environment and 5) subsequent reinforcing events and experiences outside the museum (ibid.).

Certain aspects of the model have been enriched by further research. For example, Falk carried out research on 'identity-related motivations' which extend an understanding of the personal context (Dierking et al., 2013 p.9). According to Falk and Dierking's research (2013), visitors may consider themselves as facilitators, rechargers, experience seekers, hobbyists, affinity seekers, respectful pilgrims, explorers or professionals. **Facilitators**, who typically come in a group, are socially motivated and are interested in helping to enable learning for those they are visiting with. **Explorers** are interested in the museum content and are driven by curiosity, primarily looking for things to learn about or grab their attention. **Professional/hobbyists** are people who visit the museum due to a specific connection to their profession or with a hobby in mind, such as fashion designers visiting a fashion museum or recreational sailors visiting a maritime museum. **Rechargers** are people who visit the museum for reflective or spiritual reasons. For instance, they might be seeking solitude away from a busy lifestyle, or be visiting based on their religious beliefs. **Experience seekers** are people who go to the museum because it's an important place to visit. These people may be tourists or feel they should experience a museum that may have recently opened. The companions which visitors attend a museum along with and the particular museum they are attending also has an effect on the category which they fall into. For example a grandfather may act as a facilitator when attending a museum with his grandchild but if he is on holidays in Prague he may attend a large local museum as an experience seeker while he is on holiday (Falk and Dierking, 2013).

In comparison with the personal context, less research has at present has sought to analyse the sociocultural and physical contexts (Dierking et al., 2013 p.9). Family groups may spilt up and re-group or stay together during their visit moving around the space (Dierking, 1989). Often, family members move through the museum as a unit, interacting with each other in particular ways, enjoying the museum together, helping each other to learn and explore (Leichter et al., 1989). In this way, families can mediate each other's experiences, affect what their companions learn in the museum through their conversations and their activities together (ibid.), (Falk and Dierking, 2013). For example, a child attending with an adult will likely led the way, dictating what to see for the adult. The needs of the children come first (Falk and Dierking, 2013). For example, a child attending with an adult will likely led the way, dictating what the adult sees. This is because, within this dynamic, the needs of children often come first (Falk and Dierking, 2013). In contrast, a child visiting as part of a school group will be clustered together with an adult, such as a teacher or docent leading what they see and do. Such adults often assume certain roles (ibid). For example, mediating children's interactions, scaffolding their learning, and facilitating group interaction (Hornecker and Nicol, 2011). While a range of literature highlights the role of parents as facilitators, Falk's (2009) research, along with his colleagues' research, found that only half of adults in family groups attending aquariums, science centres and zoos acted as facilitators. This suggests that it may be beneficial for designs to enable parents to have different roles within group activities other than facilitating children's experiences.

Stephen Bitgood's Attention Value Model

Bitgood developed a model for visitors' attention called the 'attention-value model'. The model places "value" as a key contributor to visitors' motivation *"to focus and engage attention on exhibit elements"* (Bitgood, 2011, p.230). It details the process and levels of visitors' attention at exhibits during the visit, rather than during the overall museum experience. The research focuses on the process of engagement, and which aspects of the museum environment visitors give their attention to. The primary aim of the model is to understand why visitors will or won't give their attention to exhibits. The model argues that this is determined through a process of weighting up, consciously or unconsciously, the cost of attending to an exhibit and the potential value they will get from this. *"Value is assumed to be a ratio of utility (satisfaction) divided by costs (time, effort)"*. Visitors thus choose where to place their attention on various exhibits, objects, or elements that appear to provide the highest value (Bitgood, 2011, p.233). Similar to the work of Falk & Dierking (2013), the model is based on the assumption that people will give an exhibit attention if they believe it will satisfy their needs. Falk and Dierking refer to this process as satisfying 'identity related needs' which can be personal, cultural or social.

Bitgood's model proposes that visitors' attention is "*a three-level process (capture, focus, engage)"* (Bitgood, 2011, p.230). The first stage 'capture' has two paths: 1) orientation, and 2) searching. Bitgood argues *"orientating is an automatic response to a powerful stimuli such as a loud noise"* (Bitgood, 2011 p.239), whereas *"searching is the process of scanning the exhibit environment for something of possible value (high utility or interest or satisfying and low cost in terms of time and effort)"* (Bitgood, 2011 p.239). Searching can be a sequential process where a person goes from one item to the next; or a simultaneous process, in which visitors scan many pieces to find something of interest. The second stage in this model is focusing, during which people are semi-engaged. This process is similar to reviewing, in which people first briefly visit and engage with an exhibit, in order to decide if continuing to devote their attention to that exhibit is worthwhile. This decision could be based on information-driven or social factors, and may depend which of these are important to that individual at that moment in time. The focus stage takes place for 5-10 seconds and involves shallow processing, as people are often easily distracted. Finally, the engagement stage of the process takes place. This stage occurs when people are intellectually and/or affectively immersed in the exhibit, and involves deep processing. Visitors' actions during this stage include thinking about the content, discussing it with others and reading text. As Bitgood notes concerning this stage, *"Engagement is associated with constructs such as learning and thinking"* (Bitgood, 2011 p.241).

Visitors choose which exhibits to devote their attention to based on their perceived value and the cost of doing so. How much time and effort will it take them? Will it interest me or is this an opportunity for me to bond with my grandchildren and explain stories from my past to them? Value can take many forms (Falk and Dierking, 2013); the reasons visitors might choose one exhibit over another can be based on more than purely information-driven motivations.

Bitgood discusses the example of text label length in order to evidence the attention-value model in action. He argues that a low-quality short label will receive more attention than a high-quality long label, because a longer passage requires more investment in terms of time and effort to read it. Fatigue and interest levels are also influential factors but regardless of interest levels, a longer passage is more work. Therefore, the model suggests that people are likely to give attention to exhibits that they perceive to have high value and low cost. According to the model, competing exhibits also play a role in which exhibits are given attention; the effort, cost and time required to engage with each exhibit, as well as the expected benefit gained from attending, are assessed by visitors, by comparing all available exhibits at that moment in time.

The focus of Bitgood's model is closely linked to other research in this field, which focuses on 'engagement'. Bitgood instead defines visitor attention which is far more specific. He clarifies that *"attention refers to both psychological processes such as visual search and depth of cognitive processing, and measures or indicators of these processes such as approaching exhibits, stopping to view exhibits, viewing time, reading interpretive text. Value is defined in terms of behavioral economics: a ratio of benefit divided by costs."* (Bitgood, 2014, p.6).

While the attention value-model is a useful prism for analysing visitor behaviour, there are some limitations to its application in this PhD research. The model is particularly relevant to this research as it provides a tool for analysing which elements of exhibits visitors devote their attention to and how they choose to do this. However, Bitgood's research is heavily orientated towards the consideration of text panels; text length; number of options available for viewers, considering distractions and competition; and visitor interest levels. Beyond this, the research does not consider any technological installations or hands-on tangible interactive exhibits and does not address social interaction or context, which are the foci of the present PhD research.

Both models discussed thus far, the Contextual Model of Learning and the Attention-value model, provide an initial idea of what visitors do and what they interact with in a museum setting based on their agenda and motivations in certain situations. Both models also provide information on how visitors use available resources, such as features of exhibits or facilities, to satisfy their needs and interests. In other words, the models demonstrate that visitors appropriate available resources in museums for their own motivations, and judge installations based on how easily these address their needs and interests.

Four different types of Museum Experience

Through interviews and surveys with museum visitors at nine different Smithsonian museums, Pekarik et al (1999) identified 4 different categories of experiences that visitors find satisfying: 1) object experiences; 2) cognitive experiences; 3) introspective experiences; and 4) social experiences. Object experiences have an element of novelty. They are based on seeing "the real thing", seeing rare valuable things, being moved by beauty, imagining what it might be like to own such things, or progressing their professional development (Pekarik et al., 1999, p.155-156). Cognitive experiences are based on enriching one's understanding and/or gaining knowledge and information. In these experiences, the importance of the object is still recognised but the primary satisfaction for visitors is gained through the intellectual or interpretive components of the experience. In this case, the visitors' experience is enhanced by the contextual presentation of objects and information. Introspective experiences are private inward thoughts, driven by feelings triggered by the object or exhibit of interest. They are established by pondering the meaning of objects and their related stories, reminiscing about personal memories, imagining other places or times, feeling connected, a sense of belonging or a spiritual connection. Social experiences are broadly defined as interactions with someone else. For example, Visitors enjoying watching their child learn or spending time with friends or family all fall into the category of social experience. This model stands out because unlike other models, it is solely based on what the visitors personally value and what they find satisfying.

The key aspect of Pekarik et al's work for this PhD research is the proposal that there are four main types of experiences which visitors value: object-centric experiences, cognitive experiences, individual introspective experiences and social experiences (Pekarik et al., 1999). Object-centric and cognitive experiences have been thoroughly researched in the field of museum studies, as they relate to the traditional core goals of museums, such as having visitors appreciate the collection and learn about it. However, at present less research has been undertaken concerning introspective and social experiences, even though it is possible that visitors place just as much value on these types of experiences.

Selinda Model of Visitor Learning

The Selinda model, developed by Perry (2012), considers what people do from a learning, play and fun perspective during a museum visit. The Selinda model maps out three perspectives that work together to shape visitors' learning experiences: 1) a motivations perspective (why visitors do things); 2) an outcomes perspective (what they get from the visit); and 3) an engagement perspective (what they do in museums). Perry (2012) outlines social interaction as a way to engage with museum exhibits, and understands visitors' experience as communication between a visitor and the museum. [ibid]. Perry's work defines six key motivators museum visits which are relevant to this PhD research; to feel in control; for play; a desire for communication and exchange of ideas; for curiosity to be raised and satisfied; and to challenge oneself. It is important to consider each of these types of interactions when examining the interactions visitors have with THIMEs and with each other.

The Introspective and Social Visitors Experiences

Similar to Pekarik et al (1999), Debenedetti (2003) also frames the MX in relation to visitors' introspective and social experiences. Debenedetti investigates the role of companions in the art museum experience. In doing so, Debenedetti indicates that while sharing experiences with others during a museum visit is essential, exhibits should also support moments in which visitors have introspective experiences and individual reflection. Such moments allow visitors to connect cognitively with the exhibit and artefact. Debenedetti concieves museum visits as cultural outings, consisting of two different motivators: as both an intimate, personal and private experience and as a leisure activity which is shared with friends or family (Debenedetti, 2003).

Debenedetti (2003) defines four different types of visiting experiences. The first is the fusion visit, during which people experience the museum together. The second is the private experience, in which people experience the museum alone. Debenedetti notes, *"A total absence of social interaction is necessary in order for the visitor to establish a personal relationship with the art works"* (Debenedetti, 2003 p.58). The third is the separate visit, during which visitors may arrive at the museum together but take different paths when experiencing the exhibits as individuals that can establish verbal and physical barriers to social interaction. This type of visit involves switching between sharing the experience and a more introspective experience. Finally, the fourth type of experience is the pursuit of social contact, in which visitors seek the emotional support that companions provide.

Debenedetti's research also maps out five functions that both shape and are fulfilled by the experience of visiting with friends or family. In the context of art museums, these are:

1) **Mutual enrichment,** in which visitors are in situations of uncertainty and use verbal communication with others to position themselves, to clarify their understanding of the artworks, and to co-construct meaning through conversation, as known as the snowball effect. The more ambiguous works are perceived to be, the more people want and need to compare opinions on them.
2) **Recreation** relates to the enjoyable and entertaining aspects of the visit. From this perspective, the museum itself is not seen as entertaining, fun or recreational, but rather the aspect of visiting with companions is.

3) **Reassurance** concerns the emotional support that companions provide. It eases anxiety, discomfort or stress associated with crowds, the austerity of museum, or visitors, relationship to art works. Affiliation, or sharing with companions, makes the experience less overwhelming and contributes to reassurance. The crowds or atmosphere in an art gallery can be softened by friendliness and warmth of a group.
4) **Prestige** relates to the emotional gratification of the leader of the group or expert on the topic, who explains or leads the group. Such group members often have a certain standing within the group.
5) **Transmission of knowledge** refers to passing on of knowledge and culture to companions, usually between parents and children.

Debenedetti (2003, p.53) highlights that a number of authors agree that social interaction is a primary factor in visitors motivates and gratification. Yet, at present, much of the research in HCI relating to cultural heritage or museum exhibits overlooks the role technology and its potential in supporting social interaction. Visitors agenda may be far more socially orientated than our museum interactive designers presently consider it to be. Debenedetti (2003) refers to McManus's (1994) work, which suggests that the social aspect of the museum visit is at the very heart of the museum experience, and is a key source of satisfaction [p.53]. Visitors place value on social aspects of the visit, such as the opportunity to *"catch up with friends, to be with loved ones, to socialise, to share an experience outside the realm of everyday life"* or to *"maintain and deepen the bonds of friendship, family, affection or romance that connect them to each person who accompanies them"* (Debenedetti, 2003 p.56).

Reflection on Models

While the models outlined do not focus on visitors' interaction with interactive exhibits and only some discuss the social experience of a museum visit, they provide an important analytical background for understanding factors that influence these types of interaction. For example, the models facilitate an understanding of influential factors such as the importance of an exhibit being attractive and 'promising' enough to warrant further attention, and the importance of keeping visitors engaged over an extended period.

2.3 Social Interaction

Having considered the models outlined above, this section will now discuss the social dimension of the MX. In their research considering social interactions and the diverse ways these interactions occur for visitors, Heath et al (2005) suggest the following design sensitivity when considering groups or co-visitors MX:

> *"Recognising and designing for variable and highly contingent forms of interaction and co-participation around the exhibit. This includes sensitivity to different degrees and combinations of verbal and non-vocal conduct amongst individuals and groups, companions and strangers – passive/active, central/peripheral, etc. It is tempting when considering ways of supporting social interaction to focus exclusively on engendering discussion between visitors. However, social interaction, in various other forms, is an unavoidable aspect of visitor behaviour. Therefore, these variable forms of (co)-participation should be recognised in design, even if simply to note that strangers often oversee how someone is using or appreciating an exhibit and to explore how an exhibit assembly could exploit that."* (Hindmarsh et al., 2005 p.36).

Heath et al outline a design sensitivity which centres around the richness of companions' social interaction, and therefore is strongly resonates with the focus of this PhD research on companions social and shared interactions. Most people visit a museum with other people (Allison and Gwaltney, 1991). For example, Draper (1985) reports that 75-95% of people visiting a museum come with family members or in groups. These people often go to museums for social reasons, such as bonding with companions and spending time with friends or family (Debenedetti, 2003). While a museum visit is often inherently social, the behaviours and interaction of visitors at individual exhibits often involve specific social actions. It is these behaviours at exhibits, whether interactive or passive, which I will discuss in this section. While, at present, there is wide recognition of social interaction at exhibits, thus far there has been limited work considering this social interaction outside of an educational focus. In this section, I will map out the social interactions that companions typically share while at individual museum exhibits, based on existing research. The present PhD research aims to understand how companions' social interactions and shared interactions are supported by interactive exhibits. This overview is therefore highly relevant in highlighting the various ways in which individuals interact with an exhibit and share that experience socially.

This PhD research draws on the visitor experience model offered by Falk & Dierking (2013), outlined in section 2.1.1 of this thesis. Their model divides the visitor experience into 3 components: the personal, the sociocultural, and the physical. This PhD research focuses specifically on the relationship between the physical and the social experience. Previous work has highlighted the significance of social interaction in people's experience and connection to the narratives of installations (Debenedetti, 2003), (Piscitelli and Weier, 2002), (Borun et al., 1996), (Barriault and Pearson, 2010). Some typical social situations, activities and behaviours which arise when companions visit a museum and interact with exhibits include discussions, competition, showing others something, demoing, and collaborating to interact with an exhibit. In addition, people assume different roles when in groups or with companions. I discuss these aspects within this present section, outlining the various social and shared interactions reported in previous literature. In this sense, this PhD literature review can be considered a contribution to a body of literature which concerns the social behaviours and shared interactions museum visitors engage in while in a museum-type context and at interactive museum exhibits (Warpas, 2014), (Hornecker, 2010), (Heath, Lehn and Osborne, 2005), (vom Lehn and Heath, 2005), (Heath and vom Lehn, 2010), (Hindmarsh et al., 2005), (Debenedetti, 2003), (Piscitelli and Weier, 2002), (Wakkary et al., 2009), (Hinrichs, 2013).

Social interaction plays an important role in shaping visitors' experience and learning (Leinhardt and Crowley, 2002). For example, talking to companions about an exhibit, how it works or what it is about, can be crucial to learning in the museum environment. Visitors learn from each other, share opinions, thoughts and interactions, and discuss pieces of interest. The social behaviours and situations companions engage in while visiting a museum include actions such as; commenting and laughing together at content (Patel et al., 2016); observing others interact (vom Lehn et al., 2007), (Barriault and Pearson, 2010), (Patel et al., 2016); suggesting ideas and creating content together (Patel et al., 2016); physically sharing control of an object by pushing or moving it in the space at the same time (Dalsgaard, Dindler and Halskov, 2011) (Hornecker, 2010); sharing emotional reactions (Warpas, 2014); seeking or sharing information (Barriault and Pearson, 2010); mediating other people's interactions (Piscitelli and Weier, 2002); negotiating turn taking (Block et al., 2015); co-creating fictional stories together (Taylor et al., 2015); or sharing by pointing out aspects to each other (McLean and McEver, 2004) (Barriault and Pearson, 2010) (Hornecker, 2016). It is also common for people to mimic the actions of others, either of companions or strangers (Weinschenk, 2011). Even if people visit museums alone, strangers in the museum have an impact on their overall experience (vom Lehn et al., 2007). For example, the presence of people at an exhibit often attracts others, as they may become curious and assume that there is something interesting to see. As such, people are drawn in groups to certain areas, a phenomenon known as the honey-pot effect (Brignull and Rogers, 2003). The list of various social activities visitors engage in together presented above, is not exhaustive but presents a representation of the social interactions which have been discussed in existing research.

2.3.1 Sharing experiences and interacting together

People share experiences in different ways. People can feel they are sharing something together even if there is no visible conduct or communication between them (Battarbee, 2004). Simply being in a space together and sharing a particular moment can be considered sharing an experience. Alternatively, people may feel connected by overt actions and behaviours. In these situations, people share experiences through direct interaction with other people. In a museum context, visitors share their visit by being close to others, through proximity; by discussing what they saw; by sharing opinions; by directing others attention to what they are interested in; by doing an activity together; by curating message for others (Fosh et al., 2014), (Dindler and Iversen, 2009), (Hornecker and Nicol, 2011), (Piscitelli and Weier, 2002), (Hindmarsh et al., 2005); or by performing for others (Taylor et al., 2015), (Meisner et al., 2007), (vom Lehn et al., 2007).

But are there specific social interactions which take place when visitors use interactive exhibits? Perhaps different types of social interactions occur. This PhD research addresses these questions by mapping out shared social interactions visitors have at THIMEs.

2.3.2 Social interaction in the museum context

In this section I discuss a number of social interactions which have been highlighted in existing research such as:

- group coherence
- observing others
- demonstrating to co-visitors
- performing or acting out with or for others
- drawing attention to thing
- reflective discussions and conversations
- coordination and collaboration
- negotiations, conflicts and taking turns
- parent-child social interactions
- introspective individual experiences and social experiences

Group Coherence

When visiting a museum with companions, visitors tend to model their behaviour in relation to the behaviour of their companions' and other visitors as they move through exhibitions. In what may appear as separate movements, companions often monitor each other and try to stay together, following each other as they move around the exhibits (Tolmie et al., 2014). Visitors will also sometimes leave exhibits before they are necessarily ready to in order to keep up with a group, or members of the group may encourage others to leave exhibits to maintain group coherence (Tolmie et al., 2014). Companions may experience the museum by moving through it together, and following each other to different exhibits (vom Lehn, 2006). The presence of many people, including companions, at an exhibit attracts people to it, which, as noted previously, is known as the honey-pot effect (Brignull and Rogers, 2003).

Observing others

A common social activity for visitors to take part in during their visit, is to observe and watch others, either strangers or companions, interacting with exhibits. Observing other peoples' interactions with exhibits enables visitors to learn what the exhibit is about and how to use it, revealing the functionality of different parts of the exhibit (Heath and vom Lehn, 2003), (vom Lehn et al., 2007), (Hindmarsh et al., 2005), (Barriault and Pearson, 2010). Observing others can give companions a chance to understand the activity in their own time, before joining in under their own initiative, if possible (Meisner et al., 2007). While observing their companions, other members of the group may suggest what their companions should do next, commenting on the ongoing activity, and sharing ideas (Taylor et al., 2015), (Patel et al., 2016). Observing others also provides entertainment and something to talk about. While there are benefits to observing others, when companions are limited to observing, opportunities for collaboration, discussion and sharing interaction are limited and offer impoverished co-participation (Heath and Vom Lehn, 2008), (Hindmarsh et al., 2005)

Demonstrating to co-visitors

When visitors use interactive exhibits, both technology-based and non-technology based, they often implicitly demonstrate how to use the exhibit to their companions. For example, a companion may approach an exhibit to watch another member of the group using an exhibit, and ask for further explanation about what is happening (Vom Lehn and Heath, 2007). Visitors also often explain and demonstrate as they make sense of an exhibit together [ibid]. This process of demonstrating and explaining can also be linked to an element of surprise or a sense of ambiguity about the function of the exhibit. For example, when visitors are unsure as to the function of an exhibit and relationship between its different parts, upon discovering what it does, they are often inclined to show others, demonstrating and explaining its functionality (Hindmarsh et al., 2005), (Vom Lehn et al., 2001).

Performing or acting out with or for others

Visitors' social interactions can include performative elements. This is particularly true at exhibits which encourage visitors to move their bodies to manipulate content or act out stories using props, such as fancy dress or interactive objects (Taylor et al., 2015), (Meisner et al., 2007), (vom Lehn et al., 2007). Meisner et al (2007) reflect on the performative interaction people have with museum exhibits, reflecting on how the performance itself was a way for people to create a shared experience with others surrounding the exhibit. A suggested area for future research in their work was a broadened understanding of how visitors create shared experiences. Usually, conversation is a key focus when studying social interaction in museums. However, Meisner et al (2007) expanded this focus to include a understanding of people create performances for others and use the space and exhibit as props in this performance (Meisner et al., 2007, p.1551). Some research in the field of HCI has focused on performative interaction in public spaces, concentrating on the role of spectators and performers as well as considering how interactions can be private or public performances (Reeves et al. 2007, Williamson et al. 2014). However, these studies have often focused on performative aspects and encounters between strangers rather than companions' direct social interactions and how the share the use of an exhibit, which is the focus of this PhD research.

Drawing attention to things

Visitors often draw their companions' attention to things they notice, whether these are traditional glass cabinet displaying artefacts, to sophisticated interactive exhibits. Visitors often call to their companions indicating they should join them at the exhibit (McLean and McEver, 2004), physically point out aspects of interest (ibid.), (Meisner et al., 2007), (Hornecker, 2016), or highlight information from the exhibit by reading out loud to their companions (McLean and McEver, 2004). In seeking and sharing information (Barriault and Pearson, 2010), visitors guide their companions attention towards common aspects of the exhibit which become focal points between companions.

Reflective discussions and conversations

The nature of visitors' discussions and conversations in the museum space has been extensively researched (Allen, 2003), (Palmquist and Crowley, 2007) . While there are many more aspects to social interaction than conversation, conversation is one of the most prevalent ways in which companions interact while in the museum, and a common way to engage with exhibit content and themes (Vom Lehn et al., 2001). Using conversation, companions share opinions about what they see or are doing, discuss exhibition material (McLean and McEver, 2004), comment on exhibits, and deliberate about various outcomes (Barriault and Pearson, 2010). Conversation enables visitors to enjoy objects together through the pleasure of discussing them, and communicating their emotional involvement to their companions (Ciolfi and Bannon, 2002, p.4).

In studies investigating museum learning, analysis of the conversation is frequently used to determine whether visitors engage with the content, and examine whether they will engage in discourse that is indicative of learning (Humphrey and Gutwill, 2005), (Gutwill and Allen, 2017). For example, conversations may also concern how to use the exhibit, or to coordinate actions or negotiate. This latter type of conversation is also social interaction, and allows visitors work together to produce a result at an installation.

Coordination and collaboration

Companions often coordinate their actions, both in the context of undertaking activities and moving around the museum space. Companions may collaborate on a task together while using an exhibit, such as carrying out an educational quiz or trail together (Fraser et al., 2003). Visitors also mediate their companions' actions, through actions such as instructing and directing during an activity or task. Such behaviours are known from the perspective of education as 'directive' behaviours (Piscitelli and Weier, 2002). Visitors organize and coordinate on a macro level how to move around the museum space, for example through planning which order to traverse the building and which exhibits to focus on, or discussing whether they should split up and reconvene later (Tolmie et al., 2014). On a micro level, visitors coordinate and align their shared interactions at individual exhibits. These co-ordinations can also vary in intensity. For example, they may be nondirective, or looser, suggestions; they may involve scaffolding, which is common for adults with children; or may involve directive action that provides instructions (Piscitelli and Weier, 2002). It is these micro level co-ordinations on which this thesis focuses.

Negotiation, conflicts and taking turns

Museum visits are not without their fair share of negotiations while visiting a museum as a group. In certain contexts, visitors must negotiate what to do, where to go, what to look at or how to take turns, which can create conflict (Humphrey and Gutwill, 2005), (Vom Lehn et al., 2001). Children can find it particularly difficult to give control to others when taking turns (Stanton et al., 2001). Even adults may limit one another's participation in an activity (Vom Lehn et al., 2001). Such conflicts are also considered social situations, albeit ones we most likely want to avoid. Companions may interfere with each other's interactions (Humphrey and Gutwill, 2005). Research around the concept of 'collective interaction' suggests that such interference is a natural part of collective interaction (Krogh and Petersen, 2010). In family groups, parents often play a role in facilitating situations which require negotiation, helping to manage conflicts and mediate turn taking (Hornecker and Nicol, 2011), (Plowman et al., 2010). However, it should be noted that children can also negotiate turn taking themselves, through actions such as asking for turns (Horn et al., 2012b). The process of taking turns can be socially valuable as well as supporting mindful engagement with content. For example, Block found that groups who engaged in turn taking behaviour at an interactive tabletop surface spent longer and engaged more with the topic than groups that did not engage in turn taking (Block et al., 2015). Furthermore, companions may engage socially to try to verbally or non-verbally negotiate to resolve situations in which their goals conflict (Davis et al., 2015).

Parent-child social interactions

It is important to recognise that many of the situations and behaviours discussed in this section (1.2 Social interactions) overlap with behaviours associated with educational models. In particular, understanding how parents and children's social interactions in the museum context is are entwined from an educational perspective. For example, parents often engage in scaffolding, facilitation and educational talk when in a museum with children (Hornecker and Nicol, 2012). **Scaffolding** is a concept which originates from educational theory. It concerns how a person at a more advanced level helps a person that is not yet able to do achieve something on their own. For example, it refers to situations in which parents assist children in completing a task successfully and supporting their learning. During this process parents may provide helpful guidance, prompt the next actions, explain, read out instructions or demonstrate what to do (Plowman et al., 2010), (Piscitelli and Weier, 2002), (Hornecker and Nicol, 2012). **Facilitation** describes situations in which parents mediate turn taking and interaction between children. In such situations parents may help to manage conflicts, or provide verbal hints on what to do next (Hornecker and Nicol, 2012), (Plowman et al., 2010). **Educational talk** refers to parents highlighting objects or areas of interest including linking immediate artefacts or interactions to previous experiences and context beyond the immediate object on display, abstracting ideas and relating to existing knowledge (Povis and Crowley, 2015 p.169), (Hornecker and Nicol, 2012), (Plowman et al., 2010). Adults may also provide emotional support to children, motivate and praise them, or try to soften their frustration. Some parents can take a more hands-off approach, allowing children to take the lead. In some cases, parents may also act as babysitters. Piscitelli and

Weier (2002) propose categories of interactive teaching and learning behaviours in relation to family engagement with objects in an art gallery. They identify three categories of coordination and collaboration: “nondirective,” “scaffolding,” and “directive”. Nondirective behaviours include physical proximity, listening, acknowledging, and encouraging. All categories are related to the social dimension of companions’ visits (Piscitelli and Weier, 2002).

However, these activities are not limited to parent-child situations. Children may also engage in these behaviours with each other, particularly when an older child and younger child are both present. To some extent, adults may also engage in such activities. While these activities are primarily defined through an educational lens, their social value should also be recognised; they encourage bonding and enable people to spend more time together, thereby enhancing the museum visit. Thus these behaviours extend beyond educational aims, in that they encourage individuals to have fun, support bonding with companions and enable positive interaction with exhibits.

Introspective individual experiences and social interactions

While this research primarily focuses on companions’ social interactions, it is important to recognise the dynamic relationship between visitors’ individual experiences and their social interactions in the museum. Often, these two experiences are considered to be fixed and distinct. For example, it is acknowledged that individual experiences enable visitors to develop a deep connection with artefacts and support an introspection, while shared experiences help to strengthen and consolidate bonds between companions (Debenedetti, 2003). However, these experiences are often fluid and interchangeable. During a museum visit, visitors often seek to balance social and individual experiences by moving between these (Allison and Gwaltney, 1991). As Lopez Sintas et al note, *“Social and individual experiences do not cancel each other out, but may occur simultaneously during the visit or at different times and places”* (López Sintas et al., 2014, p.241).

2.3.3 Types of Museums & Expectations

Museums have often been thought of as places for informal education. They are visitor attractions, and are considered to be places where people have a day out or to spend time with companions. Museums are places for socialising, learning, accessing new information, connecting with the past, entertainment and a day out. Museums are not exclusively places for learning (Falk et al., 2006). Museum visitors also visit for a variety of reasons, and are from diverse backgrounds, age, gender and ethnicity. Furthermore, there are a variety of different museums. These include cultural heritage institutions including science centres, art galleries, transport museums, maritime museums and national history museums. All of these evoke vastly different expectations and produce varying and diverse visitor experiences. The experiences visitors have and expect as are diverse as the audience. The customary museum experience is often conceptualised as an experience in a traditional museum or 'mausoleum', displaying historical painting or classical arts. In such experiences, the role of a visitor is typically passive, observing artefacts and reading (Ramsay, 1999). In contrast, science centres are typically associated with hands-on interactive exhibits, which visitors physically engage with (Ramsay, 1999). Furthermore, traditional museums often focus their exhibitions around their collections; in science centres, the exhibits are typically based on scientific phenomena, and as such, science centres do not necessarily display objects from a collection. This PhD primarily focuses on both of these museum types.

Visitors have certain expectations of their museum experience, depending on the museum they are visiting. For example, they may expect to see historical objects; take part in educational workshop activities; or be entertained or inspired by the narratives and objects in the museum.. As a result of these various expectations, there is tension over what the role of a museum should be, and its purpose in a community. Is its purpose purely to deliver information on a topic and exhibit collections related to this topic? Is it to provide a location for social interactions for families, school groups or friends? Is it to facilitate new experiences for people regardless of knowledge attainment? Cultural heritage organisations, historians, archaeologists, educators and councils regard a museums as resources for learning. However, visitor studies research reveals museums are much more than centres for learning but also serve as places for spending time with companions.

2.3.4 Being included and including others

Given the wide variety of social interactions that companions experience during their visit, this section discusses previous research focusing on visitors' activity at interactive exhibits, and how they are included in each other's activities. The body of research conducted by Heath et al (2005), vom Lehn et al (2001) and Hindmarsh et al (2005) has been particularly concerned with examining the social behaviours companions engage in while using interactive exhibits. Their research has highlighted the ways visitors co-participate in the activities together, align their actions and establish mutual understanding. In order to adequately understand these activities, Hindmarsh et al. (2005) call for sensitivity and recognition of the various verbal and non-verbal forms of co-participation companions engage in. Similarly, Meisner et al. argue that *"Exhibits should engender various levels of participation to support the emergence of an audience and open up possibilities for shared experiences"* (Meisner et al., 2007, p.1550).

To better understand these activities, Ludvigsen (2005) developed a conceptual framework outlining four different ways people engage socially while interacting with exhibits in public spaces. The framework considers the social activity which people engage in, how close they are, what they share and the attention they dedicate to the activity. The lowest level of engagement in Ludvigsen's model is called 'distributed attention'. At this level, people share the same space, but do not actively pay attention to others or the activity occurring in the space. The second lowest level is called 'shared focus', in which people pay attention to the activity but do not engage in shaping the activity At this level, they are effectively an audience. The next level above is called 'dialogue', in which companions engage with each other, and focus together on the situation at hand, for example by exploring or debating a topic. The final level in the model is called 'collective action'. This level is similar to the 'dialogue' level, but it also includes the way companions work together in achieving a goal at the exhibit (Ludvigsen, 2005). Ludvigsen's model can be related to research by Reeves et al. (2005) who discuss the experiences and actions of audience members observing interaction. Reeves et al.'s research focuses on how visitors manipulate content, through manipulations, and the ways that the outcome of these action, called effects, are made visible or hidden to other members of the group or audience (Reeves et al., 2005). Their research has particular relevance to the aims of this thesis in its consideration of the ways various members of a group assume different roles depending on their participation in the activity. Reeves identified three roles adopted by members of groups: performers who directly interact with and manipulate digital content; bystanders, who observe the interaction from a distance, learning what to do, and often waiting for a turn; and spectators who act as an audience, watching the interaction at a greater distance than bystanders and those waiting to take a turn (Reeves et al., 2005).

This thesis draws on and develops the bodies of research outlined above to understand how different members of a group participate in an activity together. Understanding how companions are included in one another's activities at interactive exhibits and questioning how these social interactions can be supported is at the core of this PhD research.

2.4 Technology

This section focuses on technology in relation to museums and visitors' social and shared interactions. I draw on both the fields of human-computer interaction and museum studies to highlight how technology relates to visitors' social activities.

While HCI literature is useful in understanding social interaction with systems, there are limitations to applying knowledge drawn from HCI literature to the museum context. This is, in part, because HCI research has often been related to vastly different contexts from a museum environment. For example, many traditional HCI studies were orientated towards work environments in which there may be clearly defined goals, people are often repeat users or they have dedicated time to invest in learning how to use a system. However, the field of HCI has significantly broaden its scope in recent years to include a focus on user experience, leisure contexts and casual users. Yet, the museum context is very specific, and as a result, not all HCI knowledge is transferable to the study of people's interaction with technology in a museum context. Museum visitors often do not have a rigid agenda. Instead, they are often inclined to negotiate the space based on their own personal interests, engaging with any exhibit which attracts them at that time. In addition, installations created for public spaces, such as airports, shopping centres, foyers or open-air spaces, may not have a specific topics and messages to communicate, as opposed to most museum exhibits. In contrast, museums have two potentially conflicting agendas: achieving learning outcomes related to the foci of the museum and its collections; and creating pleasurable experiences.

Moreover, conventional HCI literature typically concerns systems that people use repeatedly, and therefore subsequently of which people become expert users. In museums, often people are first-time users who have no prior knowledge of the exhibits. Thus, the design of an exhibit may aim to communicate a specific idea and piece of information. Once this has been communicated, the interaction process is often considered to be complete. However, there are people that re-visit an exhibit. It can therefore be challenging to cater for both types of user, providing something engaging and easy to use for first time users while simultaneously providing lasting interest for repeat users.

While increasing numbers of HCI studies focus on interaction in casual public settings, there are still a limited number of studies focusing specifically on the museum context, companions social interaction and tangible hybrid interfaces. For example, recent HCI research related to public settings has focused on the experience between strangers and the performative aspects of the experience people engage in (Reeves et al. 2007, Williamson et al. 2014). In addition, a focus has been on situations where people observe another person's actions, rather than engaging in action along with them. In contrast, this PhD research focuses on the social interaction between companions and shared interaction during which multiple people interact with an exhibit

In the field of museum and cultural heritage studies, there are relatively few studies that focus specifically on social interactions around interactive exhibits, and which examine what discourages or encourages social engagement. This section will discuss the limited available research concerning social interactions at interactive exhibits in museum or similar contexts. Overall, the section focuses on issues related to the following questions: '**who is in control, how they are in control, and does this matter for the social context of the group?**'. I aim to differentiate between the different types of tangible interactive exhibits that exist in the museum context, highlighting particular trends and considering how they relate to visitors' social interactions and their overall museum experience.

This section is divided into two parts. Firstly, I discuss interactive technology in museums, and how group interaction has been supported at these interactive exhibits. In doing so, I discuss two highly relevant research areas concerning social interaction and tangible interaction. Namely, tangible hands-on interaction and large multi-touch interactive surfaces. Secondly, I discuss design strategies and factors to be considered when developing social installations.

2.4.1 Interactive Technology in Museums and the Support of Group Interaction

Many museums, cultural centres and science centres recognize the value of interactive exhibits. Interactive exhibits can deliver a variety of experiential value (McLean and McEver, 2004), evoke emotional reactions, and support both hands-on and 'minds-on' interaction (Allen, 2004). Social interaction in museums heavily influences the overall experience (Falk and Dierking, 2013), (vom Lehn et al., 2007). In addition, museum visits tend to be group activities with the purpose of spending time together. Prior research has highlighted that there are number of challenges in supporting collobaration and social interactions with public interactive exhibits (Heath et al., 2005), (Hourcade et al., 2004), (vom Lehn et al., 2007), (Vom Lehn et al., 2005). For example, digital interactive exhibits can impact the social activities of a group. vom Lehn's (2001) research an example of this from studies with various high-tech immersive VR installations provides an example of this (Vom Lehn et al., 2001). Their work found that while these installations increased participation between the exhibit and visitors, there were impoverished opportunities for discussion, collaboration and interaction between visitors. Typically, single user exhibits lack opportunities for active engagement for the rest of the visiting group (Vom Lehn et al., 2005).

Understanding how to create exhibits that support communication and shared experiences is thus very important. The presence of others at an exhibit may disturb or enhance an experience. At present, a growing body of research has highlighted issues for groups and onlookers when interactives are designed solely for single users (Heath et al., 2005), (Hornecker, 2010), (vom Lehn et al., 2007). For example, when individuals use single-user interactive exhibits, their companions become witnesses to their actions, and are therefore limited in their participation "with the surrounding ecology of the exhibit" (Heath and vom Lehn, 2003, p.5). The rest of the group cannot always see the actions of the user or the information which is presented to that user (Heath and vom Lehn, 2003). In cases where there is a pair or group of children, companions often try to co-participate in the user's activity. When this happens, the main user often becomes irritated, and they try to keep other away or onlooking parents may try to keep others away (Heath and vom Lehn, 2003). Researchers such as Hindmarsh et al. (2005) have called for more interactive exhibits that support social interactions for family groups and diverse forms of participation. A number of design sensibilities which support these interactions have been established (Hindmarsh et al., 2005), (Snibbe and Raffle, 2009), (Ciolfi, 2004) but these can be expanded upon to include new principles.

Integrating novel technologies has a wide range of benefits for museums. For example, such technologies engage visitors; help museums compete with other attractions and spaces that people travel to visit; attract media and press attention; help the museum to appear modern and up-to-date; provide access to content that otherwise cannot be shown; or help museums to integrate playful experiences that may be attractive to a younger generation into their exhibits.

Tangible Hands-on interaction

> *"With **Tangible User Interfaces** (Ishii and Ullmer 1997) and **Tangible Interaction** systems (Hornecker and Buur 2006) the user interacts with a digital system by manipulating physical, tangible objects as interface elements. There is not just a generic mouse or abstract buttons, but instead a variety of diverse objects that enable rich physical interactions. These physical objects control the (digital) output of the overall system. Tangible Input in form of physical levers, handles and wheels constitute some of the oldest forms of interaction within the museum context"* (Hornecker and Ciolfi, 2019).

Tangible refers to the interaction involving physical bodily movement, either moving oneself or an object, which triggers the manipulation of digital content. Each of the exhibits discussed in this thesis has an element of tangible interaction. Specifically, the Phd research focuses on tangible **hands-on** interaction at exhibits. Hornecker & Ciolfi (2019).

describe several forms of tangible input in museums. These include physical levers and handles at more traditional interactives; tangible objects which are placed and manipulated around interactive tabletops, in which the main input mechanism to the digital application is the surface; everyday objects with embedded tags that can be carried around the museum, and are detected at specific interaction kiosks; and complex arrangements of tangible, manipulatable elements, such as systems which recognise stacking and inserting objects into each other.

Tangible physical interaction can support social experiences. It can enable visitors to observe and learn from each other while using exhibits, contributing to shared experience. For example, if people are unsure how to interact with abstract physical controllers, they may observe current users, prompting observing visitors to develop their own interactions (Mazalek et al., 2009). This situation is particularly evident at exhibits which have unusual tangible controllers, where their function may not be immediately evident. For example, a paint brush presented as a controllers at an exhibit is a familiar intuitive object (Clarke and Hornecker, 2012), while the interactive function of stamps representing characters at an exhibit may not be immediately obvious how to use them to interact with the system (Mazalek et al., 2009, p.247) (Hornecker and Dünser, 2008).

It has been argued that tangible interaction has a number of benefits for group interaction (Shaer et al., 2010), such as providing manipulative access to digital content for multiple people, greater observability and legibility of interaction, and a perception that tangible physical objects invite tactile interaction. Tangible interfaces are hailed for their ability to support social activities. They can be used as tools for communication (Fernaeus and Tholander, 2006), (Hornecker and Buur, 2006), resources for action (Fernaeus and Tholander, 2006) and are associated with affective experiences (Fernaeus et al., 2008). Moreover, physical objects themselves can be social (Simon, 2010b). As Simon (2010b) argues, people often find it easier to engage socially with others when they are able to focus their attention on an object, rather than solely on each other [ibid.]. This is because physical objects provide a reference point for conversations, and people can move and re-orientate an object to support their conversations. Furthermore, the physical form of objects and controllers can be designed and positioned in context to visually imply their use or restrict their use. Such design tactics are known as affordances and constraints (Norman, 1988), either affording or constraining certain actions. For example, a door handle sticking out from the doors implies a person to pull it, whereas a flat push panel on a door constrains people to push the door open (Norman, 1988). Thus, affording and constraining certain actions. Considering these benefits and functions, physical interaction with tangible objects was motivated the focus for the present PhD research.

Offline Tangible Controllers

Interacting with tangible objects outside of core interaction, meaning the manipulation of digital content, has previously been defined as 'offline' tangible interaction (Esteves et al., 2013), (Fernaeus and Tholander, 2006), (Fernaeus et al., 2008). Offline tangible interaction refers to interactions with tangible controllers which are not registered by a system and are considered to be ‘out of bounds’ of the interaction area (Esteves et al., 2013), (Fernaeus and Tholander, 2006), (Fernaeus et al., 2008). Both online and offline tangible interaction can foster children’s social actions, for example by enabling them to physically sharing the controllers with others (Fernaeus and Tholander, 2006). In addition, offline controllers allow people to distribute the controllers physically and consider them as options. This physical distribution can support companions discussions by enabling access controllers, thus allowing users to appraise the respective merits of the different controllers (Rogers et al., 2009, p.112).

Large multi-touch interactive surfaces

Large multi-touch interactive surfaces typically allow multiple visitors to play games together (Hornecker and Nicol, 2012) (Horn et al., 2012a) or to explore interactive visualisations which can have vast amounts of information, such as those depicting the evolution of species (Block et al., 2012), (Hinrichs, 2013), (Hornecker, 2008). In comparison with older computer interactives such as kiosks, multi-touch interfaces are visibly more social (Kidd et al., 2011) based on by their large size, which enables multiple people to gather around the surface and see the content easily. Tabletop interfaces thus provide a shared space for people to interact. At multitouch surfaces, multiple people can interact with the same content and interface simultaneously (Hinrichs, 2013).

However, multitouch surfaces present numerous challenges. Visitors often have expectations that interactive touch screens will respond in the same way and with the same efficiency as smart phones and tablets (Kidd et al., 2011). Furthermore, children will frequently all try to interact with the surface simultaneously, without coordinating their actions with companions. Often the technology cannot support such rapid, simultaneous interaction resulting in nobody being able to interact (Peltonen et al., 2008), or users may interrupt each other and thus prevent successful interaction (Hinrichs, 2013). In some situations, people may spend more time talking about **how to** use a multi-touch table than discussing the topic together or engaging with the content (Hornecker, 2008).

2.4.2 Design Strategies and Factors in Developing Social Installations

Previous related research has explored a number of different types of exhibits and interaction mechanisms which support companions' social and shared interactions. In this section, I draw upon this body of work to map out a variety of design strategies discussed in previous literature. These strategies provide a basis for understanding social and shared interactions at tangible hybrid interactive museum exhibits (THIMEs).

Enabling, Encouraging or Enforcing Collaboration and the Notion of Shareability

Benford et al (2000) discuss how technology may be used to support collaboration, distinguishing different levels or strengths of support. The three levels are enabling, encouraging or enforcing collaboration. They note that, at its lowest level of support, technology **enables** people to collaborate by providing the affordances for fluid collaboration and ensuring the technology doesn't prevent collaboration. At the next level, technology may **encourage** collaboration by creating invitations to collaborate. For example, by having others join in the interaction there are benefits such as the interaction and digital content becoming more interesting. This is similar to Snibbe and Raffle's (2009) recommendation that while interaction should become richer as more people interact, an exhibit needs to also function for a single user. At the strongest level of support, technology **enforces** collaboration; at this level interaction alone may not be possible or may be ineffective. This enforcement can occur through built-in rules of collaboration, such as enforced turn-taking. For instance, installations may require everyone to select the same option on their own panel for a game to proceed, thus requiring all to agree; or installations may provide each interactor access to certain parts of the interaction resources, and thus creates a situation in which interactors must work together and rely on others.

Hornecker *et al.* (2007) investigated qualities relating to the shareability of interactive systems for collocated groups. Shareability relates to 'enabling collaboration' level of Bentford et al.'s (2000) research discussed above. Hornecker *et al.* (2007) outlined out two overarching ideas: entry points, and access points. Entry points invite people to participate by stimulating their curiosity, and encouraging them to become involved in the activity. Entry points are linked to qualities such as visibility, providing an overview, turning collocated people's attention to others using a shareable interface, and tempting them to interact. Access points enable individuals to be actively involved in the group activity by helping them to understand how people interact, knowing how to join in, allowing them to manipulate digital content, and enabling them to fluidly share the interaction back and forth with others (ibid). Hornecker's model thus identifies a range of characteristics of systems that enable collaboration. This thesis will discuss and analyse how collaboration is encouraged and, in particular, enforced.

Physical Configurations

The configuration of various controllers and outputs can have a significant impact on how individuals interact with each other while using interactive exhibits (Hindmarsh et al., 2005), (Rogers et al., 2009). The physical attributes of an interactive system strongly influences group participation, shared access and inclusion in an activity. For example, large interactive tables which provide multiple access points, allow multiple people to interact and control the interaction, rather than only one (Hinrichs, 2013), (Geller and Applications, 2006). A number of research studies have also explored how aspects encourage social interaction between individuals, such as the work of Ludvigsen (2005), Krogh and Petersen (2008), and Warpas (2014).

For the purposes of this research, it will be essential to consider the nuances of multiple controllers, understanding how they relate to an activity, how they relate to people's interaction with an exhibit, and how they contribute to the manipulation of the digital content. It should also be acknowledged that there are significant challenges to achieving multi-user parallel interaction that encourages co-visitors to connect with each other and to directly share an experience, while at the same time drawing their attention and their conversations to the narrative of the installation (Hindmarsh et al., 2005), (Snibbe and Raffle, 2009).

The space and size of interactive area or display is also a factor in supporting the social context. At present, technology found in museums is less likely to be small computer or monitor-based kiosk setups, such as science centre bubbles which have multiple individual stations (Heath and Vom Lehn, 2010). Instead, technology in museums tends to be based on large displays which allow people to view the actions of others, and large interactive surfaces. These factors of size and the spatial arrangement of an exhibit contribute towards a physical configuration that influences how easily people can observe and join in an the activity.

Supporting the interaction of multiple group members

Recently, a number of exhibits have become more supportive of multiple co-visitors interacting. There are a number of types of multi-user interactive installations in museums such as: exhibits which provide multiple individual stations for visitors to interact with (Hornecker, 2010), (Heath and Vom Lehn, 2008); large multi-touch table top interactives enabling multiple people to explore interactive visualisations and browse information (Hindmarsh et al., 2005), (Block et al., 2012), to play games (Horn et al., 2012a) or quiz games (Hornecker, 2008); some play digital content such as audio and light displays which is triggered when physical objects are placed in certain areas or close to specific objects (Taylor et al., 2015); others provide members of a group with different controllers to use together to solve puzzles or tasks (Omojola et al., 2000), (Ståhl et al., 2002), (Wakkary et al., 2009), (Rogers et al., 2004); as well as various tabletop tangible interfaces during which digital content is manipulated by moving physical objects on the surface (Kaltenbrunner, 2009), (Xambó et al., 2013), (Dalsgaard and Halskov, 2014). Thus, at present, there is a variety of configurations of a range of different technology which enables multiple visitors to participate in interaction together. Some of these require visitors to manoeuvre physical levers, buttons or objects, and do not support touch screen interaction, but include a screen or projection for the digital output.

It should be noted that competitive multi-user games are distinct from other multi-person interactive exhibits. A number of these games were observed in the scouting phase of this PhD research, which sought to identify potential installations for detailed study at the Riverside Transport museum.

It should be noted that competitive multi-user games are distinct from other multi-person interactive exhibits, some of which were observed in the 'scouting' phase for this PhD, which sought to identify potential installations for detailed study at the Riverside Transport museum. Some of these take the form of quiz games, as discussed in Hornecker (2016). Such games tend to place players in competition with each other, often using a timer to encourage users to complete a task or answer a question under time pressure. Thus, such games tend to focus on individual interaction, and limit discussion of the objects or conversations about the interaction.

In the following sections, I discuss a number of strategies for how to support and invite group interaction. Perhaps the most straightforward of these strategies are those which allow for simultaneous interaction, though it should be noted that such strategies can sometimes be detrimental to productive social interaction. More complex strategies focus on interlinking individuals' activity; rewarding joint activity with enhanced results; providing joint goals; or forcing people rely on each other. Such strategies often utilize mechanisms which are familiar to group work strategies used for example in teaching. Some installations may provide equal access and visibility for all, whereas others may intentionally separate the view of digital content into separate viewpoints.

Allowing Simultaneous Interaction

One common disadvantage of older interactive exhibits is that often they only allow one person to interact. Thus, recently interactive exhibits have sought to support the social context of groups by providing multiple ways of manipulating digital content simultaneously. Providing these multiple methods can help to avoid situations in which visitors only watch companions interact, rather than being able to participate actively (Heath and Vom Lehn, 2008). Providing multiple controllers has been found to increase group participation in physical interaction (Hornecker et al., 2007). However, at present there is disparity about the effects the configuration of controllers has on the resulting social interactions. As I will go on to discuss in the next section, the effects are complex and depend on the overall exhibit and interaction design.

Enabling simultaneous multi-user input does not always support a positive visitor experience (Allen and Gutwill, 2004), as in some cases one person's actions may interrupt the interaction of others. Given that young children tend to be impulsive and have often yet to develop self-control, greater collaboration and social interaction is sometimes ensured by sequentialising interaction, often through enforced turn taking. Moreover, enabling simultaneous multi-user interaction does not always mean that there is any direct communication or interaction between active users, that co-visitors will notice and react to each other's activities, or work towards a common goal. While having multiple access points (Hornecker et al., 2007) allows many members of a group to be involved in interaction, this alone does not necessarily enable or encourage people to interact socially (Benford et al., 2000).

If there is unstructured open exploration at interactive exhibits, individuals may act alone rather than sharing the activity with their companions (Hornecker, 2008), (Benford et al., 2000). Heath *et al* (2008) describe an example of an exhibit which provided multiple stations located close to each other for visitors to play a game at the same time. They found that visitors frequently focused on their own individual game with only occasional glances or call-outs to their companions playing nearby. The activity itself therefore did not encourage companions to engage with each other during interaction or support interaction between bystanders and interactors (Heath and Vom Lehn, 2008). Individuals may only be absorbed in their own individual activity. Thus, collocated visitors carry out simultaneous parallel individual activities, focusing solely on their own interactions, and have little time, attention capacity or incentive to engage socially with others. It has also been observed that visitors may end up focusing on their own movements and interactions if the exhibit encourages energetic and flamboyant moves (Snibbe and Raffle, 2009).

One prominent development of multi-user exhibits is co-creation, during which multiple individual workstations allow people to create content alongside their co-visitors. For example, Dalsgaard and Dindler (2009) developed an interactive exhibit for a marine centre that visitors could create their own digital fish using physical construction kits. The fish were then released into a virtual ocean alongside fish other visitors had created (Dalsgaard and Dindler, 2009). The fish in the virtual ocean could be viewed by pushing a large circular screen on wheels, which was low to the ground, acting as a hydroscope, which is a device for viewing objects below the surface of the water. The researchers noted the social behaviour of individuals leaving the workstation, and on meeting the rest of the family would explain how to use the exhibit to their parents. Here, social interaction was found to be indirect, and typically occurred in a second phase after the creation of the content, when the fish is released to interact with the things created by others, and when visitors re-join their group.

Thus exhibits focused on supporting **simultaneous collaborative** activities could have high social value in a group's overall museum visit, in that they enable groups to spending time doing things together. A key motivation underpinning the present research is to develop an understanding of exhibits that support people in sharing their experience with others, often spending 'quality time' with companions while using interactive exhibits.

Interlinking people's actions together

Interlinking visitors' digital content with that of their co-visitors is a feature Snibbe and Raffle refer to as 'socially balanced' in that *"interaction equally emphasizes a user's awareness of herself, other users, and the media itself"* (Snibbe and Raffle, 2009). They suggest that merging people's manipulated content together highlights the interrelationship between multiple users. In the case of Deep Walls, an installation included in their research, the content and narrative of the installation was created by recording snippets of visitors' silhouettes and playing these on a large screen (Snibbe and Raffle, 2009). Visitors combined their bodily movement together to create content, linking their actions together. Similarly, at another of their installations, 'Fear', the found some visitors pushed each other in front of the exhibit, which would result in being seen and caught by the Jaguar that visitors were trying to hide from.

An important factor in installations such as those discussed above is single display, or one display for all visitors to view, and the merging of people actions on this display. In these examples of body-tracking-based interfaces, people are supported to maintain their own personal interaction, (control of the content) while at the same time able to merge their actions with that of other visitors. Thus, they can choose to coordinate and combine their actions to manipulate content.

The Digital burial mount installation has a similar quality in that visitors interactions are directly linked to the same media, at which collocated visitors move sand to reveal what's buried (Dindler et al., 2011).

Rewarding Joint Activities with Enhanced Digital Content

Certain configurations which reward coordinated actions with different controllers by providing additional benefits or enhanced digital content. This strategy has been adopted by a number of previous multi-user exhibits, such as the Combination Machine at the Hunt Museum in Limerick, Ireland (Ciolfi and Bannon, 2007), (Benford et al., 2000). Such installations reward joint activities, but do not enforce them, in order to encourage collaboration while also allowing individuals to pursue their own individual interests (Ciolfi and Bannon, 2007). Benford (2000) calls this process, which children use tools together, 'enhanced functionality. 'The Combination Trunk' at the Hunt Museum adopted this tactic (Ciolfi and Bannon, 2007). By placing individual keycards (controllers) into a large old trunk triggered digital content that would show in a mirror in the trunk, explaining where the artefact that keycard was linked to had been found. Placing two keycards in the trunk together triggered different content, thereby producing different results based on visitors using controllers together (Ciolfi and Bannon, 2007).

Providing A Joint Goal (Team work)

While many of the examples discussed thus far support multiple companions to act together enabling simultaneous parallel interaction without enforcing collaboration, there are also exhibits which present a joint goal for people to work towards.

These exhibits include activities such as multiple companions hunting information in the museum collectively contributing to a task (Wakkary et al., 2009), or collectively working as archaeologists to uncover items buried in the sand (Dindler et al., 2011). Such exhibits set a common goal as an incentive for team work, encouraging people to share experiences, and create a reliance on others thereby encouraging communication and discussions. Such exhibits create a motivation for visitors to maintain an awareness of each other and align their actions. These goals reflect the idea of 'collective interaction', in which *"interaction itself is a matter of collective* *action"*: *"Collective Interaction takes departure in colocated users negotiating a shared goal for the interaction and sharing the interaction mechanisms for achieving the goal"* (Krogh and Petersen, 2008).

In the case of visitors acting as archaeologists digging in the sand (Dindler et al., 2011), the nature of the task establishes a shared goal but the physicality of the exhibit enables multiple co-visitors to participate and merges their manipulation of digital content into one shared output. As outlined research conducted by Wakkary et al (2009), the interactive 'Kurio' set groups the task of repairing a time machine and its broken map by gathering information in the museum and using it to help fix the map (Wakkary et al., 2009). The activity has two steps: first an often individually performed search for information; followed by a re-grouping to join information together. Groups were given: 3 tangible portable devices, all functioning in different ways (a listener, pointer and reader), to collect information; a PDA to coordinate the tasks; and a tabletop display where the map to repair was displayed. Different challenges were given to different visitors so they could work either independently or collaboratively when solving the challenge. One person usually became the coordinator and supporter of the group activity, acting as a hub for the group, and using the PDA as a guide to the overall challenges delegated to the family members. Visitors carried out individual activities and then re-grouped, joining the collected information together. While searching for information, parents and children constantly interacted to reflect on the challenge and the artefacts. The authors suggest this was because visitors could momentarily ignore the technology. Kurio is an interesting example of museum technology that enables families to work as a team, explore together, and make decisions together beyond purely encouraging discussions about artefacts or historical events (Wakkary et al., 2009). It supported both individual and socially shared activity and tasks. It also includes an element of reliance on others, in that each of the three controllers has part of the functionality and often need to be used in concert.

Reliance

Making a group rely on each other through interdependence is an extreme case of rewarding joint action. This can be achieved, for example, through giving a group a shared goal which cannot be achieved unless the group works together, thereby enforcing collaboration (Benford et al., 2000). For example, some installations simply cannot be operated by one person alone. In the example of Kurio discussed previously, the group is reliant on each other to solve the task. This reliance can sometimes be viewed negatively in the museum domain, where exhibits are supposed to scale up and down to support groups of visitors or solo visitors. For example an individual visitor may be frustrated they cannot use a multi-user exhibit but a group may be unsatisfied if they cannot use an exhibit together. However, most visitors come to museums in groups, so there may justification for prioritising group interaction in this way. In other work on collaborative learning with tangible interfaces, such co-dependency has been argued to "*enable positive interdependence among children*" (Antle et al., 2013).

Equal Access to controllers & viewpoints or Split Access?

Several projects have advocated for equal access to controllers and equal participation through different forms of participation (Hornecker et al., 2007), (Hornecker, 2005), (Rogers et al., 2009). Hornecker's (2005) *embodied facilitation* design theme recommends non-privileged access and sufficient resources to allow for more equality in terms of participation in the activity, as this hinders individuals taking over control. Non-privileged access and sufficient resources refers to both what people can do and what they can see. Privileged viewpoints can create inequality and limit the resources others have to observe, understand and participate in the activity. Studies relating to full-body interactive exhibits combining camera tracking and projected animation also suggest providing equal interaction for all parties who enter the space (Snibbe and Raffle, 2009). Equal access to controllers and digital output can encourage collective meaning making and discovery of a story (Dindler et al., 2011).

In contrast, other research has experimented with privileged and limited viewpoints, such as in the exhibit Ghost Ship (Hindmarsh et al., 2005). The privileged and limited viewpoints prompted creative and playful social behaviours in trying to understand the connections between the input and digital content (Hindmarsh et al., 2005). In some projects and installations, a purposeful separation of inputs and outputs promoted social activity. For example, 'Ambient Wood' provides the input and output on separated mobile devices (Rogers et al., 2004). One person uses one portable device for input and another person has a different portable device to view or hear the output. Or, one person can view the content, while another person can control or manipulate it.

Distributing inputs and outputs between different members of the group creates a division of labour, a type of reliance on each other, and encourages team work, a highly social activity requiring interaction with others.

However, issues can arise when the input and output were separated too far from each other. As a result, understanding the connection between input and output becomes difficult. Hindmarsh *et al* (2005, p.34) consider the organisation and assembly of actions and the visibility of the displays *('action points and view points')*. They note that there are challenges to assembling inputs and outputs so that people can visually connect different viewpoints and action points, including viewing the output of their own actions (ibid.). How individuals see the digital response of their actions and how others respond is therefore important. They suggest that the input mechanism should not conceal the nature of the actions so others can observe and establish how to engage with the activity or interact themselves (ibid.).

The configuration of inputs and outputs, their relation to each other, and how the use of the inputs and outputs relate to the temporal flow of interaction has an impact on co-participation and direct social interaction between co-visitors. Reeves et al (2005) provide a detailed analysis of the effects the visibility of system interactions and system responses has on the experience of spectators. They refer to the interactions and responses as manipulations and effects. Considering how visible these are for an audience, they compare it to the typical actions of a magician which often involve hidden manipulations and highlighted effects.

Supporting companions' visibility and awareness of each other and the ongoing interaction are also important aspects to consider when designing the configuration of inputs and outputs. Content that is visible for many people can encourage interaction between visitors (Grinter et al., 2002). Large displays and interfaces are highly effective in allowing many people to see the interaction and make sense of the interactive relationship with digital content (Meisner et al., 2007, p.1550) .

Single User Exhibits May Also Support Groups

While providing multiple controllers is a key foundation in supporting co-participation, single control exhibits should not be discounted in their ability to support social experience for family groups. Physically large controllers located between group members with and large visual outputs viewable by the whole group have been found to support the social interactions of groups (Hornecker, 2010). Furthermore, multiple people, such as parents and children, will often use one controller together if this is easily done, for example if the controller is large enough and its movement easy to coordinate (Fischer et al., 2015). Single controller exhibits have also been found to engender a variety of group interactions, such as discussing the next moves, reading out loud options and visitors including themselves in their companions activity (Patel et al., 2016). One of the key questions proposed in an evaluation of the Loupe interface (Damala et al., 2016), a handheld device providing an augmented reality view to explore objects, was whether the device could be shared, even though it could only be held by one person. It was found that the pairs of visitors participating in the study usually looked through the Loupe together and coordinated what to do next. The results of this evaluation are therefore distinct from prior research concerning personal digital assistants, audio guides or mobile phone guides in museums, which found that such technology isolated visitors from each other and the environment (Vom Lehn and Heath, 2005).

Nevertheless, compared to systems which offer multiple access points, single user exhibits do not offer the same level of provision for enhanced collaborative communication and shared social experience (Hornecker, 2005, p.11). In part, this is because allowing for simultaneous action and multiple points of interaction are two key design guidelines recommended to engender collaborative activities (Hornecker, 2005).

Transitioning between different roles and modes of interacting

Researchers suggest that allowing users to shift between roles such as a performer or viewer of the interaction is an important way to support individuals to be aware of themselves, others and the media (Snibbe and Raffle). Being a bystander and observer or interacting are different ways of engaging with an exhibit, all of which have value in their own right. The importance of multiple roles aligns with Debenedetti's argument that both introspective and shared experiences in museums are necessary for people to connect with stories on a deeper introspective level while also fulfilling social agendas (Debenedetti, 2003). This perspective also aligns with work on situated displays discussing how people transition from observing a display to focusing their attention on interaction. Such transitions can be between different activities and ways of participating in the activity, for example transitioning from human-computer interaction to human-human interaction (Krogh and Petersen, 2008); transitioning from being observer to active participant; transitioning from joint group activity at an exhibit to individual interaction; and transitioning from inquisitive to reflective modes of engagement (Warpas, 2014), (Dindler et al., 2011). A group may observe a stranger interacting, then approach to interact with the exhibit once it is no longer occupied, or an individual may interact while their companions observe, then those who were observing may join to work on the task together, before returning to an observer role afterwards. Exhibits should support such transitions.

Passive Digital Technologies

Sometimes, technology with no interactivity, or passive digital exhibits which digitally enhance the narrative surrounding artefacts can also elicit social interactions between companions. Warpas (2014) developed a system whereupon several glass cabinets and artefacts were enhanced with audio-visual content when visitors entered the room in a museum. The presence of visitors would trigger the cabinets to start producing light, projecting animations on and around artefacts, and playing sounds (Warpas, 2014). Warpas' installation was thus reactive, rather than interactive. The system used technology to figuratively amplify the voice of museum artefacts, visually and sonically highlighting the more evocative aspects of physical artefacts, thereby drawing attention to them. Warpas found that visitors connected with the objects on a very personal and emotional level, which then facilitated sharing those engagements in conversation, particularly in families. Children were intrigued by the digital enhancement and would point these out to family members.

Warpas concludes that *"focusing on artefacts brought them to the foreground of the museum experience and made visitors more sociable"* (Warpas, 2014, p.69). She further argues that not presenting the visitors with a specific task facilitated open-ended exploration, and put visitors in charge of their own visit. Considering the focus on distribution of control in companions' social interaction in this PhD research, it is important to note that Warpas' exhibit had no explicit controller. As such, people were not occupied by trying to control the digital content. In reference to low-pace, low-intensity interactivity, Hornecker (2016) also suggests that it can be advantageous to put visitors in charge of setting their own pace, giving them adequate time to respond to each other, rather than following the fast paced interaction with an exhibit.

Performances

Several studies regarding social interaction and co-participation with exhibits highlight performative elements of the interaction, for example performance in the form of storytelling or co-creation or users interaction constituting sort of a performance for others (Taylor et al., 2015), (Snibbe and Raffle, 2009), (Meisner et al., 2007), (Hornecker and Stifter). Performance is a valuable interaction mechanism which affords possibilities for greater social interaction (Meisner et al., 2007). Public behaviours, and in particular behaviours with gestural interface,s can be understood as performative. Encouraging visitors to take part in performative interactions that are interesting to watch and fun to do can entertain other people while they await their turn. As a result, the wait may be less laborious or irritating, since, *"performances can be an effective means to support and enhance the experience around and understanding of an exhibits' functionality, not only for those using the exhibits but also for those observing the activity"* (Meisner et al., 2007, p.1541). The performance also allows people to see both how others are interacting with the exhibit, and to gain a better understanding of what the exhibit is. The performance may therefore generate greater interest in an exhibit. Such performances might also become 'talking-points', which are critical for people's experience and learning at exhibits (Meisner et al., 2007, p.1549), (Hornecker and Stifter, 2006).

Several exhibits that engender creative and playful social behaviours and interactions embed people or representations of visitors in the narrative or in the resulting representations. Representations of visitors becoming the digital content, for example through visual imagery, is evidenced in the work of Hornecker and Stifter (2006), Snibbe and Raffle (2009), and Hindmarsh et al. (2005). It immediately centres companions as the 'social object' or 'talking point' and thereby creates an inherent connection between companions, if the companions, or a representation of them, is in fact the digital content which visitors focus on.

However, translating such embodied interactions into exhibits that have more structured narratives can be challenging. Some studies indicate that exhibits which support creative playful social co-interactions do not appropriately or effectively communicate structured narrative about an artefact or topic museums aim to communicate (Snibbe and Raffle, 2009), (Hindmarsh et al., 2005).

2.4.3 Conclusion

Enabling multi-user interaction fundamentally provides a solid foundation in supporting co-participation within groups. Multi-user interaction enables multiple individuals to physically interact with an exhibit together but it is not necessarily foster direct social interaction between companions while they interact with the exhibit. This direct social interaction can also be known as human-human interaction (Krogh and Petersen, 2008). As the literature review has shown, there is wide variation in how exhibit design may structure the activity of visitors and enable, enhance, or enforce collaboration. The body of literature also demonstrated that social interaction can be rich even when a museum's digital technology is not highly interactive, and, conversely, high interactivity may not always result in rich social interaction.

Previous research calls for flexible participation, and identifies a need to support changeable forms of collaboration and interaction which are accessible for a variety of audience interests, expertise and varying group formations (Hindmarsh et al., 2005). Closely related to these varying forms of participation is the concept of transitions, which concerns visitors transitioning between different activities and ways of participating in an activity, such as transferring from human-computer interaction to human-human interaction (Krogh and Petersen, 2008). Such transitions can also include transitions from observer to active participant, and from inquisitive to reflective modes of engagement (Dindler et al., 2011).

With so many different expectations of new technologies in the museum context, this PhD research will prioritise a focus on how technology can support and encourage visitors to spend time sharing experiences and interacting with their companions as they use interactive exhibits.

Defining 'Tangible Hybrid Interactive Museum Exhibits'

Within literature relating to interactive exhibits in museums, there are multiple terms used for exhibits which facilitate hands on interaction, are interactive or include digital content. The terminology appears to be used interchangeable causing some confusion as to what exactly is being refer to (Caulton, 2006), (Bitgood, 2014), (Ramsay, 1999). To narrow the scope of the research, and to add clarity as to the type of exhibits the research is concerned with, I have developed a definition: **THIME** which stands for 'Tangible Hybrid Interactive Museum Exhibit'.

Tangible refers to the type of interaction requiring physical manipulation of objects. In a wider sense *tangible interaction*, encompasses touching or moving an object or oneself to trigger a reaction or manipulate digital content; which encompasses both tactile, physical hands-on contact and embodied interaction during which body movement is involved in manipulating digital content (Hornecker and Buur, 2006). Ishii and Ullmer provide a narrower definition of *tangible interfaces* in their work (Ullmer and Ishii, 2000). According to their work, tangible interfaces consist of a setup with physical objects that can be manipulated directly, which are coupled with digital information, thereby controlling an information system. Ishii and Ullmer define that the system response is integrated within the interaction area. In this PhD research, the use of the term 'tangible' explicitly relates to Ishii and Ullmer's definition in that interaction requires the physical manipulation of objects, but does not require a full tangible interface. The use of the term tangible in this PhD research also builds on Hornecker and Buur's (2006) relatively open understanding of tangible interaction, which focuses on physical manipulation. According to this definition, tangible museum exhibits (Hornecker and Ciolfi, 2019) may rely on moving physical objects, or tokens, on an instrumented surface, on 'old-fashioned' physical levers, pulleys and wheels, or consist of a more complex setup in which physical objects may be moved around or inserted into each other.

Hybrid refers to the merging of the physical and digital, during which physical artefacts may be enhanced digitally or connected to digital content which people can control. Some previous research links the term 'hybrid' directly to physical artefacts in the museum collection which are augmented by digital media (Koleva et al., 2009). Other research specifies that hybrid artefacts are *"installations that support visitors manipulating physical and digital material in a visible and* *interesting manner for many museum visitors"* (Bannon et al., 2005). In such accounts, there is an implied physical object that links to digital content (Hornecker and Ciolfi, 2019). While it could be argued that tangible, in the definition proposed by previous research such as Hornecker and Ciolfi (2009), already implies hybridity, it is important to emphasize the connection with digital content in hybridity, as there are also many museum exhibits that have physical objects which can be manipulated without any digital elements. Thus, combining 'tangible' and 'hybrid' implies using hands-on interaction with physical objects to manipulate digital content or information. The word hybrid therefore adds clarity to the type of tangible interaction suggested.

Museum refers to the context in which an exhibit is set up in. The work in this thesis investigates social interaction in museums. In such spaces, behavioural rules and patterns will be different from those in formal learning situations, such as schools, open public spaces (there is a whole research area on public space or urban / architecture media installation design), or work and domestic settings. The museum context is intended to include similar contexts, such as art galleries and science centres, which do not have the word 'museum' in their title.

Interactive refers to enabling people's actions or behaviours which trigger changes in the state of an exhibit. At an interactive exhibit *"change is under the visitors control"* (Bitgood, 2014). Some exhibits with controllers do not fit this definition. For example, exhibits which provide single-use controllers, in which, a button triggers content, such as a start button, and thereafter, visitors have no control over. 'Interactive' as adjective relates to the word interaction. Interaction implies a back and forth process in which the system responds to the user's input, and then the user responds to the new system state again, and so on. The term interactive alone does not necessarily imply a link to technology or digital content. However, when interactive is combined with the term hybrid, a digital association is implied.

Finally, **exhibit** refers to an object or limited collection of objects on display, which has been curated to explain or relate to a particular topic, often displayed in public spaces. It should be noted that an exhibit is distinct from an exhibition, as an exhibition denotes a collection of exhibits.

In summary, a THIME refers to an exhibit which supports tangible interaction with a physical object or objects to manipulate/control digital content.

Some examples of THIMEs are: Deus Oculi (Hindmarsh et al., 2005), Magic Cauldron (Taylor et al., 2015),Digital Burial Mound (Dindler et al., 2011), The Loupe (Damala et al., 2016), Kurio (Wakkary et al., 2009). These all provide an object, or several objects, which encourage hands-on tactile interaction with the object and in doing so control digital content. An example of an exhibit which would not be considered a THIME is 'Fear' (Snibbe and Raffle, 2009), an interactive game during which visitors try to catch fruit falling from the tree. In 'Fear' a silhouette of the visitors body is displayed on a large screen, and moving their arms allows them to catch the fruit falling from the tree in the projection. The exhibit relies on body tracking and thus falls under embodied interaction (Hornecker and Buur, 2006), however it cannot be considered tangible as it does not rely on physical touch and manipulation in order to control digital content.

2.5 Research Focus

Considering the issues outlined in the literature review, and with a design-focused aim, this PhD research is driven by an aspiration to support the design of future tangible interactive exhibits, which encourage and support companions to socially interact with one another while also being able to share interaction with the exhibit. Simultaneously interacting with interactive museum installations while at the same time engaging in social interaction and sharing these interactions with companions can be challenging. The overarching research agenda of this PhD thesis is to understand: What different factors should be considered when designing tangible hybrid interactive museum exhibits concerned with supporting and fostering companions' social interactions and shared interaction with the exhibit? The PhD contributions of these aims through insights and design considerations are outlined in the result chapters 4, 5 and 6 and the discussion chapter 7 of this thesis.

In order to focus the research, three distinct but interrelated research questions have been established. RQ1 and RQ2 serve to support the main research question, RQ3. RQ1 and RQ2 define the scope of the type of installations this research focuses on, and to roughly categorize social interactions, both of which are key elements for RQ3.

Research Question 1: What are tangible hybrid interactive museum exhibits (THIME)?

A variety of exhibits and interpretative materials in museums and galleries have technology integrated into them. Multi-user touchscreens, hands-on interactive exhibits, hybrid exhibits and immersive interactives are generally covered by the term 'interactive exhibit'. However, the term does not portray the type of interaction that can be expected at such exhibits. Does the term interactive imply an exhibit does or doesn't use technology? It is thus necessary to more clearly define the exact type of exhibit this PhD research focuses on. A classification of the term 'tangible hybrid interactive museum exhibit' will therefore be established.

Research Question 2: What are the range of social activities between companions and how does sharing the interaction unfold?

RQ2 is concerned with the social and shared interactions which unfold between companions, mapping out the different ways people share the interaction and the different social activities which develop between companions. The question will investigate what social behaviours and actions companions engage in while interacting, including how companions share interactions with each other while using interactive museum exhibits. This question will therefore determine what social and shared activities are, which supports in answering RQ3.

Research Question 3: How can social and shared interactions between companions be supported and encouraged by the way in which control is distributed?

The final research question is the most important in terms of fulfilling the motivation to aid future design. This is a two-part question with the aim of understanding firstly how control of the exhibit is distributed between companions at THIMEs, and secondly the role that the way control is distributed plays in the social and shared interactions between companions. Considering how control is distributed focuses the research to critique an aspect of the exhibit (the distribution of control), specifically in terms of the role control plays in shaping the social and shared interaction between companions while using the exhibit.

Chapter 3

Methodology

3.1 Introduction

This PhD research is design-focussed, and its primary aim is to understand the role that exhibits play in visitors' interactions and their experience. In particular, the research aims to examine visitors' interactions with interactive museum exhibits with tangible physical controllers, considering the features of such exhibits. The research aims to highlight and examine the types of interactions and behaviours companions engage in at and with these exhibits, and to understand the specific context of these interactions. To achieve these aims and address the research questions outlined in section 2.5, the research employs a qualitative research methods. Qualitative research methods can enable researchers to uncover, in rich detail, 'how' and 'why' these situations, behaviours and interactions occur.

Accordingly, a qualitative observational approach can help to understand and explain how visitors interact with exhibits, including what they do and how they react to different parts of the exhibit (see, for example Hinrichs (2013)). Using qualitative methods enables researchers to collect rich data, to analyse emergent interactions in detail, and to interpret people's meaning making (Marshall and Rossman, 2014). Such methods are thus appropriate for the research interests of this thesis. In particular, I utilise video-audio based research to investigate companions' interactions with the exhibits and with each other, as discussed later in Section 3.4 Video-based research. It has previously been demonstrated that video-audio recordings have been particularly useful resources for designers in demonstrating the nature of the interaction stimulated by particular interactive installations (vom Lehn and Heath, 2016).

Three case studies were carried out as part of the research. Where possible, the research prioritised studies in real life situations, in-situ with the general public, a research area known as 'in the wild' (Rogers et al., 2013). The case studies involved studying existing museum exhibits (study 2), and bespoke exhibits (created by myself), which were designed, fabricated and exhibited in galleries (study 1 and study 3). Studying existing exhibits as well as prototype exhibits provided insights and considerations from within the practice of designing for this context. The inclusion of existing exhibits also ensured that the researcher was unbiased regarding these exhibits.

The studies were carried out in a particular order; in which the first study involved the design and evaluation of an exhibit; the second study involved the evaluation of existing exhibits; and the third involved the design and evaluation of an exhibit. The sequence might appear unusual, not to study an existing exhibit before any design activities. However, a funded opportunity arose to design and evaluate an installation for a time sensitive exhibition. This served as an exploratory study which helped in guiding the focus of this PhD and served to inform the analysis of later studies and design considerations as an outcome of the PhD research. The following two studies were more narrowly orientated towards answering these deeper questions raised in study 1. In addition, study 2 focused on existing exhibits which directly fed in to the design of the exhibit in the third and final study. This order of studies is unusual but proved valuable as it shows how design can inform future research questions (e.g. study 1 guiding the focus of study 2 and 3) and how evaluations of existing exhibits can be formative and feed into future designs (e.g. study 2 feeding into design in study 3) (Davies and Heath, 2013).

Owing to my research background in industrial design, I approached the research by both engaging in design and fabrication of exhibits, and by studying visitors interaction with exhibits in their real world context. The exhibits in study 1 and 3 were designed and constructed specifically for the research, adopting a research-through-design approach. This approach provided an understanding of the challenges, concerns and agendas involved in developing museum interactive exhibits. As such, the research had an internal, rather external, perspective on these processes (Frayling, 1993). Embedding myself in the process and practice of designing interactive exhibits allowed for a greater practical and empirical exploration of the research topic. In addition, creating exhibits which specifically related to the research agenda meant that the research questions could be addressed appropriately. Engaging in these specified design processes was also helpful as it enabled the study of exhibits which specifically fit the criteria of tangible hybrid interactive museum exhibits (THIMEs).

The present chapter discusses the methodical approach of this thesis in detail, highlighting the cross disciplinary nature of this research. Firstly, I discuss the research-through-design approach for developing new installations. I then discuss the methods relevant for the evaluation of installations, both novel and existing methods. The research and findings presented throughout this thesis are based on data collected during 'in the wild' studies, which was then analysed using video-based analysis as well as thematic and interaction analysis of data from the studies. I will discuss the specific approach used for data collection and for the analysis of visitor interactions based on the collected video data.

Figure 3-1 Three 3 Case studies

3.2 Developing Prototype Installations with a Research-through-Design Approach

While the PhD contributions stem primarily from the studies 'in the wild', it is important to note the related research activities such as developing prototype installations with a research-through-design approach in study 1 and 3. Such activities, guided the research and supported mutually beneficial relationships between the PhD researcher and collaborating museums.

Broadly speaking, research-through-design, known as 'RtD', concerns the design artefacts which serve to generate insights and new knowledge (Frayling, 1993), (Stappers and Giaccardi, 2017), RtD is often concerned with specific designerly activities. These activities produce knowledge and introduce objects into the world which are then discussed, reflected upon and analysed (Frayling, 1993), (Stappers and Giaccardi, 2017). Unique insights can be gained from practicing design (Godin and Zahedi, 2014). This is in part because the process of constructing and designing presents opportunities to discover things and problems that might otherwise go unnoticed (Koskinen et al., 2011), and can generate understandings of the particular design space which may help to frame the research insights which future designs relate to.

This PhD research prioritises the visitor experience. However, the research is also mindful of the museums' aims. This consideration is essential in grounding the research to real-life conditions and considerations surrounding interactive museum exhibits. A desire to include museums' perspectives, and their agenda motivated collaboration with museums which took place in the practical part of this PhD research. Furthermore, it is important to consider both museums and visitors as clients. While the end user of an exhibit is the visitor, museum staff can also be considered users, and have specific criteria they wish exhibits to fulfil.

3.2.1 Adopting RtD in this PhD Research

The PhD research adopts an RtD approach through the creation of research artefacts in the form of museum exhibits for case studies 1 and 3. Developing the exhibits followed a design process involving the conceptualisation; first version prototyping, and formative studies; a development phase; and final fabrication of the research artefacts. The design process differed for case study 1 and case study 3, as outlined below.

Study 1 Design Process

Study 1 involved the design and fabrication of a digital tangible painting installation for The Ark, a cultural centre for children based in Dublin, Ireland. A user-centred design process was adopted, focusing on the audience of children and families who might visit the cultural centre. As such, the process considered the interests, anthropometric data, and cognitive abilities, of children. When designing and developing the exhibit, I engaged in an iterative design process, in which several prototypes of different levels of fidelity were evaluated with participants (shown in Figures 3-2) (Clarke and Hornecker, 2012). This process was essential in shaping the design around points of interest for potential users, and highlighted issues surrounding usability prior to the final design and fabrication of the painting exhibit. The process also provided insights into considerations for such installations, institutional priorities and museum like contexts. An initial paper prototype (Figures 3-2) supported a walk though of the initial concept with two adult participants. This walk through highlighted areas of the concepts which needed further consideration. Following this, semi functioning prototypes (Figures 3-2) were tested with 16 adults and 2 children . In this testing phase, a set up based on wizard-of-oz prototyping, replicated some of the exhibits' potential functionality. The final installation was therefore shaped, tested and altered during the design process[2].

[2] The first study of the PhD did not adopt a co-design approach as the priority was on creating a tangible interactive installation rather than adopting a co-design process. In addition, time constraints to exhibit for a specific exhibition the funding was awarded to and a less collaborative relationship with the institution than that of study 3 the study were factors influencing the design process for study 1.

Figures 3-2 Study 1, Prototypes and Testing

Study 3 Design Process

The third case study involved the design and fabrication of a prototype exhibit in close collaboration with the Riverside Transport Museum in Glasgow. I therefore adopting elements of co-design throughout the design process (Figure 3-3), in particular by conducting workshops with museum visitors and museum staff. The project took place while I was based in the museum as a design researcher in residency, a position funded by an EPSRC Impact Acceleration Account. Being embedded in the museum during the design and development of the exhibit allowed me to develop day to day knowledge of the museum context and considerations. This knowledge fed in the designed exhibit for study three and also helped to frame the overarching research outcomes.

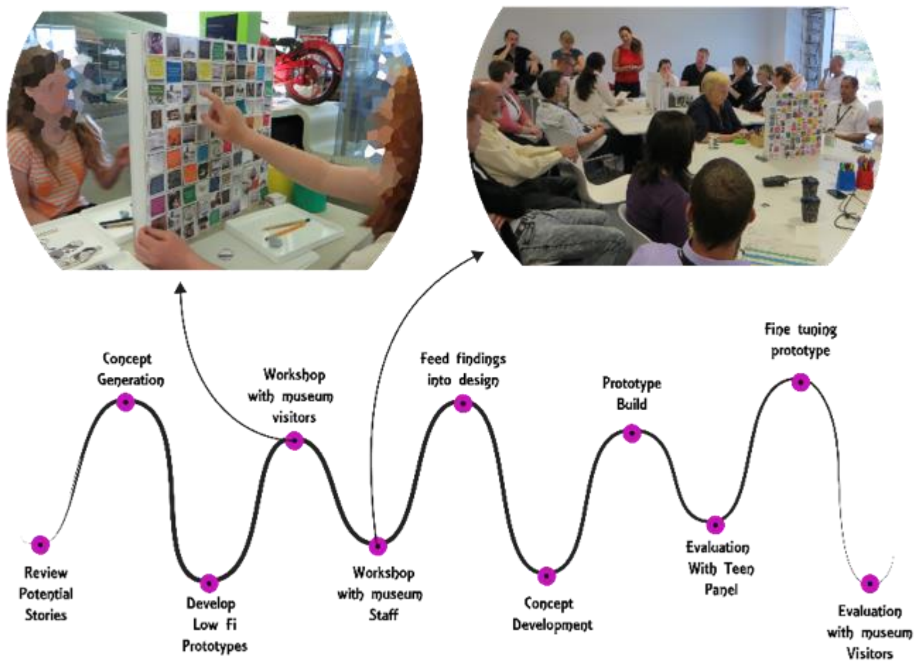


Figure 3-3: Project Overview

While the primary contribution of this research is an analysis people's interactions with these exhibits, the process of designing and fabricating of the exhibits was essential in highlighting a number of key considerations. The process provided a greater depth of understanding the contexts in which these interactions take place, of museum's institutional priorities, and of key considerations when developing such exhibits.

A strength of this research was in the different approaches for each of the studies in terms of the researchers involvement in the design process. For example, in studies 1 and 3 the researcher was the designer but in study 2 the researcher had no involvement in the design process. This situation presented an opportunity to understand the context of the research from a number of perspectives. In the role of designer it allowed a deep understanding of the rationale behind designs. Yet when researching existing exhibits in study 2 it enabled the researcher to study the exhibits without having a stake in the design rationale. I found this helped in keeping an empathetic understanding of the various perspectives, one might view the design of exhibits from.

3.3 Research 'in the wild'

The PhD research is specifically concerned with interactions which take place in museums. Conducting the research in-situ, rather than in lab based studies, is crucial in understanding how these interactions occur in real contexts (Taylor et al., 2013). Research 'in the wild' refers to studies carried out in real, natural settings, such as people's homes or public spaces, rather than out of context, such as in a research lab (Rogers, 2011). 'In the wild' studies are also sometimes known as 'field studies'. However, 'in the wild' studies are distinct in their reliance on real world situations, in which the researcher has limited control over what people will do. In contrast, field studies may include some form of guidance as to how participants should behave or what they should do with the technology. 'In the wild' research is gaining increasing prominence as a methodology in HCI studies, particularly as technology continues to spread into new and unexpected areas of people's everyday lives. Furthermore, research 'in the wild' is extremely valuable when researching patterns of use, behaviours and experiences of technology in real life situations (Taylor et al., 2013), (O'Brien et al., 2008), (Rogers, 2011). As such, in museum studies focussing on visitor research, conducting research in situ with museum visitors is already well established (vom Lehn and Heath, 2016), (Hornecker and Stifter, 2006), (Humphrey and Gutwill, 2005).

Research 'in the wild' has the ability to reveal unexpected ways people might interact with and use technology (Crabtree et al., 2013). It serves to uncover the messiness of human interaction as it happens in real life (Rogers, 2011), during which people behave of their own violation. In contrast, in lab studies and to some extent field studies, participants are recruited and invited, and as such there is a risk that people may altering their natural behaviours to try to be a good participant of the research study (Brown et al., 2011). Furthermore, 'in the wild studies' can reveal the influence of real life happenings and contextual factors (Rogers, 2011), such as group members separating from one another in museums.

Visitors experience, interactions and behaviour are affected by several factors which are unique to the museum setting. These factors include the physical and social context of specific museums, social interactions (Falk and Dierking, 2013), the distraction of other exhibits, or changing moods of visitors during a museum visit. It is thus vital to conduct studies in the museum setting in order to understand how installations perform in this real-world settings. Previous research indicates that there are differences in results between lab-based studies and in-situ studies (Marshall et al., 2011), (Crabtree et al., 2013), (Hornecker and Nicol, 2012), (Rogers, 2011). For example, Hornecker and Nicol (2012) found that parents often engage and scaffold less in real museum spaces than in lab-based studies. Similarly, they found that more visitors repeatedly used exhibits in lab-based user studies with prototypes of installations than in real museum spaces.

3.3.1 'In the wild' research throughout the PhD research

The PhD research adopts an 'in the wild' approach by conducting the research in existing gallery spaces and museums, where possible. With the exception of study 1, all studies can be classified as 'in the wild'. In the case of study 1, participants were invited to take part in the study while the exhibit was closed off to the public. This was due to specific policies regarding video-audio recording in the cultural centre where this study was based. As such, study 1 is more closely aligned with the definition of a field study than an 'in the wild' study.

Study 2 focused on two existing exhibits at the Riverside Transport Museum in Glasgow, both of which had been exhibited at the museum since its opening in 2012. This approach enabled the messiness of real-life situations and natural behaviours to be included in the data captured. Such behaviours and situations included visitors fighting, ignoring each other or leaving the exhibit suddenly. Video-audio recording equipment was set up around the exhibits. The exhibits were available for the general public to interact with. Multiple signs around the exhibit notified people that the study was taking place, and gave information on how to opt-out of the study.

In Study 3 a prototype installation was exhibited in the museum gallery space for 2 weeks at the Riverside Transport Museum in Glasgow for 2 weeks. The study adopted the same approach as study 2, setting up video-audio recording equipment with signage and opt-out information placed around the exhibit. Similarly, participants were visitors who decided to interact with the exhibit. As such, insights from the study were representative of natural behaviours with the technology of interest the museum context.

3.4 Video-based research

In this thesis, analysis of in-situ visitor interaction with museum installations draws on qualitative research methods. In particular, I employ video-audio based research methods to examine the interactions people carry out at museum exhibits (Heath, Hindmarsh and Luff, 2010). I also use thematic analysis (Braun and Clarke, 2006), which allows for an interpretative approach. Using an interpretive approach enables the data to be viewed and understood from a number of different perspectives. In this section, I discuss the advantages of a video-audio based research approach, including data collection. I then go on to discuss the analysis of video-audio data using thematic analysis, drawing on the techniques established by Heath et al (2010, p.119) and Jordan and Henderson (1995) for analysing interaction.

The overall aim of this PhD research is to investigate the relationship between features of an interactive exhibit and the social activities of a group, interacting with this exhibit. Therefore, the research prioritises the examination of social interaction and interactions with the exhibit, over the consideration of visitor engagement with the topic or knowledge attainment, which is a common focus in museum studies. Instead, this PhD aims to understand the various ways that the social context is nurtured or hindered by exhibits. Various forms of co-participation, means of inclusion, and forms of social engagement mediated by the interaction with the exhibit are of interest. Prior research with a similar focus on the social context of visitor interactions has also adopted a video-based research approach (vom Lehn and Heath, 2016), (Meisner et al., 2007), (Gutwill and Allen, 2017), (Heath et al., 2010), demonstrating that this is a viable and appropriate method choice.

Note that while my approach is influenced by the above work, in particular that Heath, Hindmarsh and Luff's (2010), I am not conducting an ethnomethodological analysis of interaction. The PhD research is concerned with determining common patterns of interaction and their relation to features of the exhibits, and offering design-relevant recommendations. In this regard, the work discussed in this thesis is more closely related to Jordan and Henderson's approach to interaction analysis (Jordan and Henderson, 1995), than to Heath and Luff's approach (Heath et al., 2010). This is because Heath and Luff's approach focuses on single incidents, which are analysed in detail in order to investigate the sequences of action in which people operate and establish social order, rather than on 'ordinary' and more general patterns.

3.4.1 Introduction & Rationale

Video-audio data is a highly effective method of capturing sequences of events, people's behaviours and their interactions in a way which attempts not disrupt natural behaviours (Meisner et al., 2007), (Vom Lehn et al., 2005), (vom Lehn and Heath, 2016), (Heath et al., 2010). For example, video-audio recordings can capture how a situation unfolds, actions which occur between people, and the sequential order of those actions (Heath et al., 2010). In summary, video-audio recordings can reveal both what happens and how it happens. Analysis of video data can uncover the ways which people organise their actions in relation to others and their environment (vom Lehn and Heath, 2016), (Heath et al., 2010).

Data collection via video-audio recordings is a valuable method of data collection as it records elements that may be missed in observations, limits bias, and can capture many events and people in parallel. It enables researchers to repeatedly review the data and moreover, to analyse it along with other people (Heath et al., 2010). Furthermore, to understand the "*frequency or prevalence of certain behaviours*" video and observational data may be quantitatively analysed, for example focusing specifically on behaviours or questions (Lazar et al., 2017, p.234).

Video analysis can *"contribute to our understanding of the impact of new technology on visitors' experience of exhibits and exhibitions"* (Vom Lehn et al., 2005). It presents opportunities to understand visitors' interactions around and with exhibits beyond quantitative measures such as dwell time (the average amount of time spent at the exhibit), stopping power (the average number of visitors stopping at the exhibit), or communication power (the effectiveness of an exhibits in delivering information to visitors) (Vom Lehn et al., 2005).

Video has a number of advantages over in-person observation. Observing multiple people in a museum space is challenging, given that there is often a large number of people present, and events unfold in parallel. Video recorded data enables the researcher to re-watch and observe the sequence of events, examining factors such as where visitors look, if they hold onto objects or hands over objects, how they share interactions and interact socially with others. Video data also removes a layer of interpretation and filtering, or bias, which a human observer may unknowingly implement while taking observational notes and sketches. In this sense, video is objective, as it can be reviewed to reveal things that are not noticeable on first sight. Repeated viewing also has a defamiliarising effect. However, it should be noted that the placement of video-audio recording equipment can also create bias, as this equipment filters the data.

Video-audio recordings allow for transcription of the exact events as they unfolded, rather than live coding of behaviours or relying upon observational notes. This is particularly useful when researching the interactions of multiple people located at different parts of an exhibit, which can be extremely challenging to accurately and reliably manage given the volume of actions being observed. Some research adopts pre-defined coding of behaviours as strategy to manage the frequency of events and the reliability of data being captured live. However, in such a process, the codes must already be defined, the observer must be trained, and is limited by the amount of observations a human being can observe and note in real-time.

Process Overview

For this PhD research, the data collection and analysis approach was based on video-audio based research. This consisted of three overarching steps, shown below in Table 3-1. Step 1 is preparation for the study, Step 2 is capturing of video-audio data, and Step 3 is the analysis of data. Step 1 and 2 in the table below show a list of things to consider at these stages. This list resembles a check list derived from my personal notes on the process of conducting video-audio research, and recommendations by Heath, Hindmarsh and Luff (2010). Step 3 in the table shows the process of analysis took place, and which is described in greater detail later, in section 3.4.3 of this thesis.

A variation of this PhD research from prior related research, is the analysis of video-audio data utilising a combination of thematic analysis and interaction analysis (Jordan and Henderson, 1995). These steps are outlined in greater detail in subsequent sections on capturing video-audio data and analysing video-audio data.

PhD Video-Based Research Overview		
Step 1: Preparation	**Step 2: Data Capture**	**Step 3: Data Analysis**
Visit museum – check out good angles/views for the cameras and where to place recording equipment – working with team in museum to agree setting up cameras and audio recorders Proposed plan/timetable agreed with staff Ethics and signage Consider how you analyse the data and what for – this will dictate how you set up the study	Be as removed as possible - invisible Charging and changing batteries or SD cards Using several pieces of recording equipment consider how you will synchronize them later. Use a loud hand clap which can help synch video and audio later. The clap may disrupt visitors but that piece of recording will be scrapped anyway	Preparing the data: Synching all the data together and rendering as one video images in the right format for the software that will be used for analysis Catalogue (excel reference) – first overview mainly noting details for reference (group size, age, times, etc.) First review of what is happening while developing questions, observations, notes, comments, initial thoughts Filter Data set – choose suitable data for detailed analysis Detailed transcriptions

Power for equipment Spare batteries SD cards		(Potentially only of selected sequences of interest. E.g. approaching an exhibit, using controller X) Develop potential codes during transcription Open coding – iterative process Develop most prominent themes, clustering codes together into themes

Table 3-1: Video Based Research Process Overview

3.4.2 Data Capture

Video-based research studies carried out in museum spaces typically focus on visitors from the general public interacting with an installation of interest (Xambó et al., 2017), (vom Lehn and Heath, 2016), (vom Lehn, 2006), (Hinrichs, 2013. Similarly, a data corpus for this PhD research was created which primarily comprised of video-audio recordings of museum visitors interacting with exhibits. As the museum is a public space, given the regulations at the time of the study and the museums policies, any museum visitors to the installations during the study were assumed to be participants of the study. Study 1, due to the regulations of the museum in question, was an exception, as groups were invited to take part in the study while the exhibit was closed off to the public.

During the initial phases of the research, open-ended observations, supported by notes and sketches and photo-collections, were conducted. This process supported familiarisation with existing exhibits, the identification of suitable exhibits, and the development of research questions. Study 3 augmented the data collection with questionnaires and short interviews post-interaction, and semantic differentials.

Video-audio recording requires particular attention to ethical considerations, such as how to ensure informed consent without disrupting people's natural behaviours (Block et al., 2015), (vom Lehn and Heath, 2016). An established procedure in related research is placing signage in several locations surrounding the exhibits being recorded. The signs should be clearly visible and inform people of how to opt out of being recorded; or how to have the recording destroyed; the purpose of the study; where the data will be used; and who it will be shared with. The last consideration is often a cause for concern in terms of the vagueness of details (vom Lehn and Heath, 2016). Signage may to some extent influence natural interactions with the exhibits in question (Block et al., 2015). However, it is difficult to ensure visitors give informed consent without disrupting natural interaction (Gutwill, 2002). Thus, signage can be the least intrusive solution. The PhD research followed this procedure with signage posted in several locations surrounding the exhibits. Only in one case during recording for case study 2, did a visitor request for data to be deleted given the adult was not a legal guardian of the children at the exhibit.

There are various practical aspects to consider when capturing video-audio data, such as agreeing timetables with the museum, and considering different days and times for data collection, in order to capture a range of visitors. Often, the museum may be aware of days or times when there is a higher probability of groups who should not be included in the research attending, for example school classes, for which consent cannot be easily provided.

Recording equipment set up

There are distinctive challenges to deciding how to set up recording equipment. These considerations include framing the action, selecting a perspective, the technical limitations of the equipment, the scope of the study, and the analytical orientation (Heath et al., 2010). Furthermore, fixed cameras have the advantage of capturing a stable image but, if poorly placed, may be unable to capture ongoing action.

With these constraints in mind, in all of the studies in this thesis, multiple fixed cameras were placed around the exhibits so that they could capture several angles of the same action. As a result of the installation of multiple cameras, actions at larger exhibits were captured; the cameras captured both close-up action, such as what people were doing with their hands, and overall actions and movements in the space and between people. It should be noted that if the researcher captures too much they may risk losing detail. However, if only a close up is captured, the researcher may lose the context necessary to understand the sequence in which the events unfold (Heath et al., 2010). For example, if only a close up is capture, the researcher may not see a person who has been observing from the side entering the interaction later-on, or an event that attracts visitors' attention away from the exhibit. As such, multiple cameras were deemed the most appropriate method to capture both close and long-range action simultaneously.

Visiting a venue beforehand can enable a researcher to determine what typically happens in the space and decide what to frame and where to place recording equipment (Heath et al., 2010). If possible, a researcher should carry out a trial run of the camera setup to decide what to focus on and the recording equipment should be placed. Audio quality is also an important consideration.

Cameras may be placed too far away from the action to capture appropriate audio, or their orientation may simply be unable to pick up sufficient audio data. For each exhibit in this thesis, separate audio recording equipment was located at locations where visitors were observed to often stand. The audio recording equipment was placed at mouth level and in front of people rather than behind a person when possible . As part of the study preparation, it was also necessary to consider how to manage the maintenance of equipment during recording such as the battery life of different devices and the capacity of SD cards.

A mixture of video cameras and separate audio recording equipment was located at the exhibits, shown below in Figure 3-4 and Figure 3-5. The size of the exhibits and multiple locations of controllers required a great deal of consideration when placing cameras and audio recording equipment. Placement prioritised the capture of people's direct physical use of the controllers, the digital outputs from the exhibit, the movement of visitors in the space, and spaces where a group might stand when watching others. No cameras were placed directly in front of visitors' faces, as maintaining a natural experience for visitors is a higher priority in the scope of this research than capturing visitors' faces.

Figure 3-4: Glen Douglas video-audio recording set up

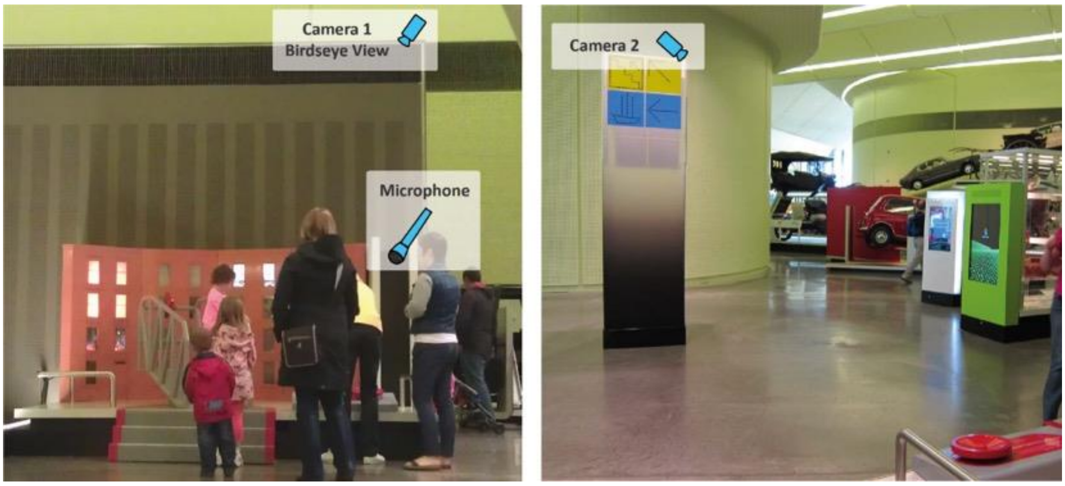


Figure 3-5[3]: Fire Fighter video-audio recording set up

Video-audio data was also supported by understanding what is happening in these situations and through contextual information gathered from observations, notes, sketches, interviews, questionnaires, and awareness of contextual factors such as odours or sounds which may not be captured in video-audio recordings. Supporting recordings with observational notes and sketches can be extremely beneficial. Being in a space as a researcher and observing what happens off camera, or what is happening in the wider museum can provide further insights into the events which unfold.

3.4.3 Video-Audio Data Analysis

The complexity of data ranging from video-audio data captured from several different positions at the same exhibit, to observations, design documentation and questionnaires raises a challenge for the analysis. In particular, the complexity of video-audio data. To a large degree the research addressed this by drawing on the recommendations from experienced researcher in this area, both from literature (Heath, Hindmarsh and Luff, 2010) and the experience from the supervisors of this thesis. Some tactics adopted were; to merge the data into one folder for each exhibit and

[3] Photo on the left courtesy of Professor Eva Hornecker

to create a catalogue of people interacting with the exhibits referencing all related data. I'll discuss these in greater detail, in this section.

Once video-audio data has been captured, the data should then be analysed in line with the research agenda. Various techniques have been established for the analysis of this type of data. For example, Heath et al (2010) take an ethnomethodology approach to video-audio analysis; Knoblauch has detailed videography from a 'focused ethnography' standpoint (Knoblauch and Schnettler, 2012); and Jordan and Henderson (1995) describe interaction analysis of video data. Other research studies have used pre-defined coding systems to analyse video-audio data (Block et al., 2015), (Horn et al., 2012). Finally, the APE ('Active Prolonged Engagement') approach to codes to categorizes visitors' dialogue(Humphrey and Gutwill, 2005). For example, they coded how many people in groups were asking questions, or suggesting a hypotheses at exhibits.

Thematic analysis (TA) was used to analyse video-audio data from the studies outlined in this thesis. This approach was supplemented by drawing upon the analysis processes outlined by Jordan and Henderson (1995) and Heath, Hindmarsh & Luff (2010). Thematic analysis (TA) is commonly utilized in qualitatively research. Braun and Clarke argue that most qualitative research involves some level of thematic analysis (Braun and Clarke, 2006). Thematic analysis identifies patterns and themes across the data set. It requires interpretation from the researcher and focuses on identifying observations and phenomena, both implicit and explicit, across the data as themes, rather than counting explicit items of interest such as explicit words, phrases or interactions (Guest et al., 2012). Codes are developed to tag the raw data and aid in the analysis of themes within the data (Guest et al., 2012). There are different types of TA. This PhD research draws upon Braun and Clarks's (2006) approach, called 'reflexive TA'. Reflexive TA involves researchers developing an interpretation of the data, to make sense of the data and explain what it might mean (Braun and Clarke, 2006). From the perspective of this PhD research, this is an advantage of reflexive TA.

Thematic analysis has a number of advantages. Firstly, the approach can capture and map out complex meanings from data (Guest et al., 2012). It can be used to describe and explain a phenomenon (Guest et al., 2012, p.18). The sensitive approach of TA helps to avoid "*fracturing or segmenting data in a way that doesn't allow for reconnection of fractured elements"* which can be a limitation of coding (Bazeley, 2013, p.191). Furthermore, 'reflective TA' uses codes which aren't predefined. As such, the codes iteratively develop during analysis to cluster similarities. These are then broken up when they become too broad and the coding structure is modified to represent the data respectfully (Braun and Clarke, 2006). The codes are then clustered together to form themes. Conversely, a challenge TA raises is its reliability, as setting the themes depends on interpretation of the data by researchers (Guest et al., 2012).

Thematic analysis is particularly appropriate for the PhD research for a number of reasons. These include its flexibility; its ability to highlight differences and similarities across the data; and its capacity to produce unexpected insights; and its ability to facilitate social interpretations of the data (Braun and Clarke, 2006).

The analysis process

In this section, I discuss the analysis process of this PhD research, which draws heavily upon the video-audio analysis techniques outlined by Heath et al (2010) and Jordan et al (1995). Each of the three case studies were analysed in similar ways, with some slight variations. In order to limit repetition in this thesis, this section will focus on the analysis process for study 2.

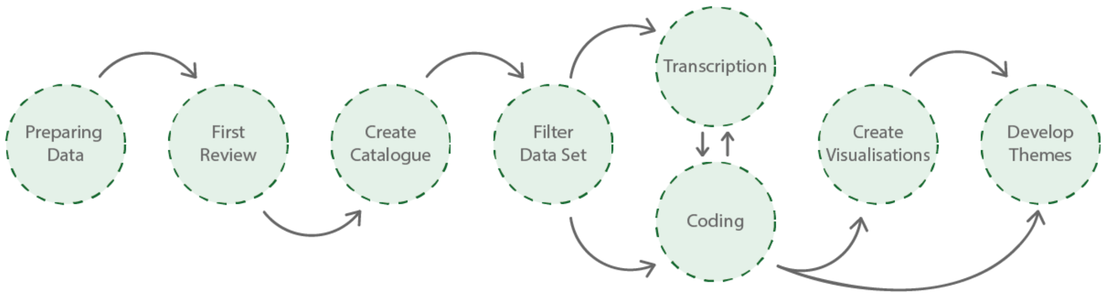


Figure 3-6: Overview of Video-audio data analysis

As indicated earlier, given the research impetus of understanding how museum installations influence and channel group interactions, the analysis was focused on determining patterns of interactions and how they relate to features of the exhibits. In adopting this analysis process, the PhD analysis differs from the approach favoured by Hindmarsh et al (2013), who state that *"Patterns in collections valuable for* *exploring certain phenomena* *...(..)... but the analysis of the* *single instance is key* (...) "*what is 'usual' is irrelevant to evidencing claims about particulars*". In contrast, the present approach does not prioritize a single instance, but instead looks for patterns, though does not discount singular or unusual episodes. Thus the present approach to video analysis bears close resemblance to the approach offered by Jordan and Henderson (1995).

Preparing the Data

Before it was analysed, the data was first organised to create a manageable data corpus from the raw video-audio files. Adobe's Premiere Pro software was used to synchronise the video-audio data, and align the multiple recordings captured in parallel of the same exhibit. The data was then arranged to show video feeds side by side, and text indicating the exhibit, the day, the time and a reference time code was included. The data was exported as an mp4 from Adobe Premiere Pro, making it suitable for media players and analysis software. Figure 3-7 and Figure 3-8 below illustrate the resulting data ready for analysis, showing multiple camera angles of the same action.

Figure 3-7: Glen Douglas Data

Figure 3-8: Fire Fighter Data

Reviewing the data and gaining an overview

Initially, randomly selected snippets of video and audio were reviewed while documenting observed behaviours. This provided an impression of potential patterns in the data, and an opportunity to note questions to consider, comments, early reflections and insights. These were collated into a word document called 'Analysis notes'. The intention at this stage of the research is to gain a broad high level understanding of what is happening and develop points of interest which will then guide the direction of the analysis (Heath et al., 2010). Thus, documenting these first impressions is an important part of the analysis process. Once a researcher has viewed the data, it can no longer be seen for the first time without any prior impression or bias.

In the early stages of this PhD, this phase was conducted in an apprenticeship mode; several joint sessions with an experienced researcher (the supervisor of this thesis) were undertaken. Carrying out this stage with an experienced researcher acting as a mentor helped to guide the PhD researcher through the analysis process in the early stage of this PhD. The sessions involved discussing the process and collaboratively reviewing the content. Given the complexity of video-audio research the sessions were crucial resources for learning how to approach and conduct the analysis of complex video-audio data and developing the researchers video-audio analysis skills. In later stages of the PhD, initial reviews of the data were conducted independently. However, when opportunities arose for joint data analysis sessions, such as courses, workshops or sessions with supervisors, these were utilized.

Creating a Catalogue

Once data has been organised and initial observations have been noted, the researcher should then catalogue the data corpus. This serves two key purposes: firstly, it provides the researcher with an overview of the data, noting specific criteria rather than detailed behaviours or situations; secondly, it aids the analysis process, as it can be used to help locate specific situations during which the exhibits are being used or to identify various group constellations, such as a single adult with one child. For all studies, a catalogue was generated in an Excel sheet. This sheet noted relevant criteria for identify groups, the start and end times of scenes, and any key points of interest at this stage. Figure 3-9 below shows an example of the catalogue created for data from the Glen Douglas Exhibit presented in Chapter 4, noting the following criteria:

- ID reference name for the group
- Start time at the exhibit. The start time was determined by the first person from a group looking directly at the exhibit, before any physical interaction.
- End time at the exhibit. The end time was determined by the last person from the group leaving the exhibit.
- Brief description of their interaction process
- A description of the group, such as the number of people in the group and group types (single visitor, couple, family)
- Indications that the visitor(s) may have used the exhibit before or during a previous visit (if applicable)

	D	E	F	G	H	I	J	K	O	P	Q	R
1	Interaction Group Name	Scene Start Time (not start time of attention to GD)	Scene End Time	Description	Group Description	No of People in Group	Group Type	Revisit (suspsected revisit to the exhibit from a previous day)	Interact	Semi-Interact (either passing by, using screens as touch screens,	Observe (what are people observing, the artefact, other	Passby
16	GV4	00:17:57:03	00:20:03:24	gona out. Then goes straight to instrucitons.Nobdy else at it. one boy goes up first and then the older2:12.4 "what can you do here? with blonder hair same guy says "ah, you can light it" up referring to the tubes . the younger boys that come from the other end see the warning at station 2 and say "water, you need to add water to the older boys at station one. as they move to them they repeat boht of then "water, water" . seemed like the boy at the end would have stayed on longer. The rest left the area. 3:00.0 the eldest boy with bright blond hair leaves, he seems to loose interest even before it's fully working.	German group 4 boys. Boy 1(15, blond hair, black jacket, grey scarf, black backpack) Boy 2 (17, very blond hair, camera, dark shirt) Boy 3 (11, blond, black jacket & backpack) Boy 4(10, glasses, bouler hair cut, black jacket, grey square pattern back pack)	4	Friends	revist from 11-05[2:38 - 5:00.5]	yes			
17	GV4	01:18:35:08	01:18:35:08	revisting group. very staggered group, interacting at different times. one boy is left by himself to use it. 3 new boys from the same german group	Boy 1 (16, green open jacket with backpack) Boy 2(16, black closed jacket with back pack) part of a group of 4 german boys	2	Teenagers	Revist from 10-05 [1:52.4 - 4:00.6]	yes			
18	GV42	02:25:33:08	02:31:48:13	Quiet verbal with each other. Boy saying when to add coal as well as the rest of them even though the very loud audio video is playing behind them. at the start the boy is verbally trying to link up the physical controls to what they do. Look at their reactions when the video audio thing of the ship yard starts to play. Do I think they are associating it with the Glen Douglas.	Rory: Boy (7 red hair, red hoodie) Lesley: Girl 1(15, long brown hair) Yvonne: Girl2 (14, short brown hair) Mum: Woman 1(45 pony tail) Dad: (45 black jacket, green shoulder bag)	5	Family		yes			
23	GV80	00:42:37:09	00:45:20:16	come back and go again	Dad (30, beard, wine top, jeans) Sean: son (8, gray hood, navy jacket)	2	Family	yes	yes		yes	

Figure 3-9 Catalogue from Glen Douglas Data

In addition to the excel sheet, a folder was created containing images of each group which had been generated as a visual reference, as it is often easier to recognise participants from an image rather than the ID number. The visual references were created by saving images from the video data. If possible one image which included all members of the group was used. Otherwise, several images from the video data were combined together to include all members of a group.

Filtering the Data to create a data set

In line with recommended strategies for video-audio analysis [Heath et al], the data set was filtered before generating transcriptions. Filtering the data helped to focus the analysis and manage the analysis process, and identifying specific scenes within the data for further analysis. Data was selected based on a number of factors, including the quality of video-audio recordings, whether the group spoke English or physically interacted with the exhibit and the group's size. Data was also selected based on the relevance of the group for this PhD research focus; for example, a solitary visitor interacting with an exhibit would not reveal details about companions' social interactions, and how interaction with exhibits is shared. Narrowing the data set in this way makes it more manageable and builds up a rich and detailed picture of the interactions. For each study a large amount of data was collected on various days, over weeks and months which was then filtered and organised into data sets to analyse. For study 1 video-audio data was collected over the course of 11 days, for study 2 video-audio data was collected over 4 days and during study 3 video-audio data was collected over 12 days. Filtering the data set was a flexible process and depended upon the constraints of each study. For example, study 1 involved only invited groups, which thus dictated the data set. For study 2, it was necessary to adapt the procedure for selecting data for further analysis of the Fire Fighter installation. This was due to the high volume of traffic at the exhibit, which was rarely used by a solitary visitor or without a child in the group. Therefore, rather than filtering the data set based on the criteria outlined in the previous paragraphs, a randomly selected one-hour section of video-audio recording was chosen for further analysis. Given the heavy usage of the exhibit, this section was deemed to provide sufficient coverage of a range of interactions and groups.

Such collections are also useful for studying patterns in the collections and aid in exploring certain phenomena (Heath, Hindmarsh and Luff, 2010). The style of transcription and use of thematic analysis coding is the primary difference between the analytical approach employed in this PhD research and the approach proposed by Heath et al (2010). In contrast to the analysis conducted in this thesis, Heath et al (2010) prioritise detailed evidence of single particular situations, over understanding usual interactions and behaviours occur in the situation of interest. Or as Hindmarsh notes, "*analysis of the single instance is key" and "what is 'usual' is irrelevant"* (Hindmarsh, 2013).

Data Sets		
Study 1: Painting Patterns for Nature	5 Groups	27 people
Study 2: The Glen Douglas	9 Groups	43 people
Study 2: Fire Fighter	28 Groups	79 people
Study 3: Razzle Dazzle	16 Groups	59 people

Table 3-2: Data Overview for 3 Case Studies

Transcriptions and Coding

Transcription is an important stage in the analysis process. As Heath et al state, *"Transcription is not simply a way of representing aspects of the activity, but provides an important resource in developing observations and getting to grips with the characteristics and organisation of the actions in which the participants engage"* (Heath et al., 2010, p.67). There are various systems for creating transcriptions that help to produce rich detailed accounts of peoples conduct and talk (Bezemer and Mavers, 2011), (Flewitt et al., 2014). According to Flewitt et al (2014), the variety of multimodal transcription methods for video-audio data ranges from rich, detailed accounts, to more abstracted analysis using coding and visualisations (Flewitt et al., 2014). In more detailed transcription, audio data is often transcribed verbatim, detailing the spoken words and utterances. Depending on the scope of the study, different levels of transcriptions may be used during the analysis. For example, Heath et al's (2010) approach to transcription is extremely detailed. Their system transcribes talk and visible conduct with a wide range of different symbols, including dashes, commas, dots, text styles and types of brackets. In this system, arrows are used to transcribe pauses, silences, sounds or words with are stretched out, and people's actions. The system also delineates the actions and speech of different people through the spatial distribution of text, and as a result the transcription has multiple layers (Heath et al., 2010). In line with the work of Hornecker (2016), this PhD research adopts a simpler, narrative approach to the transcribing. Verbal utterances are transcribed and textual descriptions, rather than symbols, denote actions, gazes or what people are doing around the exhibits. As the activity of generating transcriptions of data can support researchers in analysing the data, the transcriptions for this PhD research were generated by the PhD researcher rather than employing a transcription service.

The software InqScribe (shown in Figure 3-10) was used to transcribe the video-audio recordings of all three case studies. Before InqScribe was selected, alternative software, CatDV and Transana, was also trialled. However, these programs were deemed to be cumbersome and difficult to use, which distracted from data analysis. Crucially, the software also had a negative impact of the performance speed of a powerful computer. In contrast, InqScribe had a number of advantages. For example, the software can be used with a transcription foot pedal, and clicking on time codes, which are highlighted in blue, plays the video-audio data linked to that part of the transcript, as shown in Figure 3-10. These factors reduced time spent on file management and software, and helped maintain a focus on the data itself. The software therefore had a positive impact on timescales and helped me to mentally engage with the research during the analysis stage.

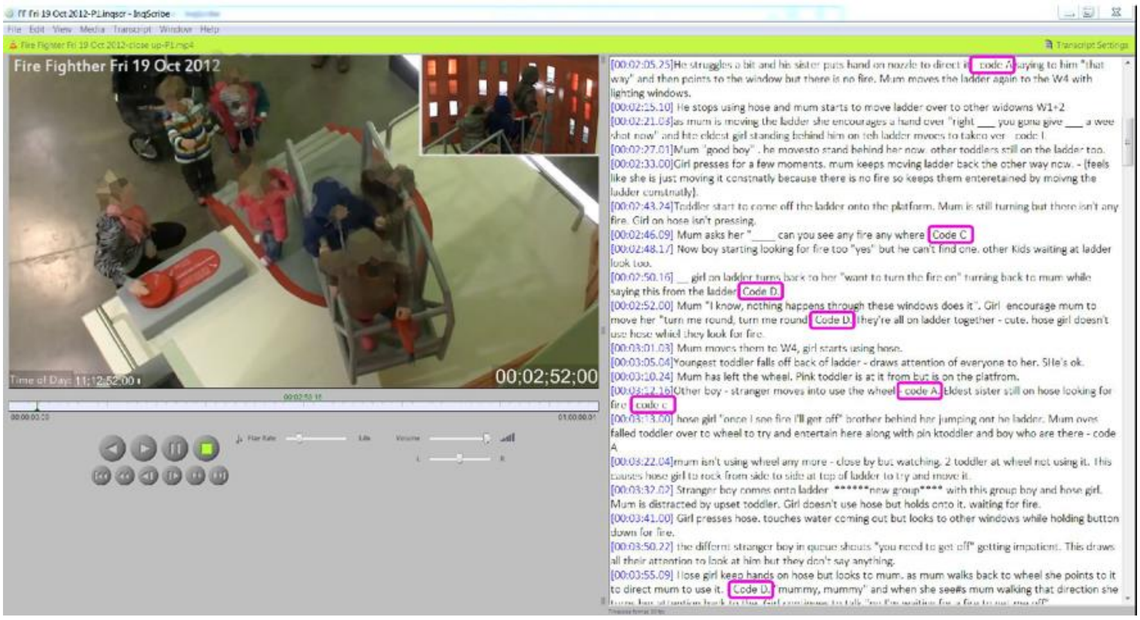


Figure 3-10: InqScribe Transcription

During the thematic analysis process, the coding stage helps define themes in the data. Coding can help researchers discover connections between data, and illuminate alternative ways of framing or interpreting a situation (Bazeley, 2013, p.126). Thematic analysis allows for an exploratory approach of data, which enables open, emergent coding, as well as coding that is guided by theory or existing coding schemes. Adopting coding schemes from previous research may increase the rigor of the research, and mean that the research can be more readily compared to other existing research. However, if predefined codes are applied to data, some of the unique intricacies of the data may be lost. This is because pre-defined codes may limit the scope to develop themes from the data. Furthermore, developing new codes based on the data can help to identify new perspectives and-findings, which are grounded in the data.

The nature of this PhD research is oriented around discovery, rather than confirming a theory. Therefore, the research adopts an exploratory approach to coding, developing codes derived from the data, rather than using predetermined codes (Guest et al., 2012, p.5). This approach was selected as predetermined codes may make it more difficult to analyse sequences of interactions and adequately categorise such complex data. As such, codes were developed from the data sets for each case study in line with Braun and Clarke's reflexive TA approach (Braun and Clarke, 2006). However, developing codes for such rich and intricate data can be challenging. Codes may be too similar, or there may be an unmanageably large number of codes. Both of these challenges were encountered in early attempts to analyse the data. As a result, the research then coded only behaviours and situations which were prominent, and had high relevance to the research questions. In addition, cross checking the codes with experienced researchers (the PhD supervisors) regularly helped to validate the codes. This involved discussing the codes, clarifying the meaning of these codes, reviewing examples of the codes and filtering out codes that were too similar or merging them together.

The development of codes occurred in parallel with transcription; reflections, comments and possible codes were noted during the transcription process. This simultaneous process is shown in Figure 3-6, which places transcription and coding beside each other. The development of the coding scheme was an iterative process. Codes were added, edited and modified to reflect the nuances of interactions which emerged. Coding during and after transcription was a useful approach, as transcription can be a highly immersive experience. Thus, coding during transcription enabled me to record important potential codes while I was heavily immersed in the data, and as such at that time had an enhanced understanding of the situation and context. Aspects of interest which were noticed during the transcription process may otherwise have gone unnoticed or been forgotten. After transcriptions were completed, another round of coding the transcriptions was then conducted.

<u>Visualisations of visitors' interactions as a tool for analysis</u>

Analysing the interactions of several visitors simultaneously is a very demanding and complex process. To create overviews and support analysis of these interactions, several visualisation techniques were explored and experimented with, with varied success. The most successful approach to generating visualisations of visitors' behaviours was adopted during analysis of the the Fire Fighter installation in study 2. Generating such visualisations was work-intensive, and as such it was decided that the approach would not be employed retrospectively for earlier studies. The approach was also found to be less useful when analysing interaction around more complex installations, such as the Glen Douglas installation in study 2.

During the analysis of the Glen Douglas exhibit, a trial visualisation was generated for one group using nVivo qualitative analysis software. The visualisation illustrated how group members used the different parts of the exhibit, as shown below in Figure 3-11, allowing me to see the data from a different perspective. However, the process was too time intensive and provided limited data insights, compared with the required time investment and data insights gained from transcription and coding. In addition, the format and display settings of nVivo for visualisation were limiting, hindering the overall analysis process.

Figure 3-11: nVivo visualisation of interactions at the Glen Douglas Exhibit

In contrast, the type of visualisation generated for analysis of the Fire Fighter exhibit (see Figure 3-12) was more rewarding, for two reasons. During the analysis process, I explored alternative software for visualisation, which enabled me to arrange the data in meaningful ways that helped to interpret the data. To create the visualisation, a specific interaction was logged in inqScribe software, and then exported as a .txt file, which then was imported into Excel and exported as a .csv file from excel. Finally, software called 'Processing' was utilized to interrogate the .csv file and generate a visualisation, shown below in Figure 3-12. The nature of the installation also contributed to the success of the visualisation. Fire Fighter had less controllers than Glen Douglas, meaning that hand-overs of controllers occurred much less frequently, and visitors moved much less frequently between different areas at the exhibit. As a result, Fire Fighter had a much more compact representation than Glen Douglas, and consequently generating and interpreting the visualisations was easier and more manageable.

The visualisation of the Fire Fighter installation provided both an overview of interactions with the controllers, and the temporal relationships between the use of controllers. For example, the visualisation demonstrated whether both controllers were used in sync, and people's behaviours when using controllers, such as when the person using the wheel would look directly at the person controlling the ladder. Further analysis was guided by the insights gained from the visualisations, narrowing the focus towards particular behaviours and relationship between the controllers. It also clearly highlighted situations such as cross group usage, or parents physically interacting. The visualisation was used a tool to interrogate the data, and to understand the relationship between different elements. It provided an overview of the data and highlighted patterns occurring between people and co-visitors, and between people and the exhibit. It also allowed me to interrogate the frequency of situations and patterns, such as sharing use of controllers, or swapping positions. The visualisation shows the level of sharing which took place at the wheel, including handing over control to others. The visualisation also shows interactions with the exhibit itself, movement between controllers, and some visual cues between visitors. Creating this visualisation helped to make sense of the data, and clarify patterns and relationships between the exhibit and the behaviours people carried out.

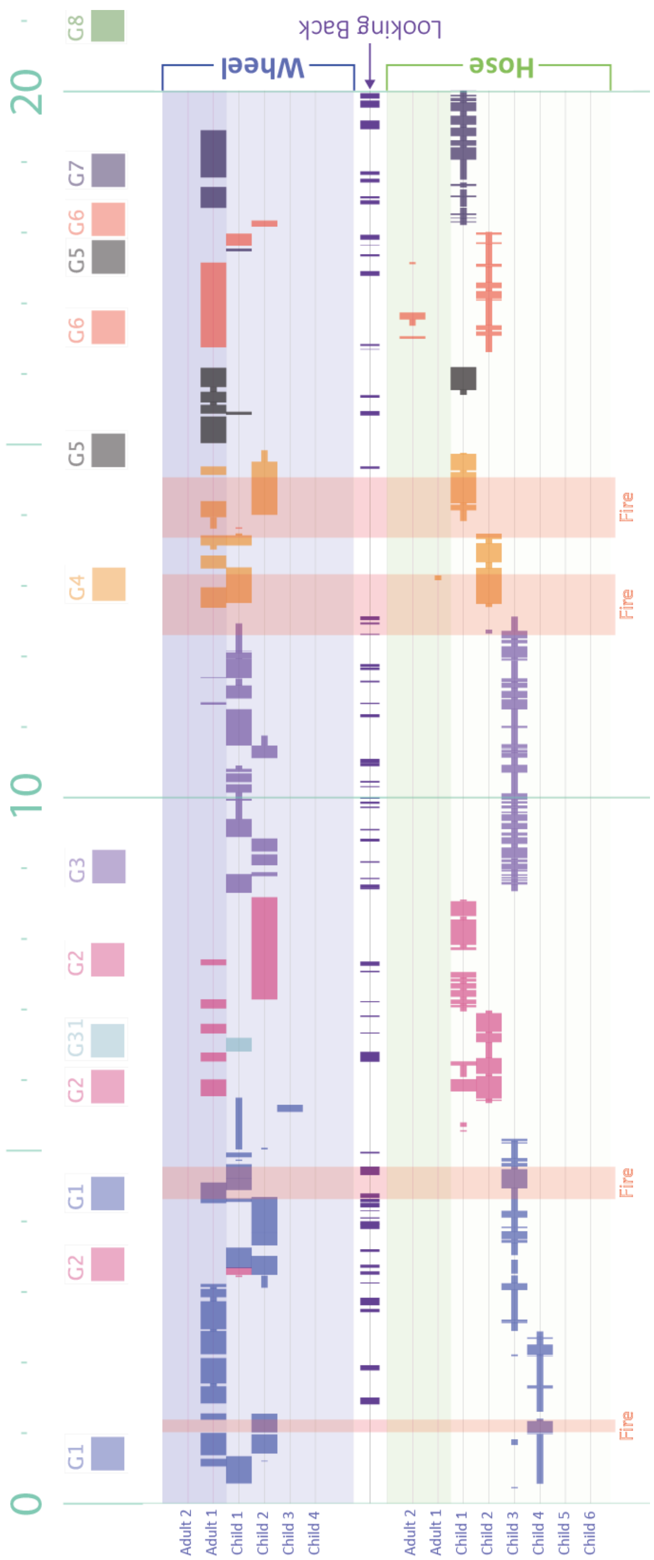


Figure 3-12: Visualisation of Fire Fighter Data

Figure 3-12 shows the visualisation generated from the interaction of seven groups with the Fire Fighter exhibit, which is discussed in more detail in chapter 4 of this thesis. On its horizontal axis, the visualisation illustrates interaction over a 20 minutes period. Labels for different groups are shown at top of the visualisation, and are colour coded. The uppermost purple row represents one of the two controllers at the exhibit, the wheel. The lower green row represents the other controller at the exhibit, the hose. A thick coloured block represents when these controllers were used, showing the duration of the interaction. A much thinner, coloured block represents moments when a person had their hand or hands on a controller but was not actively using it. At the left of the visualisation, labels titled adult 1, adult 2, child 1, child 2, child 3, child 4, child 5 and child 6 illustrated whether an adult or child who interacted with the wheel or hose.[4] Child 5 and child 6 are not listed in the purple row, as there was no 5th or 6th child in any of the groups using that controller. Finally, the central horizontal line, labelled ‘Looking back’, indicates moments when a visitor at the hose controller looked back towards the wheel controller. Moments when a fire appeared in a window of the house that the firefighters were tasked with protecting are indicated by a vertical red column.

To explain how the visualisation can be interpreted I’ll describe one groups interaction at the exhibit (Figure 3-13) explaining what the visualisation tells us about the group’s activities and interaction.

[4] No more than two adults were ever present at the exhibit.

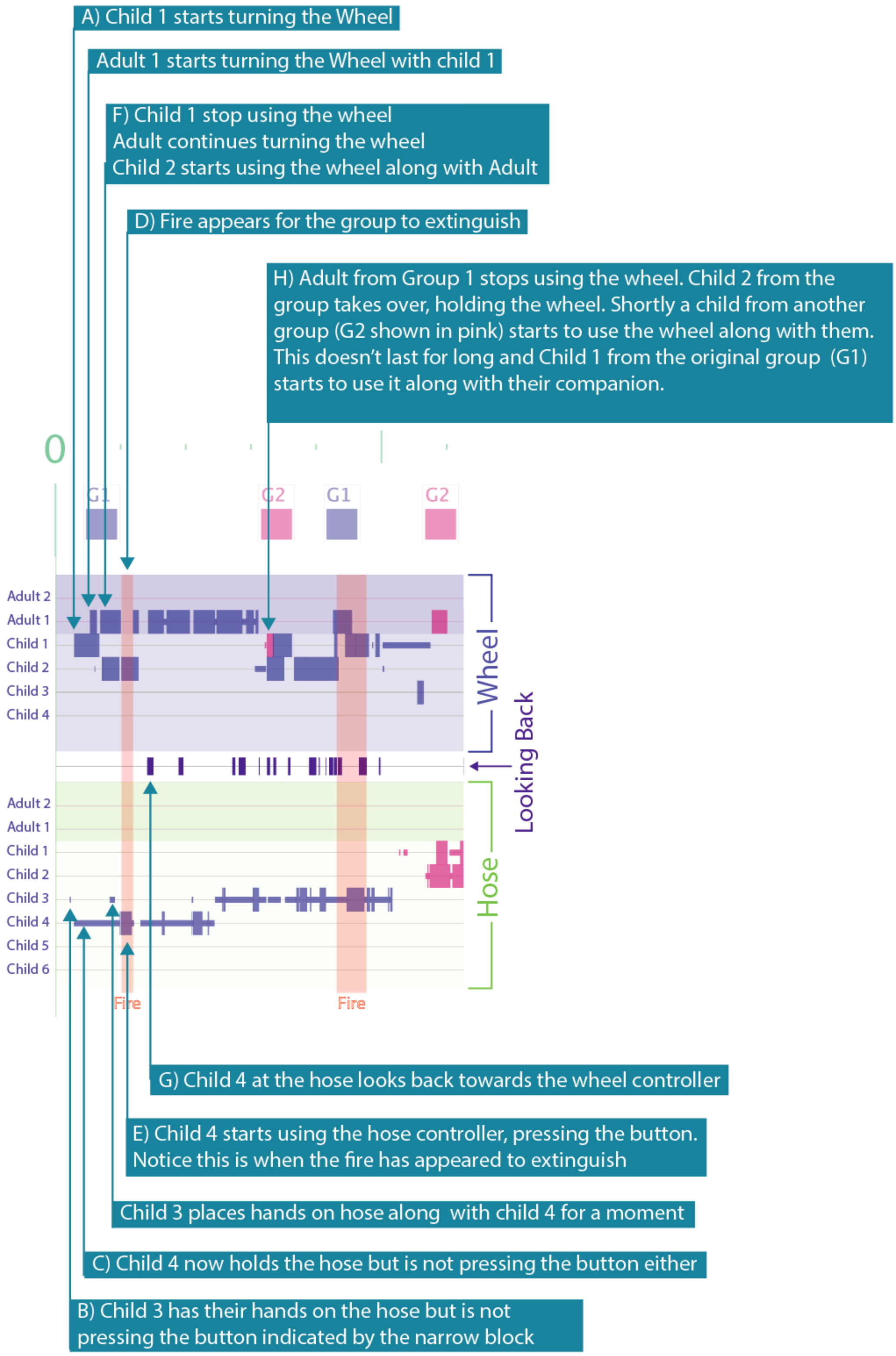


Figure 3-13: Visualisation of Fire Fighter Data

G1 represents group 1, shown in purple. From the visualisation we can see that child 1 (A) is the first person to use the wheel while child 3 (B) is the first person to hold the hose for a moment but then child 4 (C) starts to hold the hose (shown in the lower half of the visualisation). Child 1 (A) starts off by turning the wheel. The visualisation shows this by a thick purple block. Child 4 (C) is only touching or holding the hose for some time. The visualisation shows this with a thinner block along the horizontal line for child 4's activities with the hose (C). Fire is shown by the vertical red transparent column labelled fire at the base of it. When the fire appears at approximately 1 minute in (D), the visualisation shows that child 4 (E) starts to use the hose, pressing the button on the hose (indicated by the thicker block). Child 1 (F) stops using the wheel. Child 2 (F) starts to use the wheel along with Adult 1 (F) indicated by the change in blocks beside the labels 'child 2' and 'adult 1'. After the fire is extinguished Child 4 (G) at the hose looks back to the wheel controller (shown by the a purple block along the line labelled 'Looking back'). Later on, a child from the different group tries to use the wheel along with Child 2 from G1 (H), represented by the pink thick block shown beside Child 1 in the wheel section.

This visualisation will be described in more detail in chapter 5, which highlights the findings of this case study. However, at present, it is important to emphasise the importance the visualisation to the analysis of Fire Fighter. The visualisation indicates how single groups interacted with the exhibit, often one after another and sometimes with overlapping interaction. For example, a child from Group G2 briefly partakes in interaction at the wheel while Group G1 is still active. The visualisation also reveals how companions shared interaction with controllers at the exhibit. For example, companions in G1 often used the wheel controller back and forth between each other. In contrast, typically when visitors handed over the hose controller to companions, they did not share the use of the controller back and forth with companions. The visualisation aids in understanding how interaction and events between companions unfolded. The visualisation also clearly shows that adults were rarely active at the hose, with a brief exception of an adult in G4, but very often controlled the wheel. Control of the wheel usually precedes use of the hose, as the ladder has to be moved to the window where there is fire, and a new fire usually triggers the activity. While the analysis of Fire Fighter relied heavily on video-audio data in the same way as the analysis of the other studies, it was distinct in its use of data visualisation as an analysis tool, highlighting visitors' interactions with different controllers at the exhibit.

Choosing fragments to represent in the findings

Choosing the appropriate fragments to present in the thesis is a challenging task. Aligning with ethnographic studies fragments which particularly well reflect the wider observations being discussed were chosen to include in the thesis. Furthermore, representative fragments for all three studies presented in this thesis were selected based on clarity for the reader and fragments that were not overly long. For example, the fragments presented in study 1 consistently describe the interactions of the same group in order to tell a coherent story. In contrast, for study 2 and 3, to show a range of the findings fragments from various groups were considered to represent the data set.

3.5 Chapter Summary and Conclusions

In this chapter, I have described the methodological approach of my research, detailing how the studies were carried out. This approach included adopting a research-through-design process, in which installations were created to support the research studies (Stappers and Giaccardi, 2017); and conducting 'in the wild' studies, in which the behaviours and interactions of museum visitors in real world museums were studied (Rogers, 2011), with the exception of study 1, in which participants were invited to take part in the study. The chapter also highlighted the use of video-based research drawing on the approaches detailed in literature, particularly the work of Heath et al (2010). The chapter explained two parts to this approach. Firstly, how I approached capturing video-audio data in a museum context, and secondly how the data was analysed using thematic and interaction analysis.

The methods adopted for this research have been chosen for a number of reasons. The most important factors in deciding upon methods, was their appropriateness to answer the research questions effectively and their suitability to the context of the research. A 'Research through Design' approach was adopted in order to create research artefacts which had tangible controllers. Thus, enabling the research to be conducted with exhibits, relevant to the research agenda. In addition, placing oneself in the design process contributed to understanding the context of the research in relation to future designs possibilities. Developing design considerations and understanding how the research relates to the design of such exhibits, was influenced by my involvement in the design process. Another approach to this PhD research adopted was 'research in the wild' during which people's interactions are studied in real world settings and prioritising peoples natural behaviours. In addition, peoples experiences and interactions can be drastically different in various environments and contexts. Thus, as this PhD research is interested peoples social experience and their natural interactions in a complex environment, a 'research in the wild' approach was adopted. In line with previous research with similar interests, video-audio based research was selected as the central approach in conducting this PhD research (vom Lehn and Heath, 2016). Video-audio based research has proved highly valuable when focusing on individual and group conduct and interaction with others and with objects. A priority was to avoid interrupting people's natural behaviours and interactions. Capturing video-audio based content can be less intrusive. In addition, studying the interaction of more than one person at complex interactive exhibits can be too demanding to capture reliable data and data which is rich enough to answer the research questions. Video-audio data allows this to be feasible and reliable. Where it was felt suitable at individual exhibits, video-audio data was supported by observations, interviews and in study 3, a questionnaire. Observations in particular helped to develop a deep understanding of the ongoing interactions, events that happen outside of camera range, changes in the museum context, noises which are out of range or comments people make away from the exhibit. Observations remove the camera filter and places the researcher there with people, helping to understand the context of their actions. The analysis of data for this PhD utilised 'Thematic Analysis' as it allows the researcher to interpret the data, make sense of it and explain what the data represents while still remaining true to the data in that the themes are grounded in the data. Thematic Analysis allows and requires researchers interpretation of the data and focuses on themes rather than counting explicit items of interest which is appropriate for the aims and interests of this PhD. In addition, thematic analysis of the PhD data was complemented by and combined with 'interaction analysis'. Aligning with the PhD interests, 'Interaction analysis' establishes patterns rather than focusing on single instances when analysing video-audio datasets. A variation from this analysis process was the addition of visualisations as an analysis tool for study of the Fire Fighter installation in study 2. The visualisations were created and used to support analysis as they can give an overview of patterns and what's happening. However, this was only possible for one of the exhibits in Study 2 as it wasn't feasible given the complexity of activity at the other exhibits, which was discussed in greater detail in this chapter.

It was also noted that conducting research of this nature requires a level of flexibility to the approach, acknowledging that circumstances change including what the sites permit or that aspects which are feasible for one study may be impractical for another. For example, data other than video-audio was used to support findings derived from video-audio analysis such as in study 3. A questionnaire incorporating semantic differentials revealed how people felt regarding their shared social interaction with companions, backing up the findings from the video-audio analysis. Another example where flexibility was required was during study 1 where capturing video-audio data was limited by the organisation to invited study participations, rather than visitors to the exhibition which would have been preferred.

The cross-disciplinary nature of this PhD research raised a number challenges such as;

- Ensuring an understanding not only of the visitor perspective of these exhibits but also the museums perspective.
- Drawing on the related literature from different fields raised an issue of scale and presented a challenge in identifying relevant literature from a vast body of prior research.
- Drawing on my personal skillset in the discipline of product design, gaining access to the resources and facilities necessary to design and create research artefacts was problematic.
- There were practical, ethical and logistically issues when collecting video-audio data in a public space in real life.
- The vast amount of data captured required a significant amount time and organisational activities to analyse the data sets.

Chapter 4

Study 1: Painting Patterns for Nature

4.1 Introduction

This chapter discusses the first of three case studies conducted during this PhD research. This case study, entitled Painting Patterns for Nature, involved the design and evaluation of a tangible interactive installation. The project served as a catalyst to explore the ways in which tangible interaction supports children's experiences in a museum context and visitors' engagement while interacting with the tangible controllers. The study, while not explicitly designed to do so, highlighted the interactions of bystanders. It also aided the formation of a refined research focus for this PhD, based around social aspects of visitors' interactions with tangible exhibits, and considerations of how control is distributed at tangible hybrid installations.

The chapter outlines the findings of an evaluation study of an interactive installation in a children's cultural centre. The installation (shown in Figure 4-1 and Figure 4-2) was a painting installation with a tangible electronic-digital paintbrush, wooden tokens, a tabletop screen and a 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 had a range of wooden cards with RFID tags embedded in them, which visitors could use to select an animal to colour in. Visitors could colour in their chosen picture on the tabletop screen using a physical-digital paintbrush and physical-digital paint pots.

Figure 4-1 Painting Patterns for Nature Installation

The findings are presented in this chapter are from an interaction analysis of 5 video-recorded volunteer groups and observations of the general public. The study involved 133 children and 91 adults. The analysis specifically focuses on how the exhibit related to visitors' behaviours and their social activities. The chapter discusses two themes; firstly, how interactions around the exhibit contributed towards awareness and communication between companions; and secondly, the mediation of control through physical objects. This includes visitors' activities outside of core interactive interaction with exhibit, including social interactions, planning future interaction with the installation, negotiation in groups and active anticipation of one's turn.

Research in the field of tangible interaction indicates that tangible objects which can be physically and digitally detached from their system support people's actions in the larger social setting (Esteves et al., 2013), (Fernaeus and Tholander, 2006), (Fernaeus et al., 2008)]. At present, only a small body of research has investigated non-active group members' interactions (Heath et al., 2005), (vom Lehn et al., 2007), group negotiations, planning and handling of conflicts (Hornecker, 2010), (Marshall et al., 2009). These elements are the focus of this research. In particular, the research considers how tangible objects have an effect on non-active group members' experiences by facilitating physical interaction with the exhibit outside of core interaction. I discuss how qualities of tangible exhibits support social interactions between companions in the context of museums and public spaces.

Interacting with tangible objects outside of core interaction has previously been defined as 'offline' tangible interaction cf. (Esteves et al., 2013), (Fernaeus and Tholander, 2006), (Fernaeus et al., 2008). Offline tangible interaction refers to interactions that occur with tangible controllers or 'tokens' that are not registered by the system cf. (Esteves et al., 2013), (Fernaeus and Tholander, 2006), (Fernaeus et al., 2008). In the case of the interactive exhibit designed and evaluated in this research, "offline" means physical interactions with tangible features of the exhibit that do not change the digital content.

In this chapter, I reflect upon design strategies outlined by previous related research concerning interactive systems aimed to support social interaction. Such design strategies focus on supporting social interaction by, for example, providing controllers that can be detached physically and digitally from the system, and enabling visitors to transition between viewing and performing interactions (Reeves et al., 2005). Previous research in this field has examined multi-user input systems and/or group orientated tasks. However, for this study, I considered the social interactions at and around a system designed for single user input with similar design features to prior research, such as detachable controllers, a large screen projection and situations during which visitors move between performing interaction to observing interaction.

The development process of the installation from this study has been previously published in the form of a workshop paper (Clarke and Hornecker, 2012) and key findings have been published as a conference paper (Clarke and Hornecker, 2015).

Study Focus

The study focused 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 concentrating on multi-user input systems. At present, there is limited research investigating non-active group members' interactions at systems that are intended for single user input (Heath et al., 2005), (vom Lehn et al., 2007). This is the primary focus of this study. In particular, I consider how tangible objects support non-active group members' experience by allowing physical interaction with the exhibit outside of core interaction. This includes visitors feeling, touching and moving controllers without triggering the manipulation of digital content.

4.2 The Installation

The installation was 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. I was awarded funding to design and fabricate the installation as part of the Science Gallery's summer exhibition 'Hack The City' which took place in celebration of Dublin City of Science 2012, and was sponsored by 'The Public Engagement Programme (PEP) for Dublin City of Science 2012. Developing the installation for the exhibition presented an opportunity to investigate visitors' experience at an interactive exhibit supporting tangible interaction with physical controllers in a real museum environment. 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 installation's target audience was children approximately aged 3-6 years, but all visitors could use it. An integral part of the design was to engage children in tactile interaction with the installation. An iterative design process was adopted in the development of the exhibit, by using paper prototypes and Wizard of Oz prototypes to test out designs. These prototypes guided the design before its final implementation.

The installation, *Painting Patterns for Nature* (PPFN), was on the topic of biodiversity and encouraged visitors to generate digital content. At the installation, children could colour in various animals, which then become part of a larger collage, depicted as a butterfly. The activity collectively involved visitors in the co-creation of a new species of butterfly which is made up of their smaller, individual paintings. The installation aimed to promote awareness of how individuals' actions affect other living organisms, and how different species affect the larger ecosystem.

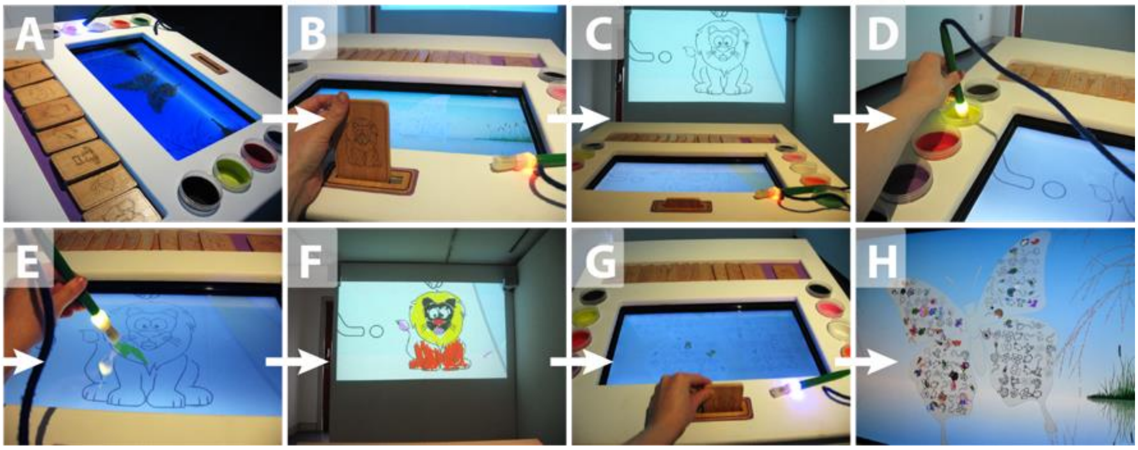


Figure 4-2 Interaction Flow

Figure 4-2 depicts how one might interaction with the installation. Children approach a table placed in front of a large screen, as shown in Figure 4-1. At the table, they choose an animal or organism to paint from a selection of wooden cards engraved with outline images (part A of Figure 4-2). On inserting this into a slot at the front of the table, an outline image appears on the table and on the projected screen (parts 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 then added to previous visitors' paintings to make up the wing pattern of a butterfly on the projected and screen image (part H).

The installation consists of a screen projection and an interactive touch screen embedded in a tilted wooden desk, which are synchronized to show the same visuals; 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 (see Figure 4-1 and Figure 4-2).

The wooden cards have laser-inscribed drawings representing animals and organisms. The slot and cards have a similar aesthetic appearance, and were fabricated using the same materials, colours and laser etching, indicating their connection. An RFID reader inside the table recognizes an inserted card via the tag embedded in each card. Visitors can use a brush, which has a real brush tip, to paint 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 stroke colour is altered. The paintbrush itself lights up in the chosen colour by means of an LED inside the brush simulating paint on a real paintbrush and provides direct visual feedback.

4.3 Study Overview & Methodology

During the exhibition, an in-situ evaluation of the installation 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. These took place during public opening times. 115 children painted while 11 adults took part in painting, even if only briefly. In addition, 5 volunteer groups made up of 18 children and 9 adults in total (see table 1) participated in 6 video-recorded sessions. Due to the centre's child protection policies, volunteer groups were invited to take part in the study and give their explicit informed consent, signing consent forms. During video recordings, the exhibit was closed off to the public, to ensure that the cultural centre's child protection policies were adhered to. 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.

Group	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)	Siblings: Stuart (13) Miles (11) Niall (7)
3	Mum (27) Mums Friend (26) female	Son: Tod (6) Tods friend: Ali (7) female
4	Mum 1 (35) Mum 2 (36)	3 girls & 4 boys: Siblings: Felix (11) Zara (4) Siblings: Lilly (8) Ted (8) Mary (11) Anthony (11)
5	Mum (32) Dad (34)	Siblings: Robert (8) Colin (10)

Table 4-1 Overview of video-recorded groups at PP4N

The data was analysed as described in Chapter 3 Methodology adopting interaction analysis and thematic analysis. Video and observational data was iteratively reviewed to develop themes. The process involved open coding, transcription, developing concepts from the data, and clustering prominent behaviours into themes grounded in the data. The analysis focused on the relationship between companions' activities and the exhibit's spatial and physical attributes. The analysis also investigated group social interactions and how these related to the features of the exhibit by identifying and recording the following situations: moments of social interaction, communication, wooden card interactions, paintbrush handovers, negotiations, holding onto cards, planning, and who was in the space. Through open-ended video interaction analysis, specific patterns of interaction were repeatedly observed, and as a result, themes grounded in the data were identified.

The following themes developed from the analysis:

1) Awareness and communication within groups discussing two aspects:

- Explicitly drawing attention to a train of thought
- Awareness of the painters' actions

2) Mediation of control and planning discussing two aspects:

- Negotiation of control through the use of objects
- Activities with offline controllers

'Offline tangibles' played a core role in supporting these themes, and as such, I will now discuss the findings in relation to offline tangible controllers.

4.4 Findings: Offline Tangibles

The findings describe the social interactions which took place within 5 video recorded groups including discussions; negotiations; and activities with the tangible controllers of the exhibit, such as the wooden cards, the paintbrush and the paint pots. These findings have been categorised into the themes for analysis, listed above in section 3.4. The discussion section of this chapter includes a reflection on these findings, discussing their relevance to the PhD research questions. In the present section, I present and discuss vignettes featuring one extended family group which illustrate findings based on analysis of the video data from all 5 groups. The vignettes represent interaction patterns observed across all groups. Focusing on vignettes of one group provides a sense of the extended conversation within that group, and simplifies descriptions of group members. Fictitious names are used throughout the section.

Within an individual group I identify three positions at the exhibit that people in groups move between: the painter, the bystander and the observer (Figure 4-3). The *painter* has the paintbrush, and is located at the table. *Bystanders* are close to the painter, and may be overlooking the activity, working closely with the painter, or playing with parts of the exhibit such as the cards or paint pots. *Observers* are situated further away, usually sitting on a bench roughly a metre away, from which point they can see the projected image and painters' actions, but are in 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 moved between all positions.

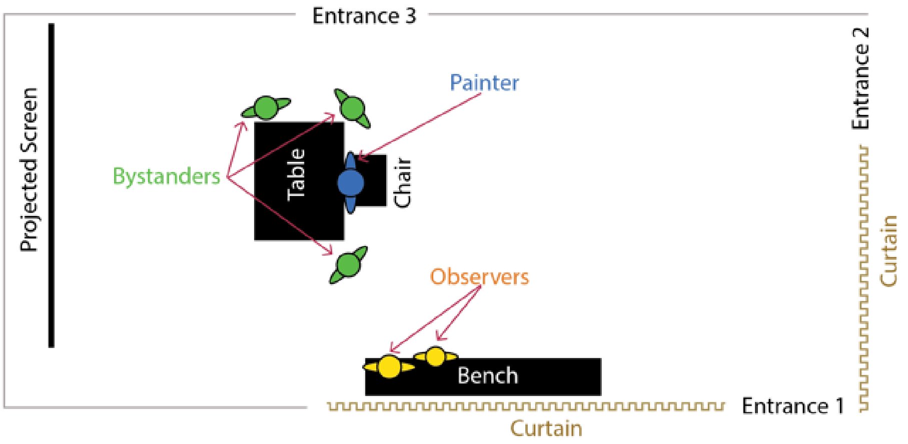


Figure 4-3 Overhead view of the exhibit layout and the positions visitors may be in.

4.4.1 Awareness & Communication within Groups

In this section, I focus on social encounters between companions and awareness within groups. There were 3 dominant situations in which people demonstrated awareness of the actions, thoughts and intentions of others. Firstly, I noted situations of awareness during which people explicitly drew the attention of others to aspects they were focusing on. Secondly, I noted situations in which people showed awareness of the actions of the current painter, which sparked discussions. The third situation I observed one in which visitors showed an understanding of bystanders' intentions.

Explicitly drawing attention to a train of thought

Visitors explicitly drew companions' attention to pieces of the exhibit verbally, or by physically pointing to them. This happened in all groups, but occurred most frequently in the groups that had more than 2 children, and in the groups in which other members stayed at the exhibit while others painted. The following vignette describes a situation from group 1, and illustrates how a resource is used to draw attention to a train of thought and to start a conversation.

Vignette 1: Visibility & access to common resources
Henry (5), Millie (8), Sarah (8), Ann (5) and Mum (35)

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 B) *"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.

In Vignette 1, Henry notices that a newly created painting on the overall butterfly is right next to the one he had just made. Henry physically points to the projected screen (Vignette 1, Figure B), and verbally emphasizes what he is interested in at that moment, drawing the attention of others to the screen too. The sequence of events opens up social interaction. First, Henry relates the content to his own actions 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 in which others can understand and acknowledge what he is thinking and can respond to him. Without the visibility of the main screen, it is questionable whether Henry would have been able to draw the attention of others to this or even to see it himself. The conversation was thus focused on a resource which was visually accessible for the whole group.

Visitors also drew their companions' awareness to their thoughts in other situations. For example, visitors made resources visible to companions by physically re-orientating and manipulating the wooden cards to show a companion. Figure 4-4 shows Millie re-orientating a card to show somebody else, thereby creating wider awareness of what Millie is focusing on. Vignette 2 describes another one of these situations.

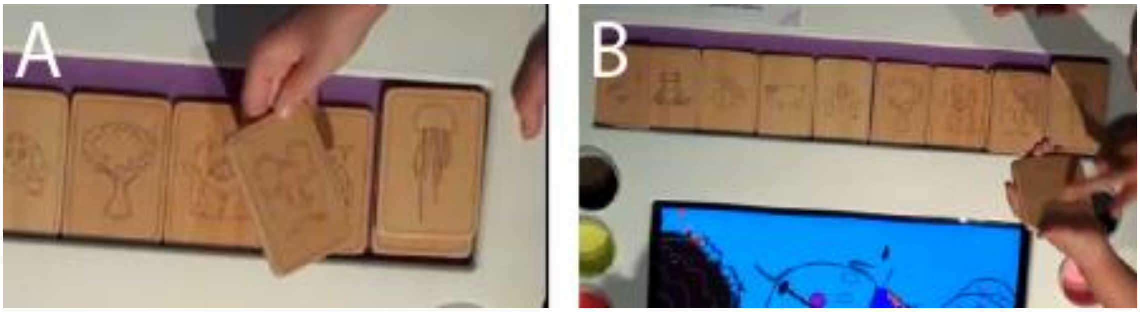


Figure 4-4 Showing a card & suggesting what to paint next

Vignette 2: Moving and re-orientating controllers
Henry (5), Millie (8), Sarah (8), Ann (5) and Mum (35)

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: *"I 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 one of the controllers, sharing information with others, making the resource visibly accessible to a companion, and including them in his activity. At the installation, it was possible to move the point of focus, in this case the card, around the space to enable companions to view and access the same information without the viewer who is not holding the card having to move to gain a better view. In contrast, if images were selected on a touch screen which was fixed to the table, or the cards were fixed to the table, observers would likely have struggled to see the object of reference without relocating themselves in pursuit of a better view of the screen. The detachable portable nature of the controller therefore permitted the action.

Awareness of the painters' actions

I found companions were aware of the painter's actions, and commented or discussed the colours selected by the painter with each other. Across all groups, awareness and visibility of the painter's actions prompted discussions. The painter's actions was the most frequent topic of conversation, even if when group members briefly commented on their actions. The next most frequent topic of conversation was what children planned to paint or could try out. When a painter chose a colour, moved the brush towards a pot, and swirled or dipped the brush into a pot, onlookers often commented or made suggestions for colour choices. Such gestures and use of the brush and paint pot were easy for companions to observe. Vignette 3 describes a situation in which this situation occurred.

Vignette 3: Awareness of painters' actions
Henry (5), Millie (8), Sarah (8), Ann (5) and Mum (35)

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 share the activity of choosing a colour together, going through the possible options while physically referring to the paint pots as a reference to support their conversation.

4.4.2 Mediation of Control and Planning

This section describes the activities visitors carried out with the tangible elements of the exhibit, such as the paint pots, wooden cards and paintbrush. I discuss these activities in two sections. Firstly, I examine how the tangible elements of the exhibit mediated control and were used to mediate control. I then discuss what bystanders in the group were doing with the wooden cards, or offline controllers, in planning, preparing and anticipating their turn to paint.

Negotiation of Control

There were two key situations relating to control which took place at the installation. Firstly, the painter maintaining control during painting, and secondly, the painter handing over control to the next painter.

In all of the groups, I 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, and stop the painter from painting. The card slot was located between the painter and the table screen. Its location helped the painter to maintain control. Painters' bodies were often positioned over the card slot, or their arm would rested across it. This positioning created a barrier between the card slots and others, even if this barrier was unintentional. Only rarely did bystanders take the card from the slot during painting (Figure 4-2G). The video-data revealed that in only 4.84% of painting interactions, the painter had to prevent a sibling or friend from removing a card from the slot. While this action was not common, in some cases painters placed their hands over the slot when others approached the table to prevent it.

Bystanders were observed playing with the paint pots, systematically putting their fingers into each paint pot, or trying to select colours with their fingers. As the only way to select a colour was to put the paintbrush in a paint pot, bystanders touching the pots did not change the colour of the paint for the current painter or disrupt them.

All groups were observed handing over control to the next painter. This happened repeatedly, except when there was not another child waiting for their turn at the table. When children handed over control of the brush, it was directly given to the next person, rather than being 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 action of handing over control 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. (Hornecker and Buur).

The cards, physical paintbrush, and paint 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.

Activities with Offline Controllers

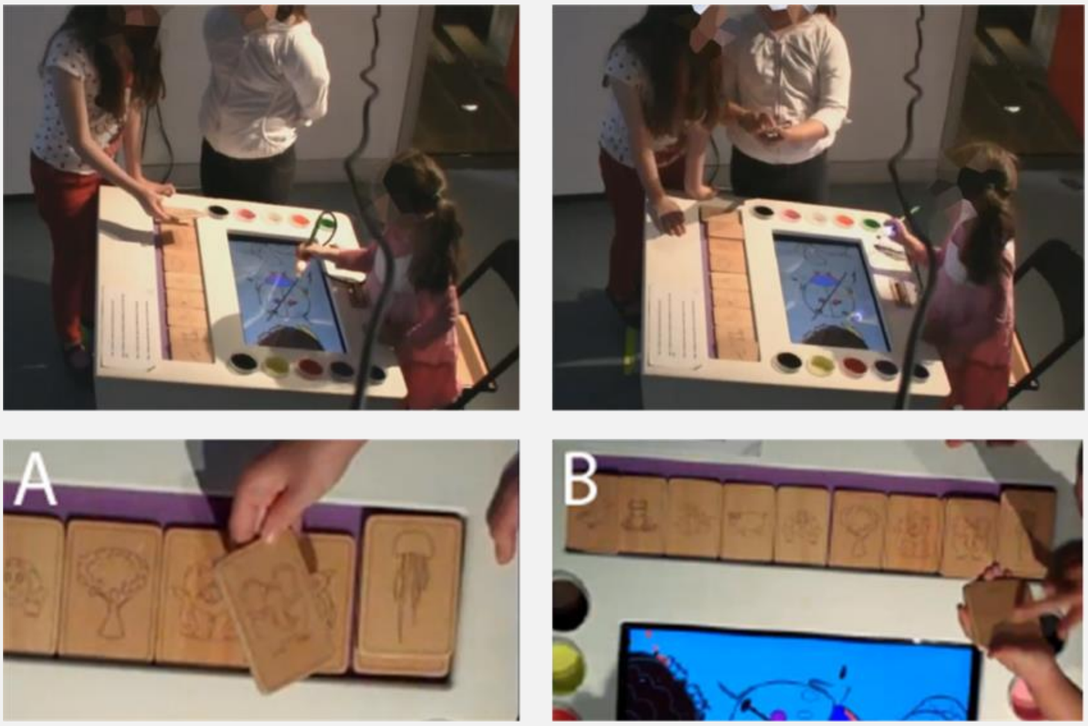
Throughout the video recorded group activities, children within the same group as the painter interacted with the wooden cards and paint pots before or after their own turn. The term 'offline' has been used in previous research to refer to the tangibles that do not manipulate or control the digital content outside of the main painting activity as offline (Esteves et al., 2013), (Fernaeus and Tholander, 2006), (Fernaeus et al., 2008). Bystanders from the same group as the painter engaged with three main activities with offline controllers: (1) browsing, touching, moving, playing with the cards at the table; (2) showing others card/s while discussing their intentions of what to paint; and (3) taking a card away holding onto it until their turn.

All groups browsed, touched, moved and played with the wooden cards at the table; this 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 which were laid out along the top of the table (

Vignette 1) and moved them around independently of the table (Vignette 2, Figure 4-4). This typically 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 and discussing what to paint, while standing at the table or at the bench, bringing the wooden card to companions to discuss. Both painter and bystander were able to physically interact with the exhibit in parallel. Bystanders were manually interacting with representations and controllers without being tracked by the system. The offline nature of the controllers enabled companions to engage in social activities together without disrupting the users' engagement with the exhibit.

The second activity, showing a card to others while discussing their intentions, was observed in 4 groups. This occurred in the groups whose members did not split up to look at other exhibits, and instead they waited at the exhibit for their turn. Companions who stayed in the exhibit space, spent their time playing with the cards, planning their turn or commenting on the painter's actions. Many discussions about planning what to paint happened while visitiors showed their companions the wooden cards. Children used the cards as physical and visual references to orient their discussions, and to communicate their intentions, as illustrated by Vignette 2 and Vignette 4. The next vignette describes Millie and Sarah's discussion on what to paint together, in which they refer repeatedly and in detail to the wooden cards as they move and re-orientate them.

Vignette 4: Activities with offline Controllers
Henry (5), Millie (8), Sarah (8), Ann (5) and Mum (35)



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 standi

Sarah holds onto the mushroom card behind her back. Millie, lifting the cards up, says: *"maybe I 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 B).

Millie lifts up cards as she verbally suggests painting the image. Sarah re-orientates the mushroom card so Millie can see it. Sarah makes the card visually accessible to Millie while still maintaining possession. Sarah then runs her finger over the card while showing it to Millie (Vignette *4*), 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, thereby actively including them.

By interacting with the cards, bystanders physically and mentally prepared for their turn in an active way, both individually and collaboratively. The previous paragraphs describe the activities with the wooden cards that relate to planning what to paint. In addition, I found children were able to do more than only speculate on their planned activities before their turn; instead, by holding onto cards, they could actively begin their own activity. On numerous occasions, I observed bystanders holding onto cards until their turn or for long periods of time.

Holding onto a card intermittently and until their turn was an extremely common behaviour, happening in all except one group, group 3, which had 2 children who were often not at the exhibit at the same time. Vignette 2 and Vignette 4 show bystanders preparing for their painting activity by browsing through the cards, discussing the options and their intentions, and securing their plan by holding onto a card. Regularly, children took cards away from the table and held onto cards until their turn, keeping them away from others. This behaviour is demonstrated by Henry in Vignette 2, who was browsing the cards then held onto the penguin card telling his companions: *"I'm gonna do a penguin".* Holding on to cards in this way allowed children to make sure others did not paint what they wished to. It also helped them to mentally prepare for their turn painting, by investing energy and thought into the activity before them. Thus, 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, built up anticipation of their turn and connected with the content outside of their turn.

4.5 Discussion

The discussion reflects upon the findings, considering firstly RQ2, the shared social interaction between companions; and secondly, RQ3, how control is distributed. Finally, I discuss key insights from the study which informed the research agenda and the subsequent studies conducted during the research. The present study is distinct from the other studies discussed in this thesis in that it focuses on an exhibit which only caters for a single user interacting at any one time. Nevertheless, the study was extremely valuable in highlighting the nature of social interactions outside of core interaction, and how control is distributed in ways which support different activities and means of engaging with the exhibit.

4.5.1 Social interactions between companions

Supporting social interactions in a museum is a highly valuable but challenging task (Heath et al., 2005), (McLean and McEver, 2004), (vom Lehn et al., 2007), (Vom Lehn et al., 2005). While using the exhibit in this study, children often used pieces of the exhibit as tools to support communication. The findings revealed how tangible tokens enabled children to act collectively, by arranging cards and passing them to each other, or drawing each other's attention by moving the tokens, and reorienting them to show companion. The exhibit also helped to manage conflicts to some extent, by enabling situations in which children could control the pace of their activities, and dip in and out of social activities, such as discussions, negotiations and planning. These situations were particularly supported by the presence of offline controllers enabling pre-interactions and post-interactions.

Visitors were able to casually engage in social activities, dipping in and out of social activity with their companions during their own personal planning, and explore the exhibit while waiting for their turn. Control was distributed across multiple tangible tokens, and thus enabled companions to engage with the exhibit and each other in various ways. Bystanders actively engaged with companions by drawing their attention to a point of reference, both verbally and physically, by re-orientating, explicitly pointing to and touching controllers such as tokens and paint pots. The activity helped group members to initiate and sustain conversations in which bystanders actively included companions in their thoughts. The findings are supported by prior research outlining the benefits of offline tangibles in fostering deeper social meaning in groups (Fernaeus et al., 2008).

Activities with offline controllers aided visitors' awareness of both their companions' actions and their intentions, such as what they planned to paint. Finding common ground and being aware of one another helps companions relate to each other, and provides a foundation for companions to socially engage if they choose to do so (Povis and Crowley, 2015). In their work considering social aspects of companions' interaction, Snibbe and Raffle argue that interactions should be socially balanced, emphasising *"a user's awareness of herself, other users, and the media itself"* (Snibbe and Raffle, 2009).

Control was distributed between several objects during the painting task, such as paint pots. The task also required large gestures to manipulate digital content, when selecting colours. As a result, the interaction was obvious, and therefore possible for bystanders to see and follow. Supporting visibility and awareness of the painters' action led to comments and suggestions over the painters' choices. These physical aspects therefore aided social interaction between the painter and bystanders.

Visitors primarily engaged in social activities outside of their turn at the exhibit. As companions could physically explore the controllers while a single person used the exhibit, multiple people could engage with the exhibit simultaneously, albeit not in the same capacity. Companions tactile explorations were often entwined with their social interactions, indicating that by enabling physical exploration of the controllers outside of users' core interactions, the exhibit fostered social activities. Supporting both individual and shared group experiences is an important aspect of allowing visitors to connect with each other and engage with content on different levels (Debenedetti, 2003), (Heath et al., 2005), (Vom Lehn et al., 2005). These activities, outside of an individuals turn, allowed visitors to engage with the exhibit beyond core manipulative interaction, and also engage with the exhibit pre and post-interaction. These pre and post-interactions with the exhibit were crucial, as they frequently involved social interactions. This a valuable insight, as prior research on offline tangibles has not considered expanding engagement beyond core interaction to pre and post-interaction activities.

Supporting pre and post-interaction activities could be particularly helpful when organising turn taking and keeping children engaged in the museum context. The case study demonstrated that the way tangible controllers and control was distributed at this exhibit supported shared activities outside of core interaction, thereby fostering situations in which companions can to socially engage with each other. Although visitor interaction with the exhibit was constrained to a single user, other studies have also alluded that **reducing interaction** can support social interaction between companions (Warpas, 2014). Supporting companions' simultaneously engaging in tactile activities with the exhibit in non-interactive ways helped to alleviate interruptions to the current visitor's interaction. This is a crucial insight, as this disruption is a challenge many interaction exhibits face (Tolmie et al. 2014). These 'on-the-side' activities allowed for the planning future actions, engaged children outside of their turn, and supported negotiations. Bystanders were therefore able to function beyond passively observing the active user as commonly occurs at museum exhibits, and instead actively engage on a personal and social level while waiting (Debenedetti, 2003), (Heath and vom Lehn, 2003).

Conflicts are a social activity in themselves. How these are resolved, avoided or provoked are points of considerations when examining how groups interact with an exhibit and with each other (Marshall et al., 2009). The pairing of tangible controllers with specific activation areas had benefits for children's negotiation, planning and mediation of control. Children were able to moderate who was able to paint by using the brush as an explicit mediator of control, directly handing it over to the next person. Furthermore, due to the pairing, the only way to choose a colour was with the brush, and as such companions could not interfere with the painting process and engagement.

As control was distributed across several objects and controllers were paired with activation areas, the painter could maintain control without being interrupted. At the same time, companions could physically explore the controllers without causing disruption. Furthermore, the painter's body or arm usually covered the token slot, preventing companions from pulling out the token during painting. Since children could easily maintain control, parents did not have to try and mediate children or prevent them from interfering in each other's activities. Thus, this distribution of control alleviated pressure on guardians and parents to manage the group, and limited conflicts of this nature. In museums, parents often spend their time mediating children's activities in order to decrease conflicts. This mediation can detract from or stop group social activities and engagement. Exhibits in which groups can carry out parallel activities with the exhibit without interfering with each other therefore lessens the time parents may have spent mediating children's actions, and increases opportunities for social engagement.

4.5.2 Distribution of Control

The findings from the study in part address RQ3, which concerns how control is distributed. Control is primarily distributed by the presence of multiple distributed tangible controllers and how controllers are located in relation to each other. Beyond this, the controllers themselves also have specific characteristics relating to how they are distributed, and which shape both visitors' interactions with the exhibit and their social interactions. I will now discuss four of the controller characteristics highlighted by this study:

1. Controllers paired with activation areas
2. Equal functioning controllers
3. Offline controllers
4. Portable, fixed or attached controllers

Controllers paired with activation areas

At the exhibit, control was distributed in a constrained way; activation areas only responding to one of the many controllers one at a time. To imply connections between the controllers and activation areas, controllers such as the cards and slots were given similar aesthetics, and the design drew upon common, related objects, such as paintbrush and paint pots. These connections helped children to understand the limits of possibility without having access to the brush or the slot. The relationship between these objects and areas helped to reduce interruptions, and enabled companions to touch controllers and manually explore the exhibit along with companions without disrupting the operator, making transitions of control from one person to another were very definite, clear and obvious.

Equal functioning controllers

Controllers which were offline and accessible to bystanders were distributed as equal controllers, also known as ‘tokens’ in the field of tangible computing. The offline tokens represented options which bystanders had the opportunity to choose from based on their personal preferences or collective decisions. It is important to note that all of the controllers companions could choose from had equal capabilities and functionality. At some exhibits, tangible controllers which companions can select and hold to use later can manipulate digital content in different ways. As bystanders were all equally excluded from the manipulating digital content at the exhibit, there were opportunities for bystanders to socially interact with each other, using parts of the exhibit to support their social interactions with companions. The paint pots has a similar quality in terms of their functionality being equal. Choosing one pot over another was based on personal choice, which prompted discussions surrounding these choices. Companions discussed the choices available to them with each other, comparing and showing others the options they were considering. In light of this activity, it is important to consider whether bystanders would have discussed the merits of different available options if the controllers had different capabilities (Rogers et al., 2009).

Offline Controllers

Interacting with tangible objects outside of core interaction has previously been defined as 'offline' tangible interaction (Esteves et al., 2013), (Fernaeus and Tholander, 2006), (Fernaeus et al., 2008). Offline controllers do not control digital content when touched or moved. Typically, these are controllers which can be physically detached from the system. In the case of this study, offline controllers fostered social interactions, even though the system did not support multi-user input. Multiple people were unable to simultaneously control digital content unless they held the paintbrush controller or a card token together, which was near impossible due to its size and the type of movements required to manipulate digital content. However, the distribution of several offline controllers meant that several companions could manually explore the exhibit together and interacting socially as described.

Portable, fixed or attached controllers

Tangible controllers can be constrained to a fixed location, attached to other objects, set in a fixed orientation, or unattached portable objects. In the case of the PP4N exhibit, the controllers had a combination of these characteristics. The cards were portable, the pots and card slot were fixed and the brush was attached. Portable controllers can be moved and re-orientated in the space allowing visitors to easily show them to companions. These controllers can be used as social objects, guiding conversations and helping people to plan their future actions. Furthermore, the controllers could be moved and gestured with, helping visitors' awareness of their companions' actions and intentions. The attached but semi-portable controller (paintbrush) enabled people to move it away or hand it over to others explicitly, which helped them to negotiate turn taking.

4.5.3 Study Limitations

While the findings respond to the research agenda, there are limitations to the study. Along with all of the other exhibits in the same exhibition space, the installation was curtained off due to lighting overexposure for projected content. This is unusual for most interactive museum installations and may have influenced visitors' behaviours. Outside of video recordings, only a small number of situations in which visitors engaged with offline controllers were recorded. I speculate that privacy or time pressure when other groups were present in the space may have been a factor in this. Lastly, the interactional analysis is limited to video data from 5 groups. To support the analysis, I referenced observational notes from the public interactions and compared interaction patterns where possible.

4.5.4 Insights gained from this study

As the study was the first of three for this PhD research, it was exploratory in nature and as such the insights gained helped to narrow the focus of the research during the PhD. This study highlighted some key insights, which subsequently informed the PhD research agenda. As such, I was drawn to consider:

1) The physical distribution of several tangible controllers
2) Situations in which visitors can physically reference and re-orientate controllers to support their social interaction with companions
3) What is happening for companions outside of core interaction, including how they engage with the exhibit and their social activities outside of core interaction
4) The interplay and transitions between individual and collaborative activities.
5) Alleviating conflicts and supporting mediation of control

Chapter 5

Study 2: Glen Douglas & Fire Fighter

5.1 Introduction

The exhibit in study 1 had several tangible controllers which, when located in specific areas close to sensors, triggered outputs. Ultimately, only a single visitor could interact with this exhibit. In contrast, the present chapter moves on to focus on exhibits that allow multiple visitors to interact with exhibits using various tangible controllers. Study 1 revealed how secondary side-line interactions can be supported by offline tangible devices, which were used in anticipation of interaction with the exhibit itself. The study revealed how features and attributes of an interactive exhibit, in particular its tangible controllers, relate to individual and group behaviours with and at the exhibit. The study helped to establish my research interest in social interactions between visitors, and consequently influenced the aims of the present chapter, which similarly examines how exhibits can support group social experience in the museum context.

In this chapter, I present the evaluation and research findings of two existing tangible hybrid interaction exhibits based at the Riverside Transport Museum in Glasgow. The exhibits have a number of similar features, for example; they have features which support multiple companions interacting at the same time; they have several tangible controllers which are arranged in a way that supports multi-person interaction; and they encourage visitors to act out the role of the people who used the real artefacts on display in the museum. Both exhibits were therefore appropriate for the research interests of this thesis.

Study 2 revealed a number of insights which have contributed to an understanding of how exhibits can support companions' shared social interactions at tangible hybrid interactive museum exhibits. The study highlights a number of themes and questions, that are focused on in more detail in the final study, such as; the idea of companions' reliance upon one another during interaction and presenting opportunities to support each other; questioning 'what constitutes as shared control' beyond the physical distribution of controllers among companions; and equality between companions, for example what visitors can do with the exhibit and when they can do it.

The chapter begins with an overview of the study. This is then followed by a description of the installations, highlighting aspects which the museum considered for these exhibits. The description also outlines how the study was conducted and how the data was analysed. I then move on to describe key visitor interactions and behaviours in relation to social and shared interaction at the exhibits. The final discussion of the chapter is conducted in three sections, reflecting on the findings firstly in relation to companions shared social interactions; secondly in relation to the distribution of control; and thirdly, in relation to the main insights gained from the study. The chapter closes with a conclusion, which relates the findings of the study to the overall research aims of this PhD.

5.1.1 Study Overview

Study 2 took place at the new Riverside Transport Museum in Glasgow, which opened in 2011. The museum won the European Museum of the Year Award in 2013, the European Museum Academy's Micheletti Award in 2012 for Best Science and Technology Museum, and Scotland's Favourite Visitor Attraction at the Scottish Entertainment Guide Awards in 2012. The Riverside Museum's distinctiveness and popularity is, in part, a result of its innovative approach to utilising new technology within a museum context. The museum uses sophisticated technology to create interactive installations that complement traditional museum exhibits. Furthermore, the museum's philosophy seeks to change perceptions of the museum as a quiet, old-fashioned place to be, to a venue that caters for everyone, which exhibits which are practical, "hands-on" and fun. Thus, the museum has a variety of hands-on interactive installations that seek to reinvent the museum experience. However, it is difficult to evaluate how these installations support both the museum's agenda and visitor experience (Davies and Heath, 2013). Supporting the social experience of visitors is one of the key criteria for visitor experience outlined by the Riverside's visitor studies team; understanding how to do this is also the primary focus of this study. Specifically, the study focuses on the way in which the exhibits support and encourage visitors to share interaction with companions, and socially engage with their companions while using the exhibit.

For the purposes of the study, I engaged in direct collaboration with the museum. This process involved meetings with curators, lightweight observations in the museum, interviews with staff members, and studying the museum's design process and documentation relating to the museum's interactive installations.

In its early stages, the study primarily focused on multimodal interaction. I sought to question the relationship between different inputs and outputs in connection to visitor experience, and understand the nature of the interaction, including its social dimension. Professor Hornecker and I scoped a number of exhibits during two visits to the museum to determine their suitability. Forty-one exhibits were considered for the study. The process involved short observations at the exhibits, personal interaction with the exhibits, reviewing the museum interpretation plans and discussions with museum staff. Carrying out lightweight observations of visitors' interactions at these exhibits provided initial insights, and these insights subsequently contributed to the research's focus on the role of different features of THIMEs in companions' social interactions and shared interaction with an exhibit. The study was therefore of primary importance in forming the research questions posed by this PhD research concerning the social dimension of the visitor experience.

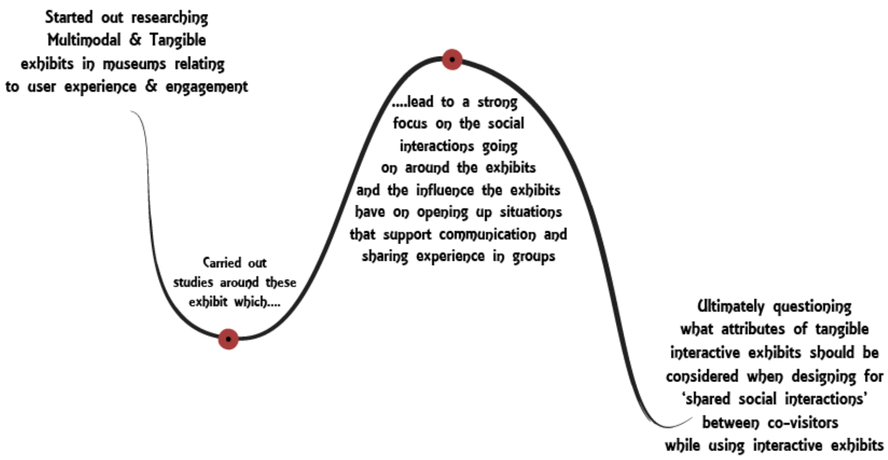


Figure 5-1: Developing a focus on 'shared social interactions'

At the time of our initial research, there were a number of multiplayer games located around the museum which focused on different narratives, as shown in Figure 5-2. These multiplayer games give visitors the opportunity to compete with each other in race type activities. For example, the exhibit shown below in Figure 5-2, invites visitors to race against co-visitors to deliver telegrams. Visitor interaction with the exhibit occurred by means of an individual touchscreen, with which visitors can move their character around a larger map shown on a central display table, as illustrated on the left of Figure 5-2.

Figure 5-2: Multiplayer Telegram Game in the Museum

These exhibits only rarely give co-visitors the opportunity to communicate with or pay attention to each other while using the exhibit. Visitors are instead encouraged to interact with their individual screen and have limited opportunities to engage socially or influence each other's interaction. While researching these exhibits, I observed visitors focusing on their own screen rather than communicating with each other during their interaction. The exhibits enabled multiple visitor interaction, and thus aided the transition of visitors from bystanders to participants. However, there were limited opportunities for visitors to socially engage with companions directly, and to share the activity together, in this way, while interacting with the exhibit. No aspect of the exhibit explicitly combined their actions during the interaction. The competitive nature and pace of the game requires visitors to focus their attention on winning, leaving little room for attention on each other. A number of prior research studies focus on this type of social experience, which enables co-participation alongside companions. However, the actions encouraged and enabled by these exhibits are often activities which occur in parallel but independently of one another, and seldom encourage direct social interaction between visitors while they interact with the exhibit. These observations therefore influenced the focus of the research on exhibits which encourage direct social interaction between companions, rather than only enabling parallel independent interaction for multiple visitors. The focus of the study thus aligns with a body of research concerning how to support various forms of co-participation and collaboration between visitors (vom Lehn, Heath and Hindmarsh 2001), (vom Lehn et al., 2007), (Heath and Vom Lehn, 2010), (Hindmarsh et al., 2005), (vom Lehn and Heath, 2016).

Following this initial scoping into types of existing exhibit in the Riverside Museum, 6 installations of interest were identified. The installations were chosen based on a specific set of criteria:

- How popular is the exhibit?
- What are the inputs (ways of manipulating digital content) and output modalities (how digital is represented)?
- Does the installation support multi-user interaction or group interaction?
- Is the nature of the visitor experience interactive or passive?
- Does the installation support tangible interaction or have tangible qualities?

In-depth field studies were conducted at the 6 installations, shown in Figure 5-3, involving observations, video and audio recording of visitor interactions, and interviews with the public at several of the exhibits.

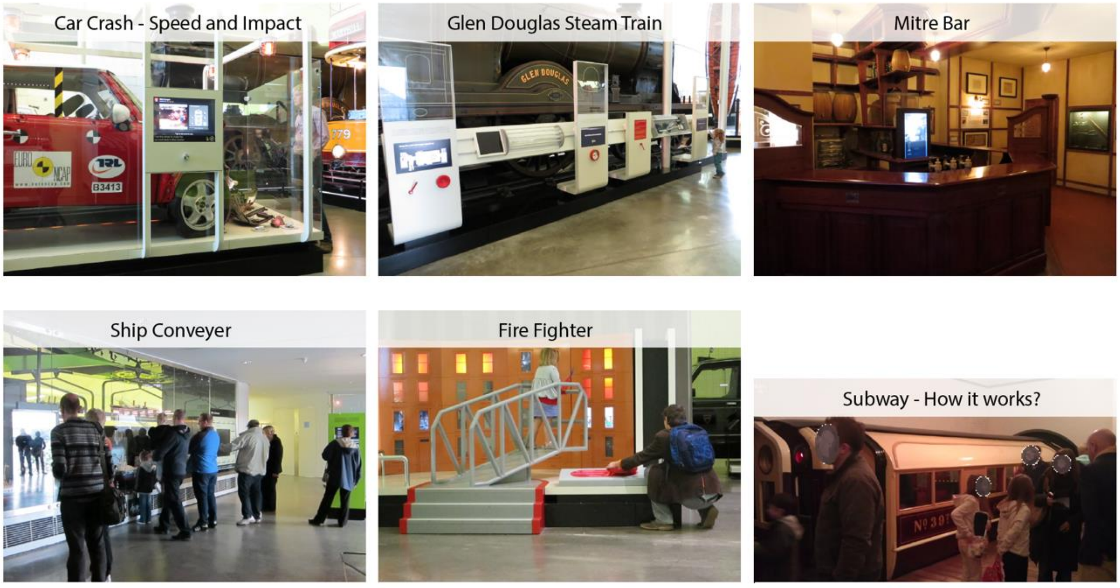


Figure 5-3: Six Installations which were initially studied

Following these initial observations, two installations were chosen for detailed analysis: Glen Douglas Steam Locomotive (GD), and Fire Fighter (FF), shown in above in Figure 5-3,. They were chosen on based on factors mentioned in the last paragraph, as well as the limitations of the other four exhibits. For example, at both The Subway and Ship Conveyor exhibits, the quality of the audio recordings was too poor to retrieve useful data from. In addition, visually observing visitors in the small spaces at the Mitre bar and Subway exhibits was found to be intrusive and affected visitors' natural behaviours. Furthermore, as Car Crash only had only a single controller and Ship Conveyor and Mitre Bar had no controllers, the exhibits did not meet the research criteria focusing on multiple tangible controllers.

5.2 The Installations of Interest

Two installations were chosen for detailed analysis: Glen Douglas Steam Locomotive (GD), and Fire Fighter (FF), shown below in Figure 5-4 and Figure 5-5, respectively. These installations were selected as they had a number of similar features, and thus allowed for a comparison; both exhibits several tangible controllers, and supported multi-person interaction.

Figure 5-4: Glen Douglas

Figure 5-5: Fire Fighter

The Glen Douglas exhibit shown above in Figure 5-4 is a hands-on tangible interactive installation, at which visitors can simulate running a steam locomotive. The Fire Fighter exhibit shown in Figure 5-5 is a hands-on tangible interactive installation at which visitors fight fires using a hose at the top of the ladder, and move the ladder around the exhibit to tackle the fires as they appear in the windows of different buildings. For the rest of the chapter, the exhibits will be referred to as GD for the Glen Douglas installation and FF for the FF installation.

5.2.1 Glen Douglas

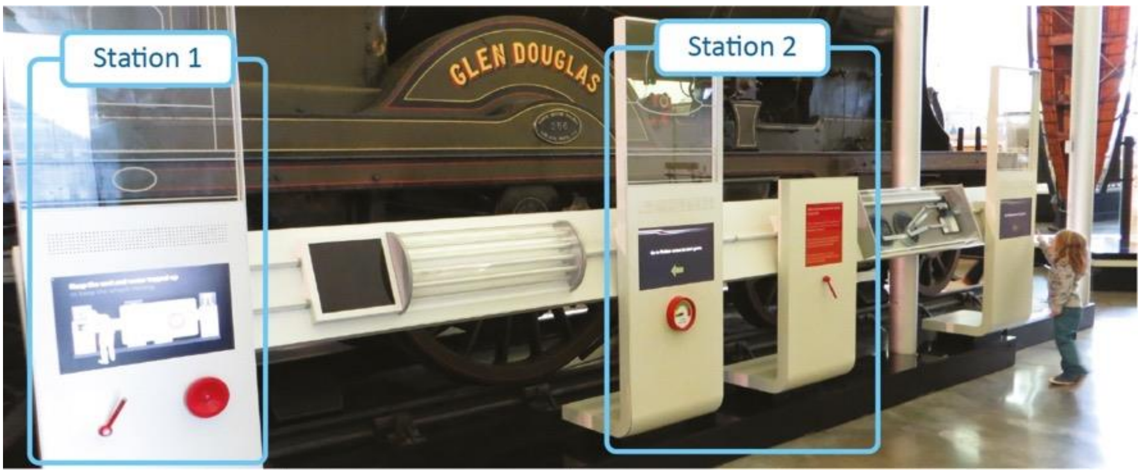


Figure 5-6: Glen Douglas Stations

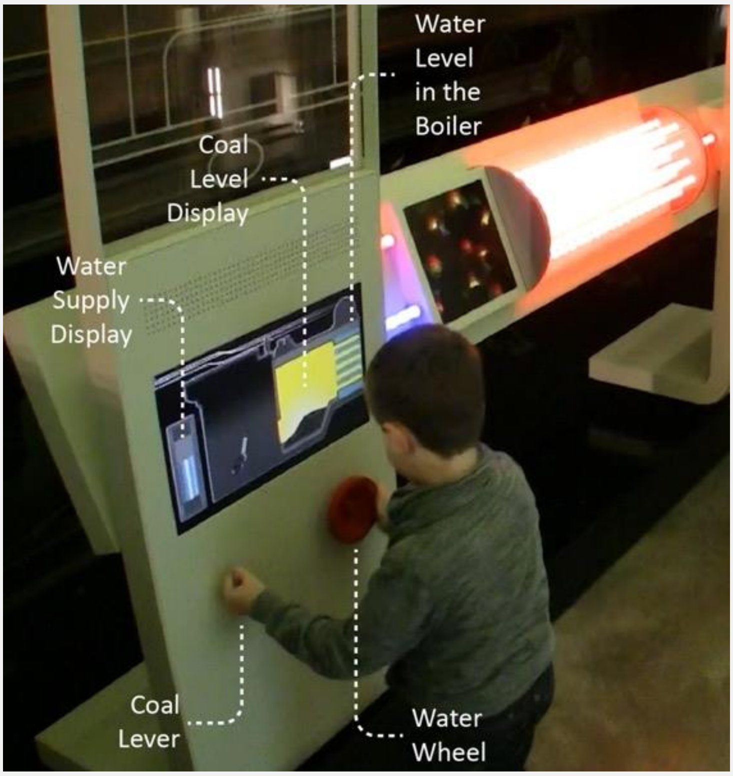
GD is a tangible hybrid interactive exhibit, designed to the various processes involved in powering a steam locomotive. The installation is positioned beside the real Glen Douglas steam locomotive in the museum. Visitors can simulate running the steam locomotive by adding water and coal at station 1 (Figure 5-6) while regulating and releasing the steam pressure at station 2 (Figure 5-6). If the actions are successful, a physical wheel model moves at the far right end of the exhibit, and steam train noises are produced. GD consists of two main interactive stations: station 1, which has two tangible controllers and a display screen; and station 2, which has one tangible controller, a pressure display, a display screen and the mechanical locomotive model.

How the Glen Douglas Exhibit Works

When visitors touch any controllers at the GD, it triggers instructions shown on the first display screen at station 1

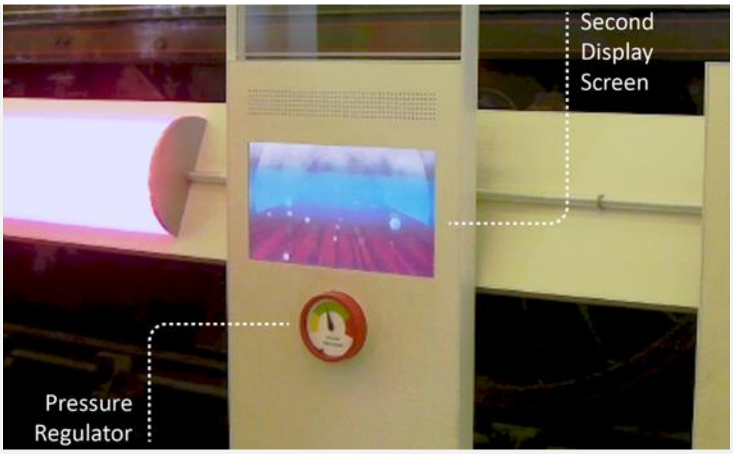
Once the instructions are over, visitors can use a coal lever and water wheel at station 1 to add coal and water to the boiler of the steam locomotive.

Pipes along the GD light up to represent fire and water in the steam locomotive.

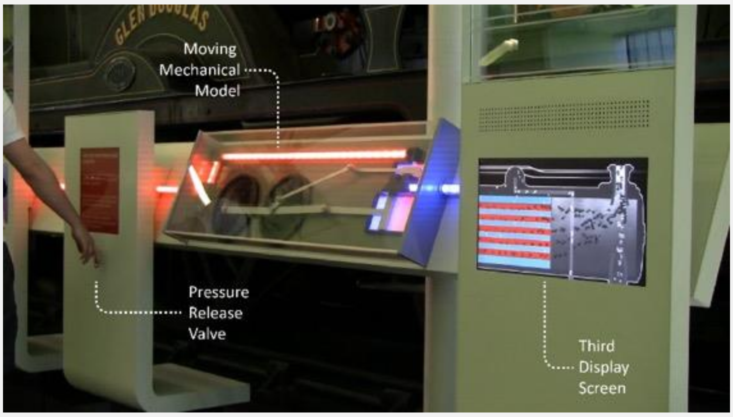


As visitors add coal and water two things start to happen:

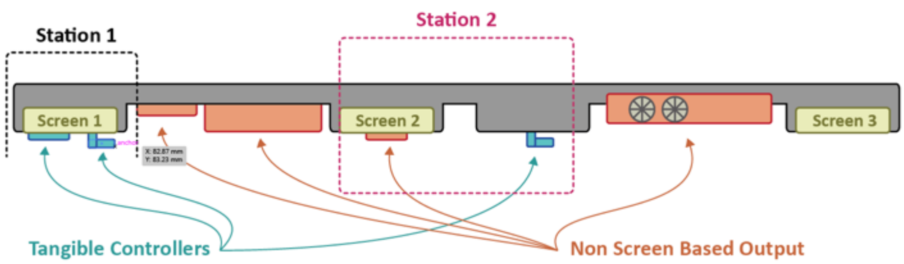
1) Pressure builds in the boiler and is shown on the pressure regulator and on the second display screen at station 2.



Turning a lever at station 2 releases the steam pressure, triggering a mechanical locomotive at the end of the GD to start moving and a visual representation of the process happening within the steam engine which is shown on screen 3.



2) While the visitors add coal and water to the boiler, instructions are intermittently displayed on screen 2 and 3. The instructions, displayed away from station 1, relate to the controllers at station 1 and tell the group how much coal and water to add to the boiler, relating to the controllers at station 1.



This birds eye view of the exhibit shows where the information which guides the use of controllers located at station 1 appears at station 2.

As visitors continue to interact with the GD, the task increases in difficulty. Ultimately the steam engine explodes, and is flooded with water or the fire is chocked if its loaded with too much coal, shown in the images below. The GD then goes back to instructions.

The primary message of the GD was to communicate that 'like all steam locomotives the GD, is powered by steam created in its boiler.'

5.2.2 Fire Fighter

The FF installation is a hands-on tangible hybrid interactive installation designed for children aged under five years old. The installation enables visitors to act as fire fighters, at an installation which has the same layout as the real fire truck located beside the installation. Visitors worked with partners to manoeuvre the ladder and put out fires in buildings. FF has two controllers: a hose at the top of the ladder, and a wheel to move the ladder, as illustrated in Figure 5-7. Fires appear in different windows of the buildings (Figure 5-9) that look like typical local tenement buildings. A visitor can occupy the role of ladder operator, situating themselves at the bottom of the ladder, where they can use the wheel to manoeuvre the ladder from left to right, and position it towards the fire. Or a visitor can occupy the role of fire fighter, situating themselves on the ladder, pointing the hose at the fire and spraying digital water towards the fire to put it out (Figure 5-10). Pressing the button on the hose triggers a fan, causing ambient whooshing sounds. Moving pieces of material protruding from the hose are blown with a fan to emulate water spraying from the hose (Figure 5-7). The installation continues on this loop as fires appear and are put out by visitors.

Figure 5-7: FF Installation

Figure 5-8: Windows not on fire

Figure 5-9: Fires appear in the windows of the buildings

Figure 5-10: Water appearing in the image in the windows

The message the installation was intended to communicate is that: *"the fire fighter was completely reliant on the ladder operator when using this appliance, demanding confidence and trust".*

5.2.3 The Museum's Considerations & Aspirations for the Installations

Both installations were developed by using a guiding set of criteria for particular target audiences established by the museum. GD was developed for family groups, and FF was developed for under-fives. For both audiences, collaboration was a guiding recommendation. At GD it was advised to engage families in both highly **collaborative** actions; and intermittently collaborative actions, in which families remain together and explore the exhibit as a group, or work independently then re-group, share and discuss their findings. The design of GD also considered parents and carers acting as facilitators. The design of FF aimed to promote collaboration and scaffolding for children under 5, to allow them to explore new ideas with confidence. Free play and social interaction were goals for the FF installation, and the design aimed to create a scenario in a context in which children could make sense of problems and tasks. Similarly, for family groups at GD, a task-oriented approach and team-based actions were included as criteria to encourage social interaction. The design of GD also considered opportunities for children to take control and lead the activity, allowing them to control the pace and direction of the activity. For both audiences, fostering hands-on physical interaction and encouraging tactile manual skills and exploration was considered.

The two installations have several aspects in common. These aspects include supporting an interactive experience, involving role-play, presenting a task or challenge to visitors, encouraging team work and involving tangible interaction with physical controllers that are physically separated from each other. Rather than generating content or offering visitors information in a didactic manner, the exhibits instead invite visitors to act out stories related to museum artefacts which are located in close proximity to the exhibits. Visitors are therefore embedded in the stories they are creating, and control what happens by, for example, putting out fires, or adding coal or water to the boiler and monitoring the pressure. The installations give visitors the opportunity to actively understand how people would have worked together to use these museum artefact in real life, either by collaborating as a team to fight fires or to run a steam locomotive.

5.3 Study Set up

The study of visitor interactions with the two exhibits took place over a week during school holidays. The study prioritised capturing visitor interactions in a real world context and with as little disruption to their natural behaviours as possible, as outlined in chapter 3.

Unlike study 1, taking into considerations the regulations at the time of the study, the museum is a public space, and the museum's policies, video and audio recording could be carried out at the chosen exhibits without visitors having been explicitly invited to participate in the study. Accordingly, any museum visitors interacting with the installations during the study were assumed to be participants of the study. Signage located at the installations informed visitors of the study, its purpose and gave information on how to opt out of the study, if they wished to do so. Visitors were observed reading these signs. Only in one case did a group request to be removed from the study.

At both exhibits, cameras were set up in fixed positions for 2 full days, prioritising positions which were unobtrusive. 6 hours and 23 minutes of video audio data was captured at GD. 11 hours and 5 minutes was captured at FF. All of the data was captured during an annual school holiday. Data was captured at both exhibits on one weekday and one weekend day. A mixture of video cameras and separate audio recording equipment was distributed at the exhibits, as shown below in Figure 5-11 and Figure 5-12.

Figure 5-11: GD video and audio recording equipment set-up

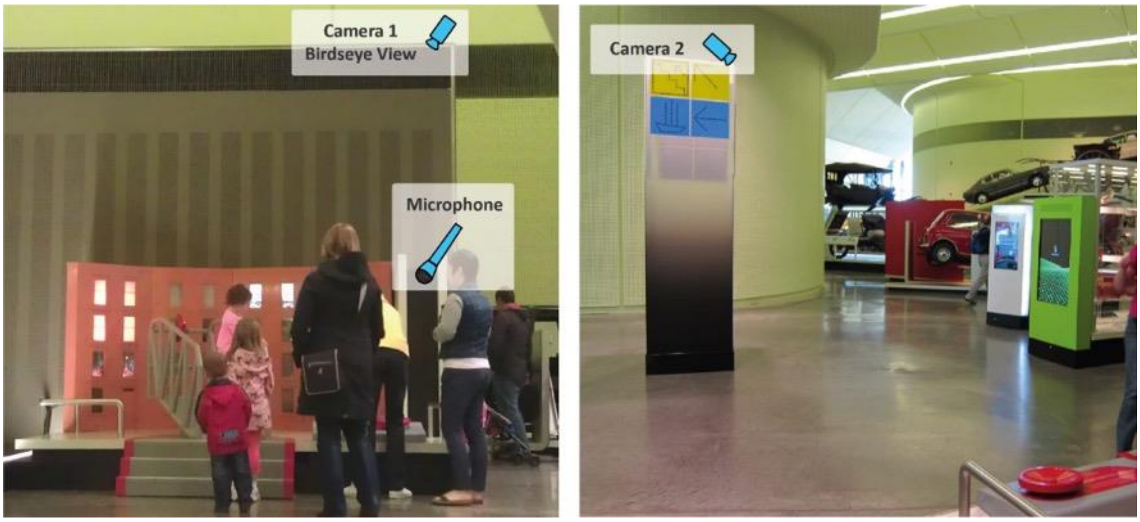


Figure 5-12: FF video and audio recording equipment set-up

5.3.1 Data Collection & Analysis

The data collection and analysis of video-audio recordings of visitor interactions and behaviours at both installations was conducted in line with the process outlined in chapter 3: methodology. At both exhibits several camera and audio recorders were used to capture different actions at the exhibits. An example of the resulting data for analysis is shown in both Figure 5-13 and Figure 5-14 which illustrates how different camera angles were captured and merged.

Figure 5-13: GD Example of Video Data captured

Figure 5-14: FF Example of Video data captured

The analysis involved reviewing the data, creating a catalogue, filtering the dataset and an iterative process of transcribing and coding the data. The dataset for GD was created by identifying groups with at least two children and one adult in the groups, resulting in a dataset consisting of 9 groups which comprised of 43 visitors. As FF had a relatively constant stream of visitors constantly using the installation, a one hour section of video audio data was selected for analysis. This section was from a Friday morning during the school holidays, and consisted of 28 groups, comprising 79 visitors. The rationale behind filtering the data in this way is discussed in the methodology chapter 3. Transcriptions were generated for 9 groups for the GD installation and for the first 8 groups for the FF installation. It was felt that transcribing the first 8 groups from the FF dataset provided sufficient coverage, in that this data showed repeated patterns occurring in visitor behaviour. However, all 28 groups were included in the dataset, in order to create data visualisation and coding.

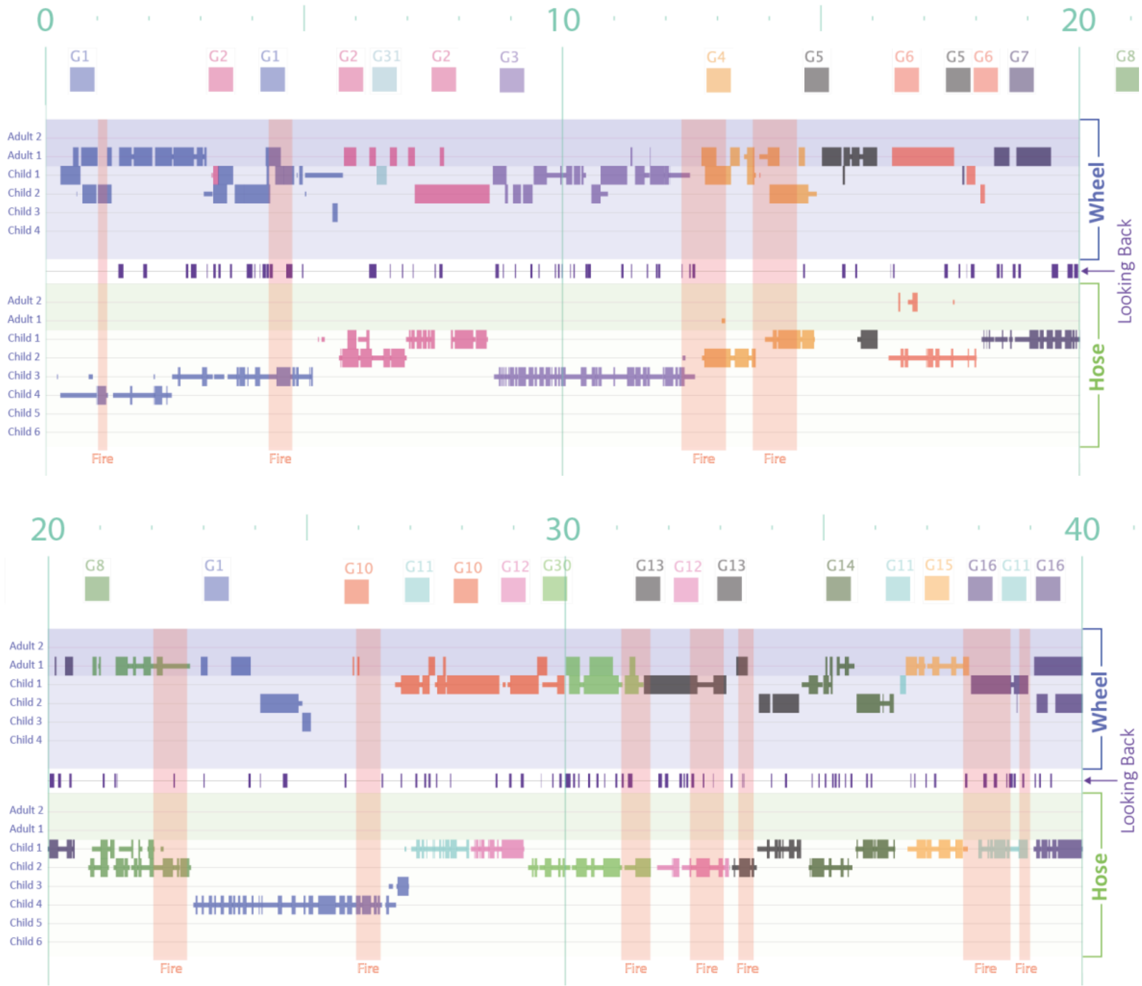
GD Transcription Data set			
	Group Name	Adults	Children
1	GV9	2	2
2	GV11	1	3
3	GV16	1	2
4	GV22	2	2
5	GV24	2	2
6	GV36	2	2
7	GV42	2	3
8	GV83	2	7
9	GV91	4	3
		18 adults	26 children

FF Transcription Data set			
	Group Name	Adults	Children
1	G1	1	4
2	G2	2	2
3	G3	1	3
4	G4	1	2
5	G5	1	2
6	G6	2	2
7	G7	2	1
8	G8	1	2
		11 adults	18 children

Table 5-1: Study 2 Transcription Data Set Overview

Data Visualisation of Visitor Interactions

The analysis of FF was supported by a data visualisation (see Figure 5-15). This visualisation represents key behaviours of interest at FF which were generated during analysis, and thus supports the transcriptions. Further detail regarding the data analysis process, including the rationale and benefits of using the visualisation as an analytic tool, is given in chapter 3: methodology.



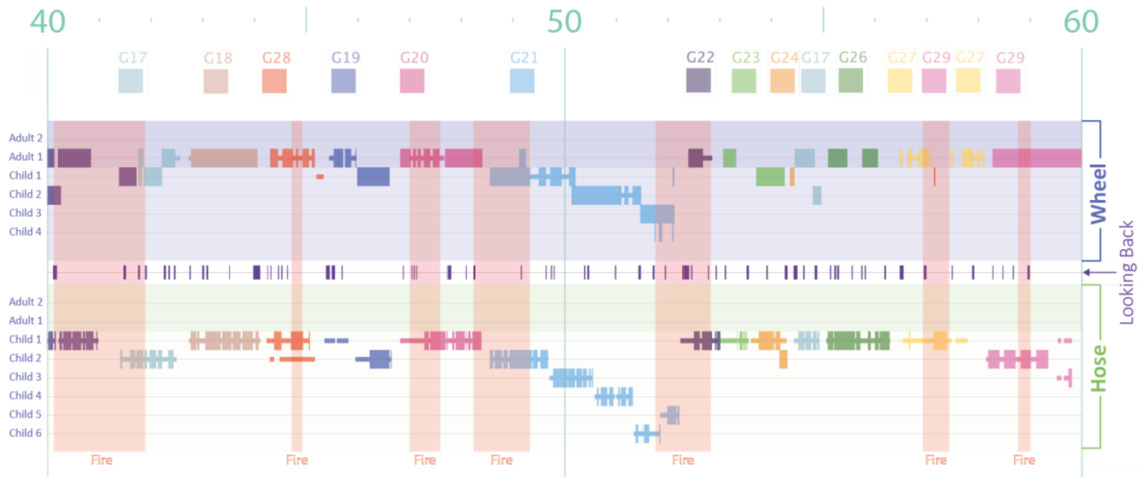


Figure 5-15: Visualisation of FF Data

Figure 5-15 shows the visualisation generated by 28 groups interacting with FF. On its horizontal axis, the visualisation shows occurrences throughout a 1-hour period. Labels for different groups are shown at top of the visualisation and are colour coded. The uppermost purple row represents the wheel controller, which when used moved the ladder. The lowermost green row represents the hose controller at the top of the ladder. The dark coloured blocks indicate when a controller was used, and the duration of its use. A thin coloured line, rather than a block, indicates that a visitor had their hand/s on the controller but were not actively using it. On the left of the visualisation, labels specify who was acting out the interaction with the wheel or hose, including adult 1, adult 2, child 1, child 2, child 3, child 4, child 5 and child 6. There were never more than two adults. Child 5 and child 6 are not shown in the wheel display as neither the 5th or 6th child in any of the groups used the wheel controller. Red vertical columns represent moments there was a fire for visitors to put out. Finally, the central horizontal line, labelled 'Looking back', indicates when a visitor at the hose controller looked back towards the wheel controller.

In order to explain how the visualisation can be interpreted, I'll briefly describe the interaction for group 21 (G21) shown above in blue starting at 48 minutes (Figure 5-15). Child 1 is the first person to start using the wheel controller, shown in the uppermost part of the visualisation by a thick blue block beside the text Child 1 at 48 minutes. At the same time child 2 is using the hose controller during which they hold onto the hose controller constantly but only intermittently press the button. Their intermittent use of the hose during which they press the button is represented on the visualisation by think blocks where. The thinner blocks indicate when child 2 is holding the hose controller but not pressing the button. At 49 minutes adult 1, in the group, starts to use the wheel controller along with child 1 for moment. At 49 and a half minutes, child 2 stops using the hose and child 3 takes over the use of the hose. Shortly after this, child 2 appears to move to the wheel controller and take over from child 1. In the subsequent section of this chapter, 5.4 Findings, the visualisation will be repeatedly referenced to support a discussion of visitor interactions at the FF installation and behaviours between companions.

5.4 Findings: Visitor Interactions with the Exhibit and with Each Other

This section will discuss the findings from the analysis of the study, firstly considering findings from GD, then discussing the findings from FF. For discussions of both exhibits, I begin with a general overview of how visitors interacted with the exhibit; I then discuss different aspects which influenced the groups' social interactions and sharing of the interaction with the exhibit. Finally, I offer a brief discussion of the findings from the analysis of each exhibit.

5.4.1 Glen Douglas: Visitor Interactions with the Exhibit and with Each Other

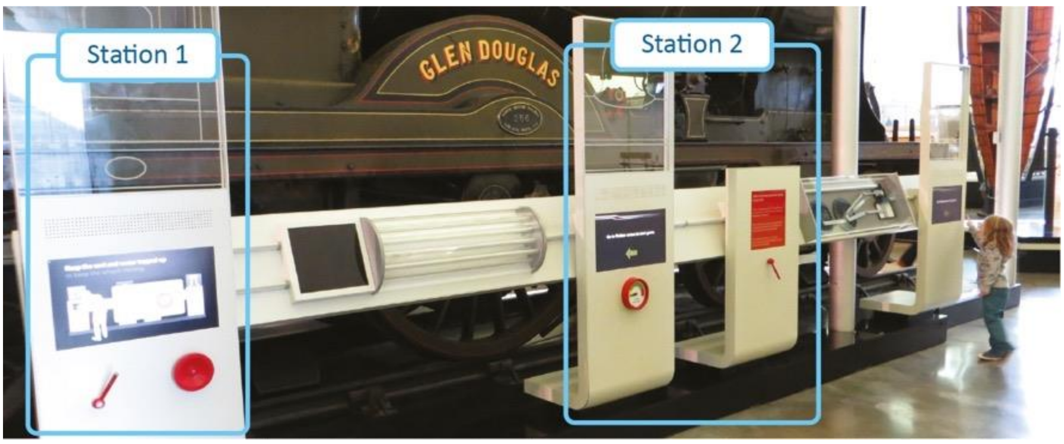


Figure 5-16: The Glen Douglas Installation

General Overview of How Visitors Interacted with the Glen Douglas

In terms of popularity within the context of this particular museum, the Glen Douglas (GD) installation had an average number of visitors. There were rarely queues or visitors waiting to use the exhibit, but it was in use frequently. For example, during a 1-hour period on a Saturday morning, 18 groups consisting of 37 people physically interacted with GD, that is to say they used the physical controllers. While some visitors did not engage in prolonged interaction at the exhibit, more than half of the groups (13 of 18 groups) were identified as having highly invested and engaged in interacting with GD. Many groups went through more than one interaction loop with GD, and some returned later in the day to interact with GD again.

When groups interacted with GD, there were moments of highly collaborative action between companions. However, this action only occurred at certain moments, and tended to be intermittent and short-lived. A typical pattern of interaction was revealed during analysis, which can I have outlined as three different stages:

Stage 1, Initiation: During this stage, part of the group explored the exhibit, usually contemplating how it worked and potential actions, while others in the group focused on other parts of the GD. Typically, visitors were drawn to station 1 which has two controllers for coal and water, as illustrated in Figure 5-16.

Stage 2, Coordination: When trying to understand the exhibit, groups reached a point at which one or more members of the group realised that there was a connection between information appearing on screen 2 and the controllers at station 1, and that this information could be used to successfully guide these controllers. With this knowledge, visitors began to coordinate their actions with companions while interacting with the exhibit. This coordination was rarely smooth. Specific attributes of the GD hindered groups in sharing the interaction and coordinating their actions. These will be discussed later in the section titled 'Factors that hindered groups in developing a pattern of interaction with their companions with the exhibit'.

<u>**Stage 3, Failure**</u>: Coordinating actions involved understanding information on screen 2 and 3 and acting upon it effectively; this was difficult for visitors. This difficulty was in part because the task increased in difficulty as the loop progressed, emulating the difficulty in powering a real steam locomotive. As a result, interaction always eventually led to failure at the exhibit, with the boiler exploding, being flooded by water or the fire being choked.

Stage 1: Initiation	Stage 2: Coordination	Stage 3: Failure
Difficulty in understanding how elements of the exhibit relate to each other. The social interaction here is based on trying to understand what to do.	Realising the connections between dynamic elements of the exhibit, visitors start to communicate and coordinate with their companions while interacting with the exhibit	Visitors are not rewarded for coordination actions when the exhibit fails. The GD explodes, chokes or floods, stopping interaction with the exhibit.

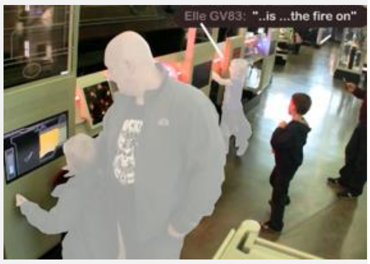
Table 5-2: Stages of people's interaction

The vignette below, Vignette 5, illustrates these stages, and also reveals how groups interacted with GD and the social activity they engaged in while using GD.

Vignette 5: Different stages groups go through
Group ID: GV83. 7 children and 2 adults
Steve: Boy 1 (6, red hair)
Elle: Girl 1 (8, purple top, blonde hair)
Lee: Boy 2 (10, jacket tied around his waist)
Will: Boy 3 (10, glasses, black hoodie lime green hood)
Sam: Boy 4 (9, black jumper with white badge)
Natalie: Girl 2 (14, black shoulder-length hair)
Dad (40, bald head)
Mum (35, brown hair, blue jumper, beige jacket)
Calum: Boy 5 (10, glasses, red T-shirt black hoodie)

Dad and Elle approach GD. Steve (at station 1) has already been

During the instructions, Dad watches and tries to explain while Elle moves up and down

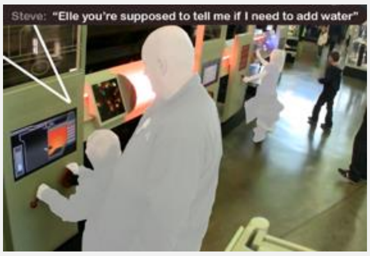


Elle asks "is the fire on" while she explores the exhibit. Dad tries to using GD with Barry, a boy from a different group.

the exhibit, touching and looking at all the different features.

use the controllers alongside Steve at Station 1.

Elle pays attention to aspects of the exhibit away from Station 1 at the pressure lever controller.



Steve informs her that she's supposed to let him know when to add water.

Elle responds to this by moving towards him. She notices information on screen 2 and reads it out. Moving towards Station 1 she tells them to *"add water now".*

Dad encourages Steve to keeping turning the handle. Elle relays the information *"Please stop... add more water".*

She moves beside them telling them *"hurry before the boiler explodes".* Elle repeatedly moves directly between the instructions and her companions (Steve and Dad) at station 1.

Elle then moves back to screen 2. She relays the next instruction to them *"no more water".* This is the moment Dad appears to realise the connection between the information at screen 2 and the coal and water controllers that Steve is using at station

Despite their coordination of actions and communication of information, the fire gets choked with too much coal and the steam locomotive goes out.

1. Dad repeats the information. This continues with
Elle telling them *"you need to add coal now".*

In total, this group used the exhibit 6 times, meaning they went through the interaction loop 6 times.

For the first half of their interaction, Elle did not help to relay information and spent her time exploring the exhibit. At this point, the group was in the initiation stage. When Steve pointed out to Elle how to help with the task, she understood how information on screen 2 related to what Steve was doing with the controllers at station 1. This helped the group enter stage 2, in which they started to coordinate their actions together, sharing the interaction with the exhibit while socially interacting with each other at the same time. However, maintaining coordinated actions is difficult, and thus the group entered stage 3, in which the exhibit fails regardless of their coordinated actions.

Physical and Spatial Distribution of Key Pieces of Interest

The distribution of the key pieces of interest at the exhibit led to a number of different behaviours and outcomes. Notable was visitors' movements at the exhibit, such as visitors disengaging from physical interaction with the controllers at station 1 to move and look at the rest of the exhibit, observing the actions of other visitors, or reading screen 2. As illustrated in Vignette 5 above, separating the key pieces of the exhibit sparked social interaction and movement between Elle and her companions. Key elements of interest, namely the guiding information on screen 2, the controller for the pressure value and the mechanical output, which were located separately from the from two main controllers at station 1. This spatial distribution of key elements appeared to stimulate visitors to step back from station 1. This process of stepping back from station 1 shifted visitors' attention from their individual interaction with station to their co-visitors and other parts of the exhibit. Stepping back from station 1 also prompted visitors to hand over controllers to their companions, in turn, reducing situations where one person dominates physical interaction at station 1. The next vignette I refer to, Vignette 6, illustrates a typical situation in which a visitor steps back from interaction, hands over physical control to a companion and begins to orchestrate other peoples' interaction with the exhibit. In this position, the visitor has the ability to view all of the sections of the exhibit and can appropriately make sense of how these parts relate to each other, while occasionally physically interacting themselves. In this position, visitors have the ability to view all parts of the exhibit, helping them to make sense of the relationship between different parts of the exhibit and thus guide companions in their interactions with the exhibit.

Vignette 6: Stepping back from Interaction and handing over controllers
Group ID: GV16
2 children and 1 adult
Dad (50, black jacket. grey hair, slightly bald.)
Casey: Girl (7 pink jacket, red trousers, long brown hair in a ponytail)
Bill: Boy (11 blue rain jacket, dark black hair, glasses)

We join the group after they've used the exhibit twice already. Bill (the boy with the blue jacket) has always been the person using the coal and water controllers at station 1. Casey attracts their attention to the other end of the exhibit.

Casey instructs them to add more at the top. Bill returns back to station 1 where he can add more.

Bill tries to see the other end and ask Dad for information to help him and find out if what he is doing with the coal and water controllers is working to build up the pressure.

Dad responds to Bill but doesn't actually tell Bill the pressure level.

Bill moves away from station 1 to see the rest of the exhibit. This opens up the controllers at station 1 for Dad to start interacting.

Dad takes on the role of adding coal and water. Bill starts to move back and forth between the different pieces of the exhibit, monitoring them and directing the others in what to do in a way that coordinates their actions together.

Bill moves between guiding Dad's interaction with the exhibit, dipping in to use the controllers himself, and then stepping back again.

Bill returns to the controllers, taking over, triggering Dad to step back from the controllers. They swap positions and control is handed over again.

Dad then starts to move between different pieces of the exhibit himself, guiding the kids' interaction with GD.

Stepping back from interaction happened when: visitors needed information; the exhibit stopped; visitors wanted to see the other end of the exhibit; or somebody drew their attention away from station 1. The behaviour allowed companions to step into a control position at station 1. In stepping back from interaction and swapping positions with companions, visitors could view information and the output. The action led to visitors communicating and supporting each other with instructions and information, thereby sharing the activity together. Moving between different parts of the exhibit presented visitors with different perspectives of the same installation. Bill knew what information was needed at station 1, so communicated that valuable information to his Dad who was now located at station 1, the position he himself had been in before.

Vignette 6 highlights a number of interesting situations which arose when companions stepped back from the controllers at station 1 such as: firstly, companions shared the interaction, handing over and back control of the same physical controllers; secondly, visitors listened and referred to companions and; thirdly, visitors halted their own direct interaction, and began mediating and guiding their companions' interaction with the exhibit. In this way, control was distributed by accessing different parts of the exhibit. One individual was unable to physically interact with all of the controllers while viewing the output and useful information, and thus had to rely on companions to interact successfully with the exhibit, working together as a group. Gaining an overview of how parts of the exhibit relate to each other including useful information enabled visitors to help guide the interaction with the exhibit. Control was therefore not only distributed by various controllers but also through different perspectives.

The Multitude of Activities, and Relationship between Station 1 & Station 2

Visitors initially found it difficult to understand connections between parts of the exhibit. For example, visitors often approached only station 1 or 2, and did not appear to notice the rest of the exhibit. I will now discuss the relationship between station 1 and station 2 and the challenges that visitors faced while using the resources in coordination with other co-visitors. As a result of the relationship between station 1 and station 2, companions had to rely on one another and work together. As the two stations were interlinked, visitors had to and use information offered to them by companions to interact effectively with the exhibit; for example, the appropriate and effective use of the coal and water controllers was based on the guiding information displayed on screen 2. Utilising the related resources in combination with each other, prompted communication between companions and coordinated actions, as discussed in the last section. While the multitude of stimuli spread throughout the space may have encouraged visitors to step back from their individual interaction and coordinate as a group, it also made it difficult for visitors to initially understand the relationship between parts of the exhibit. At first, visitors struggled to realise the benefits of coordinating with companions and of maintaining these coordinated activities. The exhibit was relatively demanding as it had multiple stimuli, including controllers, screens and digital media at both stations. In the previous section, I discussed the social shared interaction between visitors based on understanding of the connections between station 1 and 2. In this current section and the following two subsequent sections, I highlight factors that hindered visitors in making these connections.

Actions and Stimuli at Station 1

For an individual to use the controllers at station 1 effectively, that is to run the steam locomotive, it was vital to acknowledge the guiding information displayed on the screen at station 2. However, visitors standing at station 1 were given little indication of the connection between station 1 and the information on screen 2. In addition, station 1 had a number of stimuli which demanded visitors' attention and limited their capacity to actively examine the information given at station 2, or information provided by their companions. For example, at station 1, there were two different controllers, a screen and glowing pipes which demanded visitors attention (Figure 5-17).

Figure 5-17: Different stimulus at Glen Douglas Station 1

The next vignette, Vignette 7, illustrates how visitors initially intently focused on station 1, and did not consider the rest of the exhibit.

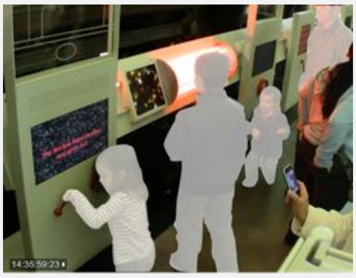
Vignette 7: Visitors heavily focused on station 1
Group ID: GV91
3 children and 4 adults.
David: Dad 2 (40, grey hooded top)
Anne: girl 2 (5, pink and red jacket, blond hair)
Teresa: Lady 1 (35, light blue jumper, long black hair in pony tail)
Alison: Lady 2 (35, pram, black jacket, glasses)
Peter: Boy 1 (10, black leather jacket with beige trousers)
George: Dad 1 (35, grey jumper, no hood, black jeans)
Sandra: girl 1 (3-4, jeans, blue rain jacket with coloured dots)

Peter's first encounter with the exhibit involves watching his siblings use station 1 (which they have been using for almost 10 minutes when he arrives at the exhibit).

Peter them moves in to use the controllers at station 1 with his siblings. Peter spends his time using the controllers focusing on the visuals surrounding station 1.

Peter's sibling, Sandra, moves back and forth between station 1 and station 2 but doesn't communicate what to do to the others.

Notice that Mum and others stand in the way between the stations, an action I will discuss in greater detail a later in section titled 'Factors that Hindered Groups in Developing a Pattern of Interacting with their Companions while they interact with the Exhibit'.



After 30 seconds the exhibit fails. Peter moves away momentarily to look at part of the exhibit close to station 1.

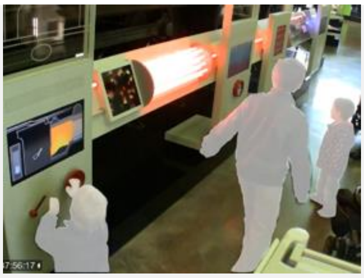
Peter then returns to station 1 where he watches the instructions along with Sandra. When it starts again Peter's focus stays on station 1. Peter seeks guidance from his sibling Sandra who has been using the exhibit: *"right, is that enough?"* Sandra responds "*Yeah"* without using any information from station 2.

In the meantime, a warning message appears on screen 2.

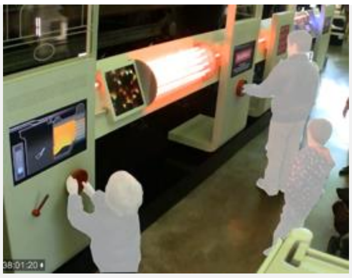
Sandra moves from station 1 to see the mechanical output her Dad pointed out to her earlier.

Peter focuses on station 1 missing the messages of screen 2.

After 29 seconds, it fails again. It starts up again and the siblings keep their positions side-by-side at station 1



Peter stops using both controllers for a moment and another child (a stranger) steps in to use controllers at station 1. Only then, does Peter step back from interaction. At this point he starts to look at the rest of the exhibit. Peter moves to screen 2 and a warning message appears.



Peter doesn't communicate the information to the stranger child at station 1. After this, Sandra moves back to station 1, Peter relays the information to Sandra, who is now at station 1 with another child. Peter: *"you have to add more water".* But with people in between them and in between Peter and the exhibit it's difficult to develop this pattern any further for Peter and Sandra. They leave the GD soon after this.

Vignette 7 illustrates a typical situation in which a child uses the exhibit for the first time, focusing extensively on station 1. Sandra exemplifies this behaviour until her father points out the mechanical model at the other end of the exhibit to her. She then repeatedly goes back and forth between station 1 and the mechanical model. Station 1 appeared to be the most desirable position as it was the position which the children were primarily drawn to from the outset. Peter only moves away from station 1 after the exhibit failed. Upon doing so, he realises the connection between station 1 and the rest of the exhibit. He then began to coordinate with Sandra. However, their coordinated activity was hampered by the presence of other visitors who had moved in to use the exhibit and were standing between them, blocking their communication.

I suggest that a number of factors play a role in situations outlined in Vignette 7. Firstly, at station 1, the most prominent point of interest, there is no indication that there is a relationship between the controllers and retrieving information at any other part of the exhibit. Secondly, the controllers may be located too far from one another and too far from guiding information creating a disconnect. Thirdly, a range of stimuli, including the mechanical output, engaged visitors' attention, and thus limited visitors' ability to notice and understand connections between the station 2 and the rest of the exhibit. Similarly, station 1 required visitors to tend to the different controllers and stimuli at station 1, limiting their capacity to connect with the rest of the exhibit. Only when visitors had stepped back from station 1 did they realise the connection.

Activities and Stimulus at Station 2

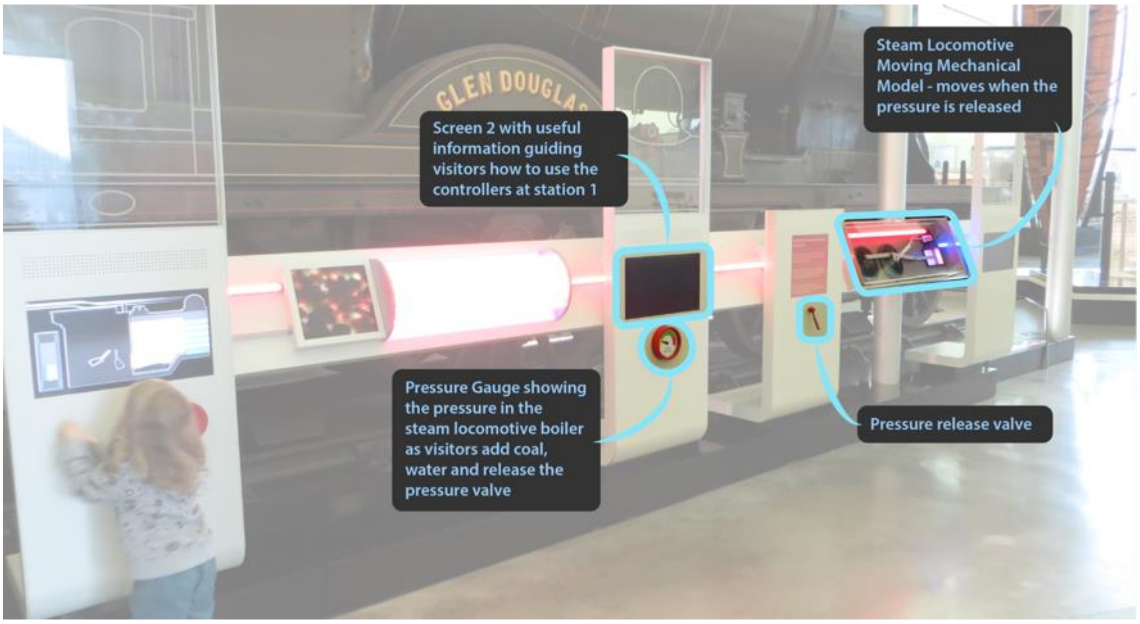
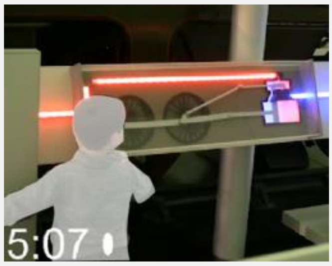


Figure 5-18: Different stimulus at Glen Douglas Station 2

Similarly, at station 2 there were also several stimuli, such as the mechanical output, the pressure gauge, the pressure release valve, and screen 2 which intermittently displayed important guiding instructions (see in Figure 5-18). This stimuli simultaneously demanded visitors' attention, competing with each other. As a result, information on how to use the controllers at station 1 was often not communicated to companions at station 1, as visitors did not see warning messages and information displayed on screen 2. The dynamic mechanical output was one of the most engaging elements of GD, attracting visitors and diverting their attention away from the information displayed on screen 2. The next vignette (Vignette 8) shows strangers using the exhibit together. This is their 4th time using the exhibit. Tom, who is located at the mechanical output, had been using the exhibit for 11 minutes with another group briefly before the events depicted in this vignette took place. He frequently used information on screen 2 to inform other visitors how to use controllers at station 1. Vignette 8 demonstrates that even Tom, an expert by this stage, focused on a range of different features and thus missed information appearing on screen 2. Vignette 8 begins 43 seconds into the group's 4th time using the exhibit.

Vignette 8: Visitors heavily focused on station 2
Group ID: GV11 & GV8
3 children and 1 adult. 1 child is from another group (GV8)
Bob: Boy 1 (9 white and navy stripped top)
Martin: Boy 2 (5 camouflage trousers and dark green top)
Dad: (40, blond, blue jumper)
GV8: Tom (7 grey top) A stranger from another group



Tom pushes pressure lever down, staring intently at mechanical output while concentrates on using both controllers at station 1.

A warning message comes up on screen 2 but Tom is intently watching the mechanical output.

Bob notices something and leans back from station 1 to look at the other end for a moment.

Bob then works hard to only add water but it's too late. He's added too much coal and the fire has gone out.

Despite Bob's effort to add more water as screen 2 suggested, it's failed again, frustrating Bob.

Vignette 8 effectively illustrates a challenge that visitors faced when collaborating with the people at station 1 while undertaking their own personal interaction at station 2, such as using the pressure lever, or viewing the mechanical output that they directly controlled with the pressure lever. Tom, who used the exhibit repeatedly with several different groups over a 25 minute period, understood that information from screen 2 could guide the effective use of controllers at station 1. Yet while he was positioned at station 2, he focused on viewing the mechanical output and using the controller he was located at. As a result, he missed the guiding information on screen 2. Thus, with so much available stimuli, visitors had difficulty noticing messages on screen 2. Some children struggled to both read and communicate the textual information on screen 2 before the exhibit failed, or even to simply understand the information on screen 2. When visitors did notice messages, they engaged in coordinated actions, and communicated information from screen 2 to companions at station 1. Visitors at station 1 acted upon this guidance from their companions. However, messages frequently appeared but went unnoticed. Thus opportunities for social interaction while using the exhibit were not fully realised.

To successfully operate the exhibit, companions had to relay on information between one another. This process appeared to be an effective incentive to spark communication and collaboration between companions. However, in order to relay messages in this way, visitors had to dedicate their attention to screen 2, ignoring other stimuli. The range of stimuli at the exhibit thus led to a distributed focus for groups, and made it difficult for companions to successfully align their interactions with the exhibit.

Sharing the Controllers Side-by-Side at Station 1

Visitors also shared interaction by using the controllers at station 1 along with a companion. Four (GV42, GV24, GV22 & GV91) out of nine groups shown below in Figure 5-19, Figure 5-20, Figure 5-21, Figure 5-22, Figure 5-23 and Figure 5-24 were observed amicably sharing controllers side-by-side at station, and for a prolonged time. There were instances in which visitors shared the two controllers at station 1 for short periods of time; these were not considered to be prolonged side-by-side sharing.

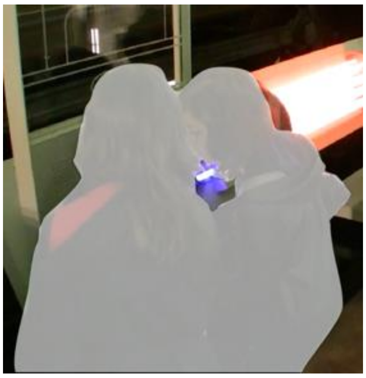


Figure 5-19: GV42 Siblings side-by-side

Figure 5-20: GV24 Siblings side-by-side

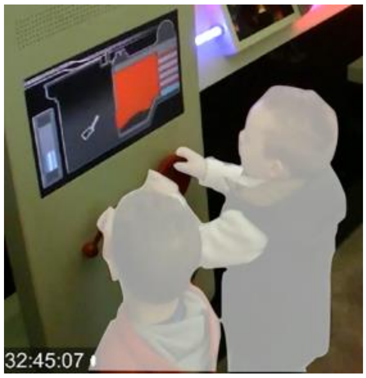


Figure 5-21: GV22 siblings side-by-side

Figure 5-22: GV91 parent and child side-by-side

Figure 5-23: GV91 siblings side-by-side

Figure 5-24: GV91 other siblings side-by-side

Sandra in group GV91 (shown in Figure 5-22, Figure 5-23 and Figure 5-24) shared side-by-side interaction with multiple people within the group. The following pattern was observed during this sharing process regarding visitors movements: one companion frequently stepped back from interacting in order to view the rest of the exhibit, then returned back to station 1 to share the controllers side-by-side with their companion. The side-by-side location of the two physical tangible controllers allowed visitors to intermittently engage in interaction in close proximity alongside their companions. If a companion returned to station 1, both controllers did not need to be handed over. Instead the two controllers could be shared between companions, often handing back and forth control to companions as visitors moved to and from station 1.

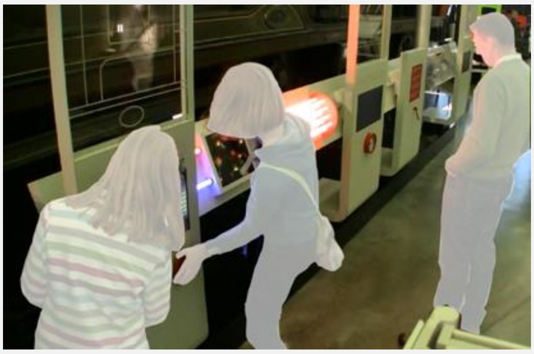
Vignette 9 shows two siblings sharing controllers side-by-side during their interaction.

Vignette 9: Sharing Controllers Side-by-side
Group ID: GV24
2 adults and 2 girls
Mum (38, navy hoodie)
Dad (40, green jumper and jeans)
Karen: Girl 1(15, red hair, green jumper)
Ashley: Girl 2 (13, striped top, red hair)

Ashley starts off watching her sister Karen use the controllers. Ashley then expresses that she'd like to use the exhibit too. The girls agree on how to both use the controllers.

The girls use the controllers side-by-side while Dad gives them information from the rest of the GD.

Ahsley and Dad start to move back and forth between station 1 and station 2, almost taking turns in different positions



They continue doing this until the exhibit fails

The close proximity of the two controllers supported visitors in sharing the interaction side-by-side with companions. Visitors may have been encouraged to share the controllers with a companion as both controllers were required attention at particular moments, such as coal or water had to be added. The controllers were also physically demanding, as they had to be rapidly turned to complete these actions. When visitors were alone at station 1, they were observed using only one controller at a time. This indicates that using two controllers simultaneously was challenging for one person. Younger children were observed placing two hands on a single controller to use them. This action may have occurred because coordinating different actions simultaneously with two hands can be difficult for children. In Figure 5-25, Karen walks away from the controllers shaking her hand, as if it was getting sore as a result of the repeated and rapid movement required to turn the wheel. This is perhaps a reason she was happy to share usage of the controller with her sister.

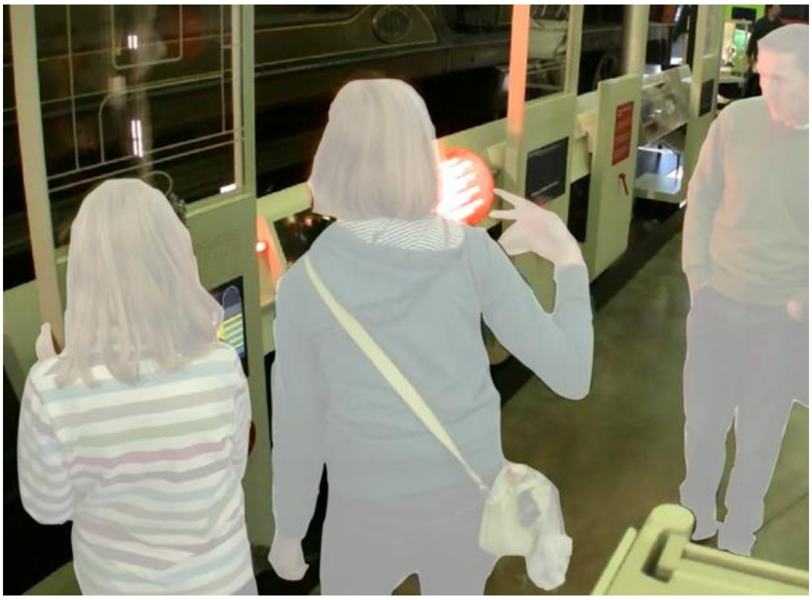


Figure 5-25: Karen shaking her hand after using station 1

Side line Social Interactions at the Mechanical Output

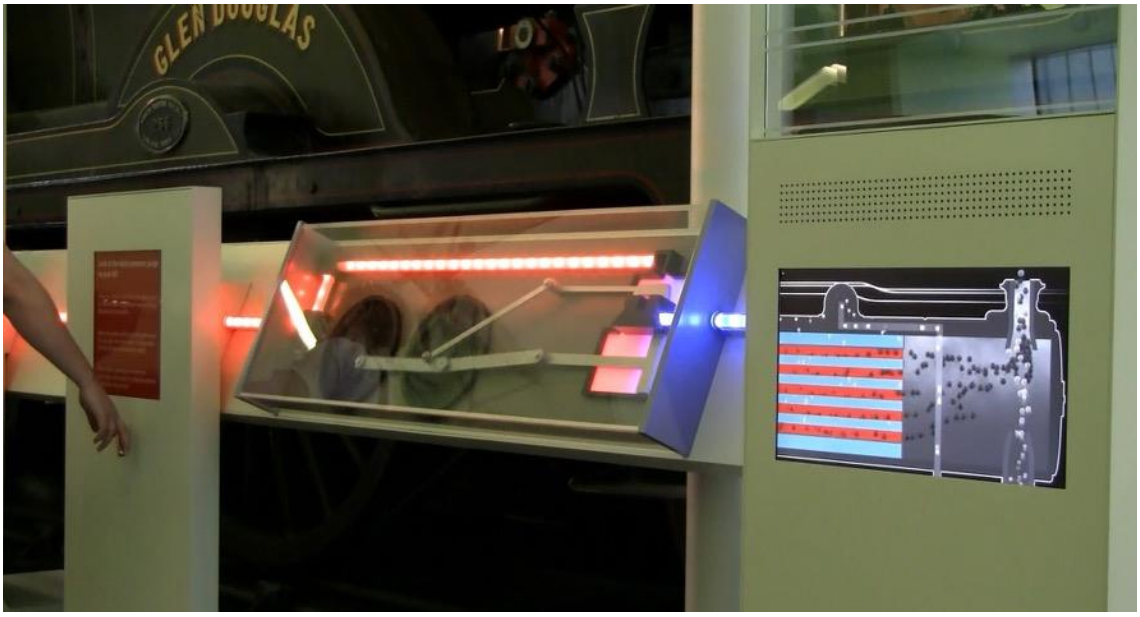


Figure 5-26: Dynamic Mechanical Locomotive model and display screen 3

As outlined in the section entitled 'the multitude of activities, and relationships between station 1 and station 2', the exhibit had a number of stimuli that attracted and competed for visitors' attention, often drawing attention away from information which was central to coordinating successful interaction with the exhibit. However, the mechanical locomotive model (shown in Figure 5-26) was also a common focal point for visitors. Visitors were attracted to it and would often point it out to their companions. As such, side line social interaction relating to the exhibit often occurred there. Visitors acted out the motion of the locomotive, and pointed the model out to companions while engaging in discussions, as illustrated in Figure 5-27.


GV16 *GV83*


GV91 *GV42*

Figure 5-27: Mechanical Output Activities

These side-line social interactions around the mechanical model were intermittent rather than constant; however, despite occurring only occasionally, these interactions are important in that they facilitated social activities beyond sharing control of the exhibit. They also provided social activities which weren't solely based on interaction with the exhibit. In their nature, these social interactions were closer to activities usually associated with traditional non-interactive exhibits, during which visitors orientate conversations around an artefact on display, pointing out its different aspects.

Factors that Hindered Groups in Developing a Pattern of Interacting with their Companions while they interact with the Exhibit

Overall companions intermittently engaged in shared social interaction while using GD. However, as outlined in the preceding sections of this thesis, several factors hindered groups in coordinating their actions together. In this section, I highlight four factors which hindered companions developing a stable pattern of interaction with each other and the exhibit. These four factors are: the large space, location and orientation of the exhibits features; the increasing difficulty of the task over time; the long introduction; and confusion as how to add water.

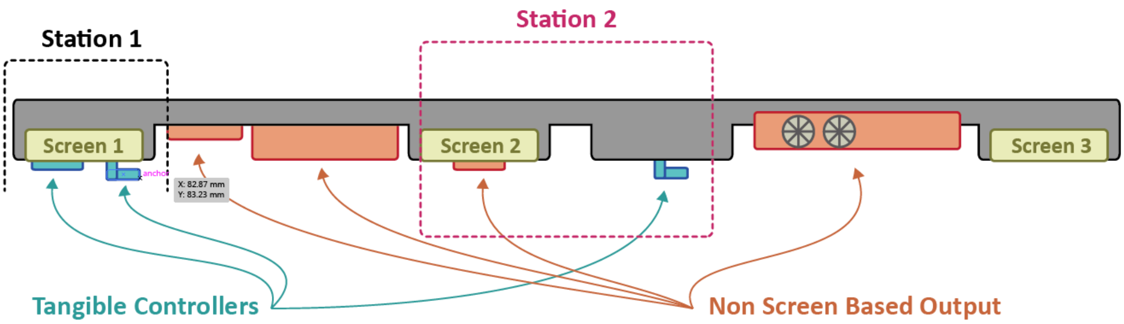


Figure 5-28: Birds eye view of the GD

The previous sections of this thesis noted that the size and layout of the GD instigated sharing and social activities. However, in this section, I suggest that the size and layout of the GD installation also presented challenges for companions using the installation. For example, if visitors were situated between communication points, blocking line of sight of companions trying to work together at the GD, as illustrated in Vignette 7. In some cases, this blocking occurred when companions were trying to observe the actions of visitors at station 1. It also occurred when visitors were trying to interact alongside one another at station 1, as shown in Vignette 5. . In this vignette, Dad was trying to use the exhibit along with his son at station 1. However, Dad blocked the line of sight from Elle to Steve, and as a result communicating or coordinating their actions was difficult. It was therefore difficult for companions to observe what others were doing at station 1 without moving too close to them. If visitors did move too close to others, they risked restricting the view between station 1 and station 2, and diminishing the ability of non-interactive members of the group to observe interaction and understand the relationship between the different parts of the exhibit. Therefore, it is evident that the layout of an interactive exhibit should not encourage visitors observing the action to stand in positions that block communication.

The distance the controllers were distributed may also have hampered visitors from immediately determining a connection between the controllers when approaching the exhibit. As a result of the considerable space between controllers, often strangers would interact with GD when others were not finished using it. This distribution could be considered a strength of the exhibit, in that it encouraged strangers to interact along with other visitors. However, it should be noted that it also disrupted current users and stifled both visitors interaction with the exhibit. The distance between controllers also made it hard for companions to relay information to each other. This difficulty was compounded by the speed with which messages appeared on and disappeared from the screens, highlighted in Vignette 5 & Vignette 8.

While using the exhibit, its difficulty increased, and ultimately the steam locomotive failed, with either an exploding or flooded boiler. The design intention was to emulate the level of difficulty involved in running a steam locomotive in real life, and to add an element of challenge to the interaction. However, visitors were regularly frustrated by the quick failure, as seen in the case of Bob in Vignette 8. As such, this difficulty hindered companions from developing a protocol for working together. By the time companions had begun to coordinate their actions or communicate information from screen 2 to the person at station 1, often the exhibit had already failed.

The negative impact of the difficulty level of GD upon visitors' ability to develop a collaborative pattern was reinforced by its long introduction. The introductory instructions were lengthy, and as such significantly reduced visitors' sense of momentum. After completing an interaction loop only occasionally did visitors watch these introductory instructions again. Sometimes, visitors would leave during the introductory instructions, as they felt unable to begin the activity again quickly. Related literature suggests the ability to skip long introductory instructions is a desirable feature at exhibits. However, while skipping the introduction may be desirable, the introduction also acted as a break in the interaction, giving visitors time to step back from interaction at station 1, often allowing them to gain an overview of the exhibit and to organise themselves.

Another factor which hindered companions' coordinating their actions was poor feedback from the exhibit. Often visitors were unsure as to which controller added water. When visitors were aware of this message on screen 2 and subsequently communicated it, their companions were unable to effectively use the information as they did not know exactly which controller added water. Vignette 8 illustrates this, as Bob repeatedly asks Tom how to add water. This hindered their progress as a group, and companions focused on figuring how to add water over interacting and collaborating. As a result, these actions at the exhibit are more closely aligned with 'how to' conversations discussed in previous research (Hornecker, 2008). These conversations are argued to sub-standard social interactions when compared to explorative discussions (ibid.)

Summary

Before, moving on to discuss findings from the FF installation, I will now briefly highly key points raised by my analysis of the GD. While this chapter has highlighted a number of barriers to social interaction when using this installation, GD provided a number of useful insights. Such insights will be used to guide future social and shared interactions with tangible interactive museum installations. Notable aspects are:

- how long visitors spent at the exhibit. Despite challenges visitors faced, there were visitors who spent considerable time at the exhibit suggesting the exhibit provided some experiential value.
- how many times visitors repeated their attempts to use the exhibit. Similar to the previous point, it is unusual to see visitors repeat the use of an installation, suggesting a valued experience for visitors
- there were moments before the exhibit failed, when visitors communicated and coordinated their actions with companions suggesting the exhibit encourages SSI but SSI was hindered when the exhibit failed (responding to RQ2 and RQ3)
- the social activity of showing companions the mechanical outputs suggesting there are side line social activities that companions may engage outside of core interaction
- difficulties arose when companions who need to communicate couldn't see each other, suggesting maintaining a line of sight between companions supports communication
- distributing resources which rely on each other at separate locations prompted social interaction between companions. In the situation at GD the information at station 2 informed the group when to use controllers at station 1. Visitors often engaged in social

interaction and coordinated actions when they understood the connection between the two stations and could see and understand the information

- the difficulties involved in using two controllers in close proximity may encourage companions to share controllers side by side which was observed at station 1 at GD
- the observation that stepping back from interaction aided in understanding of the exhibit, prompted social interactions and led to visitors sharing controllers with companions. In trying to understand how different parts of the exhibit related to each other, visitors stepped back from interaction at station 1 which often led to visitors handing over of controllers to their companions and directing the action of their companions with the exhibit. This aligns with previous research suggesting the configuration of action and view points plays a role in companions social activities and shared interaction with an exhibit (Hindmarsh et al., 2005).
- The observation that visitors' movements to different parts of the exhibit occurred while exchanging controllers located at different parts of the exhibit with companions (Vignette 6). Perhaps encouraging movements during use of the exhibit is related to shared interaction during which visitors can understanding their companions' interactions and the exhibit from different perspectives

5.4.2 FF: Visitor Interactions with the Exhibit and with Each Other

The FF installation was a highly popular and busy exhibit. During one hour of video and audio data analysed, 28 groups consisting of 79 people (54 children and 25 adults) physically interacted with FF. At no point during the hour was FF not in use. Groups were distinguished by watching the video and observing people coming to the exhibit together, what they say to each other, who people are talking with, who they are repeatedly looking at, if they were trying to maintain awareness of certain visitors and who they stay in close proximity to. These indicators were used to establish members of a group, who know each other. If members of the same group came later than others, these indicators established if they were strangers or included in the group. A variety of groups interacted with FF. These ranged from groups with only one child and adult, groups with two children and adult/s, groups who had a toddler and sibling in them, groups with more than 3 children, and groups in which there was only one child who interacted with FF, shown in Figure 5-29: A breakdown of the groups.

Figure 5-29: A breakdown of the groups

Three of the groups (G1, G11, G17) revisited FF within the hour, indicating the popularity of the exhibit. Children were observed enjoying the exhibit. They were often immersed in the activity. This was illustrated by the energetic body poses some children adopted while using the hose (see Figure 5-30).

Figure 5-30: Body Stances adopted by visitors on the ladder

The Draw and Attraction of the Ladder

FF constantly had a queue of visitors (Figure 5-31), and there were only a few short periods throughout the day when the exhibit was not in use by a visitor. Most children were initially drawn to the ladder, implying it is the most desirable position. It was unusual for children to initially be drawn to the wheel or to queue at the wheel controller. As a result of the exhibit's popularity and the consistency of its queue of visitors, many parents encouraged their children to leave FF before they wished to, in order to let other children use the exhibit.

Figure 5-31: Queue at the FF (also large queue at the end of the video)

The ladder was evidently an enthralling piece of the exhibit; some children did not interact with the hose at any point, and instead only engaged with the ladder. In particular, younger children (see Figure 5-32) would simply climb and stay on the ladder but only occasionally using or completely neglecting the hose, while the ladder was moved by the person using the wheel controller. While they may not have been using the hose, the experience of standing on the moving ladder and being embedded in the exhibit included children in the activity. As their companions moved them on the ladder, they shared the activity with the group. It is possible that the level of strength and dexterity required to handle the hose made this action difficult for toddlers, and simply standing on the ladder provided a way for them to engage in the activity with their siblings.

G1 *G6* *G7*

Figure 5-32: Visitors being on the ladder at FF

As well as toddlers, other groups also frequently stood on the ladder alongside their companions. Figure 5-33 shows various members of a larger group who have all climbed the ladder.

Figure 5-33: Large group on the ladder while one child uses the hose

The arrangement of the exhibit presented children with a decision: to queue for the ladder and hose, or move to the wheel and lose their place in the queue for the ladder and hose? Faced with this decision, children tended to avoid using the wheel controllers until after they had used the hose. Thus, the arrangement of the exhibit to some extend hampered the use of the wheel controller. This choice is discussed in greater detail in the later section titled 'Patterns of Moving and Swapping between Positions' on page 178. However, enticing children to queue for the ladder presented adults in the group with an opportunity to physically interact with the exhibit along with their children. The queue therefore gave adults physical input into a situation that may otherwise have been dominated by children physically interacting. I will discuss adults' physical interaction with the exhibit in a subsequent section entitled 'Accompanying Adults Physically Interacting with the Exhibit'.

Coordination with Others

While interacting with the exhibit, visitors coordinated their actions with companions in different ways. For example, visitors searched for fires in the windows together, pointed out fires, requested the ladder be moved, acted in response to their companions' requests to move the ladder and while at the hose visitors turned to look directly at their companions. All of these behaviours were frequently observed in groups using FF. I will refer now to Vignette 10 and Vignette 11 to illustrate the ways groups coordinated their actions.

Vignette 10: Coordinating Actions, searching and pointing out fires
Group ID: G1
1 adult and 4 children.
Mum: pink scarf, blonde hair, snow leopard top
Girl 1: Sally: (toddler) with leopard print jacket
Girl 2: Rosy: (toddler) pint jacket
Girl 3: Amy (7) Khaki jacket with hood up
Boy 1: Mark (6) Blue jacket with hood up

The group wait for a fire to appear in a window, in the meantime moving to windows that have red lights in them but not fires.

A fire appears in the window and Sally points it out shouting *"hhoooo"*

Toddler points out the fire

Amy on the ladder turns to look directly at her. Then Mum points out the fire too *"oh look look, there you go"*.

Girl on the ladder looks back to them

A man from another group waiting with his grandchild starts to point out the fire as well.
Amy looks back at the fire and starts rocking on the ladder from side to side to try and move it. The boys on the ladder with her try to see it too.
Amy asks to be moved on the ladder *"Mummy I said ..."*

Mum is half talking to the stranger *"...trying to steer it but it doesn't seem to do anything"* (referring to the wheel)

They all point out the fire

Rosy is already using the ladder. Mum responds to Amy on the ladder and starts to move the ladder using the wheel. Mum: *"right, watch"* as she starts to use the wheel with Rosy.

They move the ladder for her to get to the fire

In Vignette 10, we see how visitors coordinated their actions. For example, bystanders pointed out the fire to the group, which sparked more group members to join in pointing out the fire; the hose operator looked back to others in the group for guidance, communicating with the wheel operator; and other members of the group moved the ladder to manoeuvre it into into a desirable position. Many members of the group were involved in sharing the overall activity of interaction with the exhibit. The next vignette highlights the frequent behaviour observed of people on the ladder pointing out the position to which the ladder should be moved.

Vignette 11: Coordinating Actions, directing where to move the ladder
Group ID: G8
1 adult and 2 children.
Mum: Short blonde hair, dark green jacket, bag across body
Boy 1: Fred (11) short brown hair, navy hoodie
Girl 1: Barbara (5) red hair, pink dress, navy jacket

The children approach the ladder and go straight up, along with another child from a different group behind them.

Mum walks forward to the wheel controller saying *"right, ready to go"*

Mum: *"right, what do you do Barbara?"* Mum continues: *"trying to put the fire out aren't you"*

Fred puts his hand on the hose, helping his sister while she presses the button.

Fred notices the red lights in the windows to the left and points to them. Mum responds by moving towards the windows.

Mum: *"right, lift it up and then fire, fire it!"* she stops turning the wheel but they still aren't fully positioned at the window Fred pointed to.

Fred starts to point to the window again.

Then Fred feels the fake water coming out of the hose (a piece of material being blown by a fan coming out of the hose) and places his hands back on the hose along with his sibling. Mum responds by moving the ladder for them again.

Vignette 11 highlights the frequently observed behaviour of people on the ladder pointing out the position to which the ladder should be moved. As vignette 11 demonstrates, the person or persons on the ladder requests the wheel operator to move the ladder to a particular location. The behaviour highlights how the physical separation of controllers that manipulate different elements of the exhibit can interlink companions' activities. To successfully interact with the exhibit, companions must rely on each other. The separation of these controllers therefore created a reliance upon companions and enabled companions to share physical interaction, giving them mutual involvement in the activity. Thus, fostering social interactions between companions.

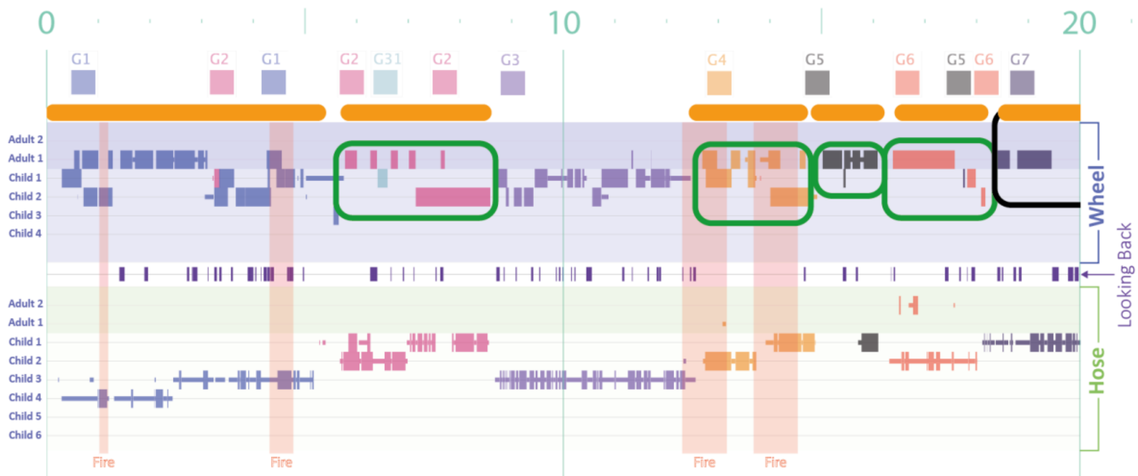
A frequent behaviour of people using the hose was briefly looking back towards the wheel, and person using the wheel. This action is evident in images shown in Vignette 10, and in the data visualisation shown below in Figure 5-34. Encouraging a visitor who is holding a controller and is directly in front of digital content to turn their attention away from the exhibit towards other people is an unusual behaviour in a museum context. However, this behaviour can support bonding and social connection at exhibits. I believe this behaviour stems from the interconnected controllers and their separation, which created reliance between group members and encouraged teamwork.

Figure 5-34: Visitors looking back from the hose to companions moving the ladder

Accompanying Adults Physically Interacting with the Exhibit

Importantly, adults were also observed frequently physically interaction with FF alongside children. The orange lines at the top of the visualisation in Figure 5-35 indicate groups in which parents were actively involved in using the wheel controller. They indicate instances during which parents either physically used the wheel themselves which often was for more than half of the time they were at the exhibit, or when parents supervised children's interaction they would dip in and out of using the wheel controller along with children. In some cases, parents would take over use of the wheel from children so parents could move the ladder themselves. Unlike children, parents were typically drawn to the wheel. The green boxes in the visualisation highlight 11 situations in which parents interacted with the wheel controller before children. The black boxes highlight 8 groups in which only adults interacted with the wheel controller. 6 of these groups had only one child in the group. In these cases, an adult would use the wheel and move the ladder while their child was on the ladder using the hose. For groups with only one child, the interplay between the two tangible controllers and control of the activity being distributed across them, facilitated a shared activity between children and parents. As such, in these situations, supported parent and child bonding while using the exhibit. Furthermore, the arrangement of the exhibit allowed children to independently carry out their own interaction with the hose while on the ladder, but also facilitated parental support and involvement in the activity.

The arrangement of the exhibit enabled children to use the hose while parents were included in the activity and shared interaction by moving the ladder. 21 out of the 28 groups had a parent who moved the ladder while a child or children were on the ladder, as illustrated below in Figure 5-35. FF therefore gave family groups an opportunity to do an activity together. Children could experience the exhibit by being on the ladder, while parents were actively involved in shaping that experience by moving the ladder. All groups except for G11 had at least one adult who physically interacted with the exhibit. It is possible that parents had such ample opportunity to interact with the exhibit as children were drawn to the ladder and hose, thus opening up the wheel position to parents.



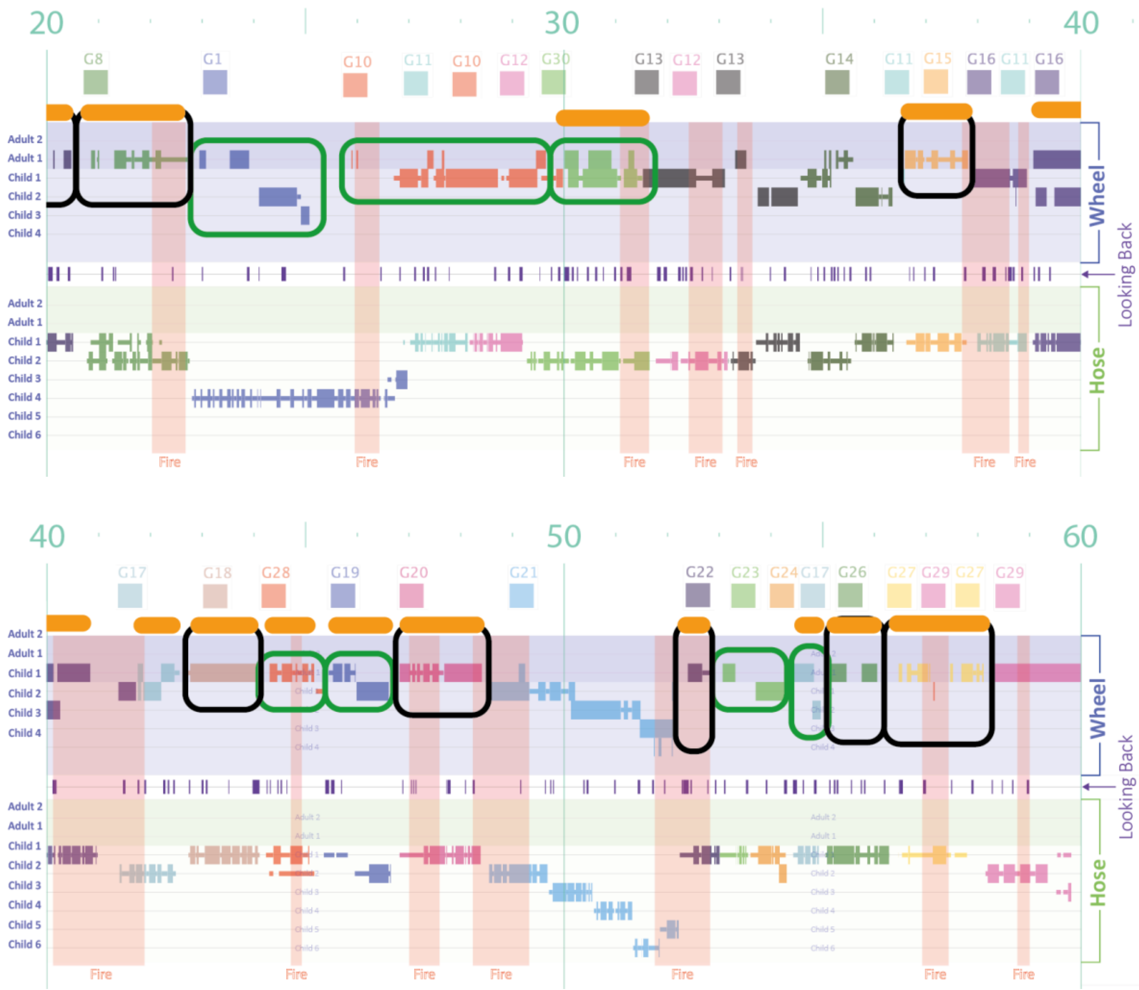


Figure 5-35: Parent physical interaction with FF

For some parents, their interaction with the wheel controller occurred when the children from the same group swapped positions with each other. Presumably, parents assumed this position to prevent children from a different group moving in to use the wheel controller while their children swapped positions, as shown below in Figure 5-36.

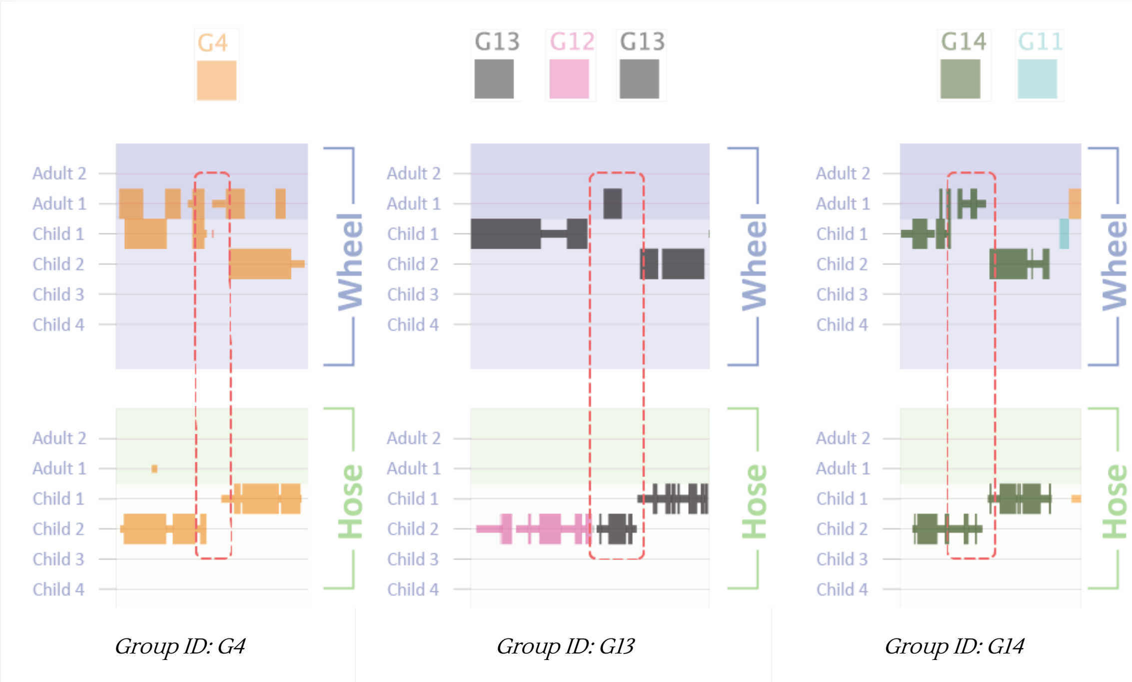


Figure 5-36: Parents using the wheel while children swap positions

These situations demonstrate how the physical distribution of tangible controllers and the relationship between these controllers encouraged children up the ladder, filtering them away from the wheel controller. The arrangement of the controllers therefore gave parents the opportunity to physically interact with the exhibit along with their children.

Patterns of Moving and Swapping Between Positions

Movement patterns developed when visitors interacted with the exhibit. In particular, three patterns emerged regarding visitors' movements between different tangible controllers. The first pattern was rare during which visitors directly swapping positions with companions. The second pattern was more frequent in which visitors moved from the hose to the wheel but the opposite movement was not observed as frequently. The final pattern of movement was when multiple people exchanged various positions at one time.

Directly moving and swapping controllers

One observed pattern was children directly swapping positions between the hose and the wheel controllers. This behaviour typically involved parents guarding the wheel while the children moved, as seen in Figure 5-36. This behaviour was rare, with only 3 groups observed engaged in this type of direct swap over.

Movement to the wheel after using the hose

A more frequently observed pattern was children moving from the hose controller to the wheel. There were 13 instances of children using the hose first and moving to use the wheel afterwards, which are illustrated in the visualisation in Figure 5-37 by the purple highlighted boxes. Four of the children who moved to use the wheel after using the hose did not continue using the wheel for any sustained period of time, either because their group was leaving, or because another group was moving in to interact with the exhibit (Tolmie et al., 2014). The opposite movement from the wheel to the hose was not as frequent, with only 6 children using the wheel first before moving to the hose. This movement is illustrated by the blue boxes in Figure 5-37. It is possible that following their initial use of the ladder, visitors realised the importance of the wheel controller and its relationship to the effective use of the hose, and consequently wish to move to the wheel. The ability to move between positions in this way potentially allowed children to gain different perspectives of the same activity and encouraged children to support each other's interactions. I would argue that this pattern developed because of the ways control was distributed. Crucially, control was distributed at the exhibit through the relationship between the tangible controllers. as well as through their physical distribution. For example, the effective use of the hose controller was reliant of use of the wheel controller. This relationship was not to always immediately evident to visitors. However, once they had used the hose, visitors developed an understanding of how the exhibit worked, which encouraged them to move to the wheel. Future designs could use the idea of visually implying a primary desirable position at an exhibit as a design tactic. For example, creating a desirable position which initially attracts visitors that has a primary controller (up the ladder to the hose), along with a secondary controller which appears less desirable, but the secondary controller is vital for the primary controller to function effectively. This design could make it easier for visitors to move away from the primary controller and to hand over control of the exhibit to companions.

Figure 5-37: Visitors' movements between the controllers at FF

Exchanging Positions

Another pattern observed at FF was several members of groups exchanging positions and controllers. Often these exchanges began with a child descending the ladder, gradually moving towards the wheel, and then displacing the wheel operator. When this happened, another child would take their place at the hose. The visualisation in Figure 5-38 illustrates how the group shown in Figure 5-33 exchanged positions. As children moved between the controllers, control was passed between many members of the group. All members then remained at the exhibit in different positions, including on the ladder.

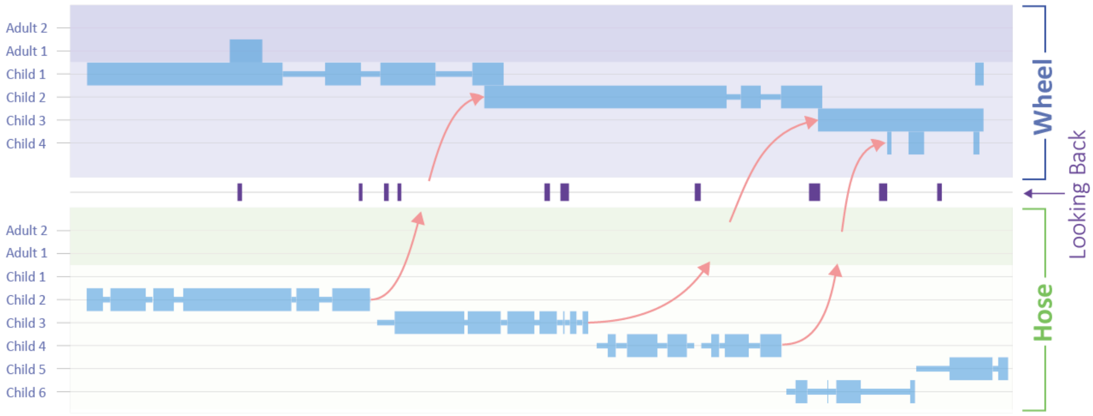


Figure 5-38: Group G21. Movements between controllers

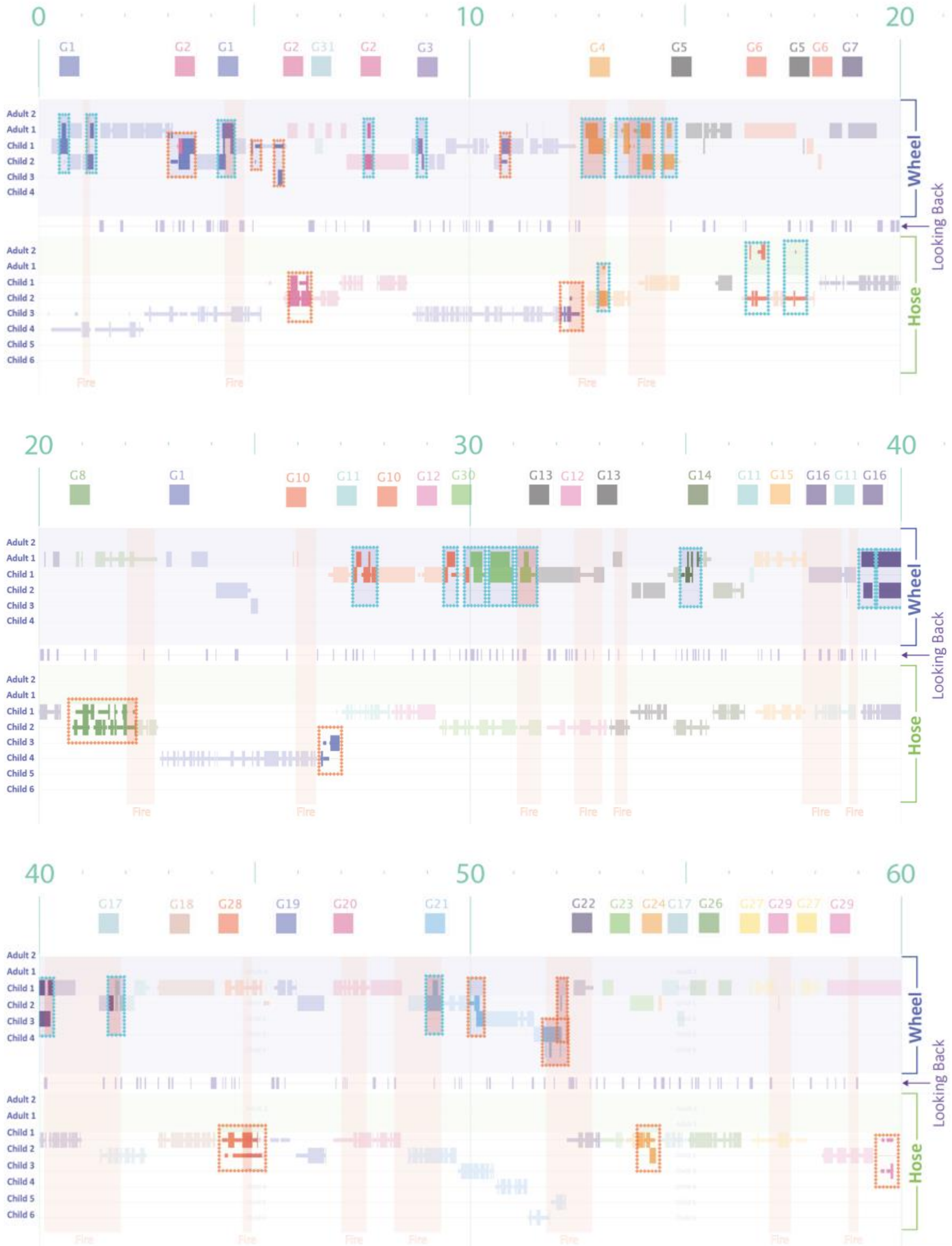
The visualisation in Figure 5-38 shows child 2, child 3 and child 4 using the hose first and then moving to the wheel afterwards. This action is highlighted by the red arrows in the visualisation. Visitors were encouraged to try out a different interconnected controller after using the hose. The physical arrangement of the tangible controllers and group members' apparent desire to use different controllers after handing over control of the hose stimulated these movements within the group, leading them to exchange positions. Thus, in exchanging positions, the group engaged in shared interaction with the exhibit. The nature of the social activity between companions at FF centred around handing over control, sharing control, supporting each other to use the hose, and sharing different perspectives of the same interaction.

These three patterns regarding visitors' movements between each other played a role in groups' shared social interactions. When children interacted with the wheel controller first and then exchanged or swapped positions, the overall group stayed at the exhibit for longer, with members of the group interacting with both controllers and supporting each other on the ladder. Therefore, these patterns of movement and exchanging of controllers demonstrate how the design of the exhibit enabled different members of the group being included in the interaction after they handed over controllers. Beyond simply exchanging controllers between group members, the relationship between the wheel and hose controllers meant that different members of the group could support each other by being the wheel turner for their companions on the ladder. Notably, it wasn't only parents taking on this supportive role. After moving away from interacting with the hose controller children often supported their companion's interaction with the exhibit.

The patterns also demonstrate the ways which visitors were drawn to certain parts of the exhibit, and how this led to social interaction. Using one element of the exhibit, such as the ladder and hose, and understanding how it linked to another element, such as the wheel, encouraged visitors to move around the exhibit and experience these related elements. Thus, these interlinked elements encouraged visitors to hand over and share control, and also enabled companions to share interactive experiences and different perspectives.

Sharing the Controllers: Simultaneous & Intermittent Use of a Single Controller Between Companions

As well as moving between positions and the controllers, companions also shared individual controllers either simultaneously and or intermittently. The data visualisation in Figure 5-39 highlights instances when companions shared both the hose and wheel controllers. This section will discuss sharing of each controller, examining how sharing transpired, and considering how characteristics of the controllers influenced visitors to share control of the same controller. As not all behaviours were counted during analysis, here I present behaviours indicating their frequency.



Blue boxes highlight the adults and children sharing controllers.

Orange boxes highlight children sharing controllers together

Figure 5-39: Companions sharing the use of a controller together simultaneously

Visitors (Mainly Children) Using the Hose Together

The visualisation in Figure 5-39 demonstrates that visitors simultaneously shared use of the hose more frequently than the wheel controller. Most commonly, children shared the hose, as highlighted in the orange boxes in the visualisation. In three of these instances, siblings or adults briefly dipped in to use the hose with a child in order to support them, by, for example, pressing the button showing them what to do or repositioning the nozzle towards the fire, shown below in Figure 5-40.

G3-repositioning the nozzle for their sibling

G4-an adult repositioning the nozzle and then pressing button before going back to the wheel

G6- an adult repositioning the hose for the children

G1 - Handover/take over

G24 - Handover invited by older sibling

Figure 5-40: Companions dipping in to use the hose for a moment

Notably, in four instances, children shared the use of the hose for a prolonged period of time, as shown below in Figure 5-41. In all of these instances, an older sibling gave precedence to a younger sibling holding the controller for the entire duration of their interaction with the controller. During these interactions, the older sibling would intermittently use the hose along with them, without taking over the interaction.

G2-siblings sharing the use of the hose | *G8-siblings sharing the use of the hose* | *G28-siblings sharing the use of the hose* | *G29-siblings sharing the use of the hose*

Figure 5-41: Siblings sharing the hose controller

Children who were not operating the hose often touched the pieces of material protruding from the hose as they were blown by a fan to represent spraying water. When touching this material, children did not interrupt the hose operator, as shown below in Figure 5-42. The material qualities of the water also enticed hose operators to touch and feel the water as they were using the hose too, as shown below in Figure 5-42.

Figure 5-42: Group ID G8. Sibling touching fake water coming from the hose.

The hose had physical qualities that enabled visitors to use it simultaneously with their companions. For example, companions could help each other with the task at hand by re-adjusting the position of the nozzle and holding it in position. Alternatively, visitors could touch and explore the materiality of the controller without disrupting the person using it. The size, shape and actions required to use the hose influenced its shared use. It was large enough to be held by two visitors simultaneously, and had two different sections on which two people could place their hands at the same time. Furthermore, to use the hose, visitors were required to hold it in a fixed position rather than to move it rapidly. Therefore, the calm interaction was easy for companions to synchronise their hand actions. Thus, in these situations, the qualities of the tangible controller supported the equal distribution of control during shared use of a single controller.

While visitors only occasionally shared the hose controller, it appeared easy for children to control the hose together, sharing the interaction, if the wished to do so. Despite the situation occurring only occasionally, understanding behaviour is valuable in evaluating social interaction between companions. Siblings are rarely observed physically using the same controller simultaneously, which suggests this is an unusual behaviour. In groups of siblings which included very young children, the older child shared the controller with the younger child in a way that supported the younger child. Therefore, single controllers which foster shared use can facilitate bonding between siblings. In the case of the hose at FF, the physical attributes of the controller supported shared use due to its form, shape and the actions required to operate it all enabling shared use.

Parents and Children Using the Wheel Together

Most commonly, adults and children shared use of the wheel. Instances of this are highlighted in the visualisation in Figure 5-39 by the blue boxes. In these instances, two patterns were evident: 1) firstly parents and children used the wheel together constantly for the duration of the interaction with the controller, 2) secondly, and more frequently, children took primary control of the wheel while parents occasionally and intermittently dipped in and out of using the wheel with children. In 12 instances, parents occasionally and intermittently shared use of the wheel with children. The wheel operator sometimes objected to parents' dipping into use the wheel; at other times this involvement was accepted, or even invited. If objections were made, these were usually subtle and short-lived, for example if a child removed a parent's hand. Parents usually used the wheel controller when there was a fire in the window. In some cases, the child turning the wheel was moving the ladder away from the fire and parents intervened to reposition the ladder. In other cases, a child on the ladder would ask to be moved somewhere, prompting parents to intervene and use the wheel controller with children.

In three groups, children and parents shared the wheel controller for the duration of the interaction, as shown in Figure 5-43. The central image shown below in Figure 5-43 shows Mum and toddler turning the wheel. While Mum turns the wheel, the toddler touches it too, making turning arm motions. Although he is too young to turn the wheel himself, he is able to physically participate in the activity of moving a sibling on the ladder by sharing the controller with Mum.

G4 *G16* *G30*

Figure 5-43: Parents and child sharing interaction with the wheel controller

Children Using the Wheel Together

Less frequently, children also shared use of the wheel controller. One instance, shown in the left hand image of Figure 5-44, involved two toddlers sharing the wheel intermittently throughout the group's interaction while their siblings were on the ladder. Mum also occasionally used the wheel with them. The central image of Figure 5-44 shows an unusual situation in which two boys intermittently shared use of the wheel back and forth between each other while another child was on the ladder using the hose.

G1 *G3* *G21*

Figure 5-44: Children using the wheel together

Short bouts of sharing also occurred. These involved children using the wheel controller with another child for a very short amount of time during handovers, as shown in Figure 5-44. In these situations a second child began to use the wheel along with the first child. The first child then stopped using the wheel while the second child continued, as shown in Figure 5-38 by the children in G21. Handovers of this type at the wheel appeared to occur smoothly. Children rarely objected, and instead, the handovers appeared to be subtle and relaxed. This ease of handover may have been because people rarely had a full and constant grip on the physical controller. Instead, visitors had to repeatedly remove their hands from the controller in order to spin or turn it. It was also large enough to be touched by multiple people simultaneously.

Physical Aspects of the Wheel and Physical Interaction Required

As with the hose controller, the physical aspects of the wheel controller had an effect on people's ability to share it. Visitors often attempted to move the wheel along with others, but usually struggled to do so. Sharing the wheel was difficult, due to the speed at which it needed to be turned and to the gesture required to move it. Visitors' hands or arms would often collide into each other unless they made an effort to change their pace and hand movements in order to synchronise with their companions. The wheel could also be moved slightly without disrupting the person using the hose, which allowed toddlers to play with it and not disrupt the hose operator.

The physical aspects of the wheel and the hose controllers differed from each other. For example, to use the hose together the physical space at the top of the ladder made it difficult for two people to stand side-by-side. In the case of the wheel controller, people could stand more comfortably beside one another. In addition, the form and mounting of the hose allowed two people to have their hands on the controller without blocking their companions' hands. In comparison, the wheel controller was large enough for two people to comfortably place their hands on it together but the action required to use it hampered them sharing the controller. The number of actions required to use the wheel and hose controllers effectively also differed. The wheel required one action which was to turn it. When people tried turn the wheel together, they simultaneously moved their whole arms in the process. Often their movements were out of synch with their companions as they tried to execute the same action. In contrast, the hose required two actions: firstly, is pressing the button; secondly, positioning and holding the nozzle in place, usually towards the fire. The two actions provided different activities for companions to do together with the same controller, potentially avoiding mis-synchronised movements.

While simultaneous use of the wheel was shared more frequently than the hose, the interaction required to use the wheel hindered visitors' ability to share interaction for any prolonged period of time. In contrast, the hose controller could be shared for a longer time. To operate the hose, visitors had to calmly hold the controller in a fixed position, pointing at a fire. In contrast, the wheel required rapid movement. The hose supported child-child bonding and shared social interaction, while the wheel supported adult-child shared social interaction.

Strangers

Finally, in 11 instances, strangers interacted with the exhibit at the same time, moving the ladder for another stranger, as highlighted in Figure 5-45. For example, at no point did the boy from G10 use the hose himself. Instead, he remained at the wheel moving the ladder for three different groups he did not know.

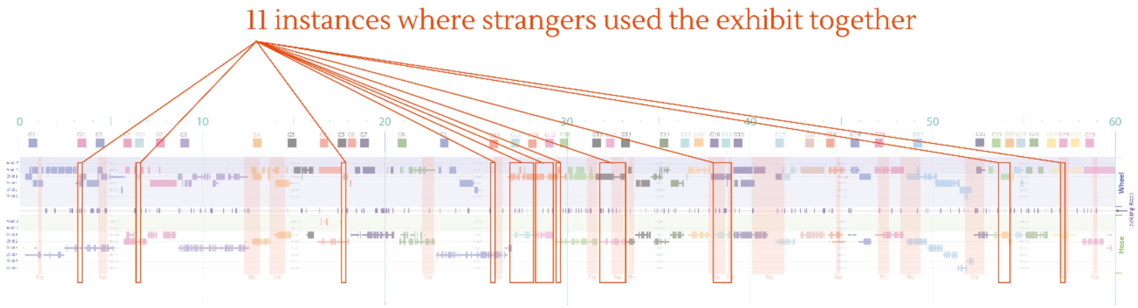


Figure 5-45: Strangers interacting with FF at the same time

5.5 Discussion

The discussion reflects upon the findings from the evaluation of both GD and FF. The discussion begins by considering the nature of companions shared social interactions (RQ2) and how control is distributed (RQ3). Finally, I discuss key insights gained from this study that inform the final study in this thesis, Study 3, and which contribute to the overall PhD argument I present in Chapter 7: Discussion.

5.5.1 Companions' Shared Social Interactions

When developing museum experience, it is important to consider ways of enabling multiple visitors to participate in the interaction with an exhibit and including others in the activity surrounding the interaction (Heath et al., 2005). Equally, it is important to consider ways of enabling visitors to engage in social interaction with companions, and support complex forms of collaboration and interaction (ibid). Visitors at GD and FF engaged in a variety of social interactions and shared interaction with the exhibit. These interactions occurred when visitors were:

- coordinating their interactions with the exhibit
- aligning their actions with companions
- responding to companions' suggestions
- relaying information to companions that guided their interaction

- sharing the interaction with the exhibit using different controllers, including the interplay back and forth between different controllers on a temporal level. For example, the exchange of different controllers over the time a group interacted with the exhibit
- in close proximity to companions and included in the activity, sharing the experience of being on the ladder with companions
- sharing the use of the same controllers together
- supporting companions in their actions with the exhibit

There were several commonalities between the exhibits relating to shared social interaction such as:

- the interplay of controllers between companions
- the physical separation of controllers and important parts of the exhibit
- companions' reliance upon each other
- opportunities for companions to support each other
- drawing visitors' attention to their companions
- visitors' movements at the exhibit and between each other
- the different ways in which sharing occurred at the exhibit

I will now discuss each of these factors in greater detail below.

Social Interaction Based on Interplay between Different Parts of the Exhibits

Social interaction and shared use of the exhibits with companions most commonly occurred when visitors used different controllers, relayed information from different parts of the exhibit, and coordinated with others. I understand this to be the interplay between different parts of the exhibit.

At GD, visitors' frequently[5] interacted with companions when trying to understand how to use the exhibit, when utilising different pieces of the exhibit, or when coordinating their actions with companions. It is not unusual to observe companions attempting to understand how to use an interactive exhibit together. Within the field of museum studies, this action can be viewed negatively (Hornecker, 2008). However, the separation of digital content and vital information from relevant controllers appeared to prompt a number of social interactions. For example, this separation encouraged companions to coordinate their actions, and to guide their companions' interactions; encouraged visitors to step back from interaction and to move between different parts of the exhibit which led to handovers of control and shared social interactions between companions. The separation of different parts of the exhibit prompted visitors to move back and forth between different parts of the exhibit, observing the exhibit and also observing what companions were doing. In addition, the variety and shifting use of different pieces of the exhibit hampered single visitors' dominating the interaction.

At FF, visitors shared social interactions played out in multiple ways. For example, companions interacted with separate controllers in coordination with each other; directly shared the same controller with each other; searched for and pointed out fires together; or simply stood on the ladder along with others while another person physically moved the ladder. Similar to GD, visitors' social interactions were typically orientated around the use and interplay of different controllers between companions. This interplay elicited communication and encouraged companions to coordinate their actions. These findings support the work of Hindmarsh et al (2005), who found similar coordinating behaviours in the museum space at exhibits where digital content was not visible from the action points at which visitors manipulated digital media , but was visible elsewhere at viewpoints. Thus, separating the viewpoints and actions points from each other.

The findings support previous related research from Hindmarsh et al (2005), which suggests that an understanding of the relationship between separate elements of an exhibit can foster social

[5] 7 out of 9 groups were observed engaging with companions in relation to the exhibit at least 5 times over the course of their time at the exhibit.

interaction and shared use of exhibits. This finding is particularly relevant to GD, as at this exhibit visitors initially struggled to understand the connection between different parts of the exhibit. Upon realising the connection, companions communicated with each other and coordinated their actions.

Companions Engaging in Simultaneous and or Sequential Interaction

Both exhibits guided visitors to use particular controllers at specific moments, encouraging visitors to coordinate their actions with companions. The FF exhibit strongly encouraged sequential interaction, whereas at GD, different visitors often engaged in simultaneous interaction alongside each other, or a single visitor used two controllers simultaneously at station 1. At both exhibits, visitors tendency to turn their attention towards companions during interaction was reduced when they engaged in simultaneous interaction. This observation suggests that a sequential pattern of interaction could be more supportive for companions social interactions at interactive exhibits. Similarly, Block (2015) found there are benefits when visitors take turns to interact at exhibits, engaging in sequential interaction,. For example, people spent longer at exhibits and engaged more with the topic, narrative and content.

Coordinated actions at FF were more frequent, shorter and less complex than at GD. GD required highly demanding coordinated actions, for example when visitors had to quickly relay information, and add water or coal. At FF, coordinated actions were less complex and did not require continuous parallel interactions with the exhibit. In contrast, at GD visitor’s attention was often distributed, attending to their own interactions with the exhibit, making it difficult for companions to align their attention and to coordinate their actions together. At FF, there were not several simultaneous events occurring at any one time. Finally, FF encouraged open-ended interaction, whereas GD had a structured set of steps with a clear start and finish.

Different Communication and Coordination between Companions

The distribution of resources and division of labour also had an impact on how actions were coordinated of at both exhibits. The nature of how visitors coordinated actions played out appeared to be influenced by their understanding of the relationship between parts of the exhibit and of the exact moments when they should coordinate their actions. At GD, there was frequent direct verbal communication between companions. At FF, there was less direct verbal communication, but most coordinated actions were highly effective. It is thus important to highlight these varied trade-odds. For example, the more complex interactions with an exhibit (GD) may elicited direct verbal communication but the less complex interactions (FF) may spark less communication but lead to effective coordinated actions.

How controllers related to each other was more explicit at FF than GD. Potentially, this effectively supported companions to cohesively coordinate their actions at FF. This finding aligns with previous research suggesting that an understanding of the relationship between different parts of an exhibit can support social activities between companions (Hindmarsh et al., 2005).

The majority of coordination which took place at FF did not involve visitors explicitly guiding each other. Instead, actions were coordinated through glances, rather than by verbally communication. In contrast, at GD, companions often verbally guided each other step by step through interaction. At FF, visitors most frequently coordinated their actions when fires appeared. Visitors on the ladder relied on companions at the second controller to interact by moving the wheel so that they could effectively use the first controller. At GD, visitors coordinated their actions by handing over and handing back the same controllers with companions, and guiding their companions' use of controllers based on information they were accessing. Overall, coordinated actions at GD were more sporadic and varied than actions at FF.

At both exhibits, visitors guided companions as to how to use controllers. At FF, this occurred when visitors pointed out fires, instructed companions to use the wheel in a particular way, or moved the hose into positions for toddlers to use. At GD, visitors instructed their companions how to use controllers based on the instructions from the screens, or waiting for the pressure to go up.

At FF, there was less direct social interaction between companions than at GD. At FF, companions' social interaction was based on aligning their actions, when they were in close proximity to each other, or had a shared focus in doing an action together. Verbal communication did occur but not to the extent that it occurred at GD. At GD, there was more direct communication and interaction between companions. The social behaviours observed at GD closely relate to Ludvigsen's (2005) conceptual framework model outlining different social interactions in a hierarchy, which was discussed in greater detail in Chapter 2. Ludvigsen's research demonstrates that companions engaged in different categories of social interaction such as collective action, dialogue and shared focus, shifting between these categories repeatedly (Ludvigsen, 2005).

Visitors Turning Their Attention Towards Companions

At both exhibits, visitors not only focused on their personal interaction with the exhibit but also turned their attention to companions. The ways visitors focused on companions at GD and FF differed. At FF, the primary interactor would turn their attention away from the exhibit towards companions at the secondary controller at very specific moments. These moments appeared to be linked to the sequential nature of the use of different controllers at specific times prompted by the exhibit, which involved staggered sequential interaction. At GD, companions' turned their attention to each other more sporadically, and these actions were not directly linked to the sequential use of different controllers. Nevertheless, at both exhibits, the distribution of important resources between companions, the arrangement of particular moments these resources were useful and the connection between these resources appeared to encourage visitors to balance their attention between their personal interaction with the exhibit and their companions. This finding relates to the work of Debenedetti (2003), who argues that museum exhibits should support an interplay between social and individual experiences.

The findings reveal how companions interacted with the exhibits alongside each other during which visitors shifted their attention between companions, the exhibit and their personal interaction with the exhibit.

Difficulties When Coordinating Actions

The study highlighted a number of difficulties that companions face when coordinating their actions and engaging in shared social interaction at exhibits. Particularly exhibits like GD where these difficulties are compounded by multiple simultaneous inputs and the vast amount of stimuli demanding visitors' attention. These competing demands for visitor's attention hinder their ability to focus on companions and communicate with them. In contrast, at FF, there were fewer stimuli and the exhibit directed companions' attention to a single focus. FF almost paused the interaction at the primary controller which shifted focus from the primary controller to the secondary controller, maintaining companions' aligned attention. Thus, findings from FF support the argument that it may be difficult for companions' to work together cohesively when their attention is distributed. In a museum context, supporting joint attention helps to foster conversations relating to the object of interest (Povis and Crowley, 2015), (Simon, 2010b). Finally, the distance between communication points at GD made it difficult for visitors to communicate effectively and allowed other visitors to stand between companions thus blocking their communication and reducing visibility, and hindering their social interaction while interacting with the exhibit.

Interaction was structured differently in terms of time and pacing at the two exhibits. This structuring appeared to impact on the ways which companions coordinated their actions. At GD, the temporal sequence of interaction was tightly structured. Visitors had only a short amount of time to coordinate their actions and guide companions before the exhibit failed. The **limited time** stifled companions coordinating their actions for any prolonged period of time, and from building any sense of momentum when working together. In contrast, at FF, the temporal structure of the interaction enabled visitors to coordinate their actions throughout the entire activity at certain moments, without limiting the time that visitors had to coordinate actions together. Previous research has suggested that time constraints can hamper companions' ability to talk about the topic with each other, or for visitors to refer between digital resources and related museum artefacts on display (Hornecker, 2016). Furthermore, time constraints impact negatively upon visitors' social experience in the museum, by limiting their ability to coordinate their actions together at their own pace.

In addition, whereas at GD visitors always failed, with the steam engine either flooding or blowing up. Punishing visitors in this way led to frustration or confusion for visitors when they were coordinating their actions together and following prompts from the exhibit. In addition, GD always failed, with the steam engine either flooding or blowing up. Punishing visitors in this way prompted frustration or confusion from visitors when they were coordinating their actions. Consistently failing to reward or even punishing visitors' interactions with an exhibit can also have a negative impact on their social interaction. Although the museum's intention was to communicate the difficulty of running a steam locomotive, often visitors were left frustrated or dissatisfied when it failed so quickly, and no longer interacted with the exhibit. Punishment or failure to reward is a thus valuable consideration when designing future installations which encourage social interaction. For example, the exhibit could instead have been designed so the steam locomotive stopped, rather than exploded or was flooded, which would have allowed people to re-start the engine and successfully reach a destination. However, there is a balance to be struck here. It is also important to ensure that an activity at an installation is not too easy for visitors. Perhaps this balancing act between being too easy or too challenging is specific to each context and is a worthy reason to implement formative evaluations. The challenge offered by GD clearly motivated visitors to some extent, as they often repeatedly the interaction loop a number of times. Thus, the findings from GD support Csikszentmihalyi's (2017) concept of flow, which posits that matching people's skills to challenges they can overcome helps them to enter a state of consciousness called flow, associated with satisfaction and achievement. However, it should also be noted that being unable to overcome that challenge can be frustrating. Therefore, exhibit design must consider how difficulty and reward or lack thereof will impact on visitors. One way of supporting exhibit design in this challenge is through formative evaluation during the installation design process.

The issues highlighted here from the findings from GD and FF provide further support for previous research concerning social interaction between companions who are interacting with exhibits at which action and viewpoints are separated. Such research, such as Hindmarsh *et al* (2005) and Hornecker *et al* (2007), suggests that certain qualities of the exhibit including distance and visibility between key points of interest at the exhibit must be considered when designing exhibits which encourage social interaction.

Companions Relying and Depending Upon Each Other

It has previously been recognised that encouraging interdependency during collaborative activities can reduce conflict and encourage companions to explain their own intended actions to others (Wise et al., 2015). Reliance and dependency between companions was evident at both exhibits. Both exhibits required companions to rely on each other to some extent for their own effectively interaction with the exhibit. However, at both exhibits different controllers manipulated digital content with varying levels of influence, and certain controllers were more reliant on partner controllers than others. Thus, reliance was imbalanced at both exhibits. For example, at FF there was a dependency in only one direction. A visitor could not effectively use the hose without a companion at the wheel moving them into a suitable position. However, use of the wheel was not dependent on another controller; the person at the wheel did not rely on another companion using a controller to enable them to use the wheel. Similarly, at GD a visitor at station 2 was unable to effectively manipulate the digital content unless the visitor at station 1 used their controllers in a particular way. The use of the pressure lever at station 2 was ineffective unless visitors at station 1 had built up pressure in the locomotive using the controllers at station 1. As a result, the visitor at station 2 relied on the visitor at station 1. Visitors at station 1 were to some extent reliant on visitors at station 2 but this was not a result of the relationship between the controllers. Instead, it was a result of distributing valuable information away from the relevant controllers at station 1, as useful information required to operate station 1 was located at station 2, visitors at station 2 had to relay information to the visitor at station 1. In this case, the reliance appeared to encourage visitors to turn their attention to their companions, communicate and interact socially, coordinating their actions and guiding each other.

Encouraging companions to depend on one another has been previously recognised as a means of fostering social interaction and bonding in both the field of CSCL (Wise et al., 2015) and some HCI research (Rogers et al., 2004). Some related literature has discussed exhibits which are unusable without a companion to share the interaction (Hindmarsh et al., 2005) (Wakkary et al., 2009) (Taylor et al., 2015). However, at present, limited research has recognised the benefits of dependency in multi-user museum interactive exhibits. Instead, many multi-user exhibits favour independent parallel interaction, often involving competition. Co-dependency on others during interaction also appears in game design strategies. It particularly relates to the scale developed by Benford (2000) by considering how exhibits enforce, encourage or enable collaboration (Benford et al., 2000). Considering this scale, it is evident that both FF and GD enforce collaboration, as both exhibits are nearly impossible to use without companions. Crucially, children often try to interact alone in museum contexts if they can. Thus depending on companions may therefore be a suitable way to foster shared and social interactions, particularly for family groups. Rather than acting alone, exhibits such as GD and FF help children to learn sharing skills; depend upon their siblings or friends; and offer opportunities for parents to physically interact with the exhibit alongside their children, instead of supporting them verbally.

Visitors' Movements and Stepping Back From Interaction

The findings of study 2 suggest that the physical distribution of controllers and desirable positions encouraged visitors to move around the exhibit, drawing visitors to particular areas initially and, during the interaction, initiating a number of social situations. Sharing the interaction with the exhibit, swapping positions and sharing perspectives all contribute to companions social experiences. Rather than experiencing only one position or perspective while using the exhibit, at GD and FF companions could experience different roles and perspectives, thus sharing the activity with companions in this way.

At both exhibits visitors appeared to be drawn to certain desirable positions, which stimulated particular patterns of movement to occur. Thus, prompting companions to share interaction, and fostering co-experience. Enticing visitors to particular parts of the exhibits both initiated and supported movements to and from different controllers. For example, at FF children were typically initially drawn to the ladder. Filtering children to one part of the exhibit, gave parents the opportunity to be included in the activity in a physically interactive capacity at an understated secondary but powerful controller. This is unusual as it is typically children, rather than parents, engage in interaction with exhibits (Diamond, 1986).

A repeated and unusual behaviour at GD was visitors stepping back from interaction at the main desirable position to move or see other parts of the exhibit. In some of these situations, children initially did not want to share the two controllers side-by-side with a companion, but, once they had stepped back from station 1 to view the rest of the exhibit, they began to share the controllers alongside companions as they moved between parts of the exhibit.-The movement of stepping back from interaction at GD supported a number of social situations such as: 1) companions sharing the interaction by handing over and back control of the same physical controllers; 2) visitors stopping their interaction to listen and refer to companions; and 3) visitors mediating and guiding their companions' interaction with the exhibit.

Once they had stepped back from interaction, visitors often began to orchestrate others' interaction with the exhibit. From this position, visitors had the ability to view all of the parts of the exhibit and make sense of how these related to each other, often dipping in to physically interact themselves, or simply guiding companions based on their view of the instructions, pressure levels and mechanical locomotive. As Ackerman argues, stepping in and out of interaction is beneficial for engagement (Ackermann, 1990). Furthermore, stepping back can also benefit the social dimension of a group's experience at interactive exhibits. Thus, this action encouraged social interaction.

When using the primary controller at both exhibits, visitors appeared to realise the usefulness of the resources located at other areas, encouraging movements to different parts of the exhibit and away from the primary controller. These movements prompted visitors to hand over controllers, enabled them to share different perspectives, and afforded them new opportunities to support companions. Future designs could utilise the idea of creating desirable positions as a design tactic. By creating both an attractive primary position and a secondary, but equally vital, position, designs can encourage visitors to move away from the primary controller and hand over control to companions. At both FF and GD, visitors often realised the power and importance of the secondary controller while using the exhibit. A similar pattern was observed by Hindmarsh et al (2005) who reported that companions engaged in social activities upon realising the connection between different parts of exhibits. At FF, reliance on the wheel operator helped visitors to understand of the level of control which the wheel operators had over the situation while they were on the ladder. As a result, visitors appeared to want to operate the wheel controller and gain a different perspective, opening up movements to other areas, letting others interact and swapping of positions.

The idea that an exhibit can stimulate visitors to give up control and move around the exhibit while they were using the central controller is an important design consideration. This movement is potentially impacted by an equality of power between controllers in terms of how they influence the activity. The controllers at FF and GD function in different ways. For example, the magnitude of their influence on the digital content is different and the effectiveness controllers is based on the use of other controllers. Equal or unequal levels of influence of controllers and the ways which companions influence each other at exhibits are thus important aspects to consider when designing exhibits which encourage movement and social interaction. Interconnecting companions' use of controllers has previously been identified as a way to encourage or even enforce collaboration between companions (Benford et al., 2000). However, at present how equality of power is distributed between related controllers impacts upon social interaction it is less understood (Hornecker et al., 2007), (Rogers et al., 2009). Thus, it is an important open question for future research to consider: how different distributed resources in fixed positions relates to equality between companions in a way that stimulates movement and sharing?

The patterns of moving and exchanging controllers observed in both GD and FF highlights how exhibits can include members of a group in the interaction, before and after handing over control of the most desirable controllers. Encouraging movements where visitors disengage from interaction could be a strong foundation to support sharing of control and perspectives, and include parents in the physical interaction with the exhibit. Deprioritising key controllers or positions could thus create opportunities for social shared interactions. This presents an opportunity for future designs and research to consider making powerful or desirable positions appear undesirable at the outset. Exhibits designed with understated positions of control could firstly help to include companions in important physical interactions and, secondly, to encourage visitors to move away from controllers and hand over control, thus sharing the interaction with companions.

Opportunities to Support Each Other

A strength of both exhibits in terms of social value was providing companions with opportunities to support each other. At FF, visitors supported each other by using the secondary controller (wheel), enabling the visitor at the primary controller (hose) to use it effectively. Similarly, at GD some controllers were ineffective unless companions used other controllers. In addition, visitors at GD supported each other by relaying guiding information and by verbally directing their companions' interaction.

The arrangement of controllers and their different functionality also specifically presented opportunities for children to **support each other** and share the interaction together. For example, the relationship between the wheel and hose controllers at FF helped different group members, including children, to support each other by turning the wheel for their companions located at the hose. Thus the exhibit allowed children, as well as parents, to adopt a supportive role.

At both GD and FF companions and, in particular, siblings were able to support each other in a number of different ways. At FF, older siblings were able to support younger siblings by (1) using the controller with them without taking over control, often helping them to use a controller effectively. In these situations, the older sibling was involved in the interaction, while supporting their younger sibling or siblings. Companions were able to share the controller in this way due to its physical form and the gesture required to use the controllers. Similarly, siblings supported each other (2) at GD when they stepped back from interaction and gained an overview of the exhibit, including the guiding information. They would then support companions by directing them as to how to use controllers, thus supporting other people's interaction with the exhibit. Visitors also (3) moved between controllers and exchanged positions at FF, which offered new opportunities to interact with and support each other. Finally, at both GD and FF, (4) visitors used controllers that enabled their companions to use controllers effectively, thereby helping their companions to interact with the exhibit.

There are two aspects to the interaction relating to reliance: firstly, one person relies on a companion, and secondly, the companion is able to support another visitor. For groups with only one child, the interplay between the tangible controllers at FF and control of the activity being distributed across the controllers facilitated a shared activity with parents, supporting parent-child bonding while using the exhibit. This arrangement facilitates children in carrying out their independent use of the hose or being on the ladder **while having the support of parents**.

Future design could support social shared interactions between companions by presenting opportunities to support each other. For example, by creating aspects of the exhibit which require supportive roles, and encouraging companions to move into these supportive roles while using interactive museum exhibits. At FF visitors could support others by interacting with the wheel controller so a companion could interact with the hose effective or at GD visitors could relay useful information to a companion who was using the controllers at station 1.

Ways of Sharing

Sharing between companions occurred in different ways at the two exhibits. At GD, controllers required demanding physical interaction and were located beside each other. This appeared to prompt companions to share the controllers side-by-side. While it was possible for visitors to interact alone at station 1 using both controllers, on occasion companions chose to share the interaction and use of controllers beside each other. The arrangement of controllers thus enabled visitors to share the interaction with the exhibit simultaneously and in close proximity to each other, side-by-side, if they chose to do so.

At FF, sharing the hose controller was straightforward due to its size, and it was easy for companions to synchronise their hand actions with those of their co-visitors. In this case, control was thus distributed between companions through the shared use of a single controller, which was made possible by qualities of the tangible controller. These findings support the work of Hornecker (2010), which found companions shared a single controller that enabled them to jointly move along a singular axis and hold it in position due to the physical qualities of the controller. Overall, the hose controller at FF was relatively novel, as it is unusual to provide a controller that supports close proximity, sharing and physical touching of the same controller for a prolonged amount of time.

Importantly, exhibits which encourage shared use of single controllers facilitate bonding between siblings. At FF, the controller supported bonding of this type due to its form, shape and the actions required to use it. A factor which may have encouraged shared use of the same controller was the level of skill required to use the hose. This made it **difficult for younger children to use** the hose, thus prompting older children or parents to help by sharing the controller with them. Principles of usability suggest that **making things difficult to use** is poor design practice, and as such it is possible to view young children's difficulty using the hose controller as a design flaw. However, it is also important to recognise that the situation provided companions with opportunities to control the exhibit together and bond with each other by helping others. Situations in which visitors need help can result in companions sharing and spending quality social time together. Furthermore, unlike GD, FF also gave visitors the opportunity to be embedded in the exhibit with companions on the ladder. This allowed visitors to share the experience and engage with their companions and with the exhibit in an embodied manner, rather than simply watching.

Controllers located side-by-side at GD allowed companions to share their interaction with the exhibit in close proximity to each other, and share controllers back and forth as they moved between viewing points and action points. In previous studies, companions sharing a single controller at a public interactive exhibit in this way has rarely been rarely reported (Hornecker 2010).

The study highlights different ways in which companions shared the interaction and the overall activity such as:

- Sharing controllers side-by-side in close proximity to companions
- Using the same controllers simultaneously which happened both between parents and children, and between children and included dipping in and out of sharing
- Sharing the same controller back and forth intermittently, enabling distributed control through shared objects (Simon, 2010b)
- Sharing by handing over control while stepping back and moving to other parts of the exhibit
- Sharing the activity by using different controllers in coordination with companions
- Sharing the activity by guiding the use of companions using controllers
- Sharing the experience by being embedded in the installation alongside companions who are interacting, such as being on ladder at FF

The study has highlighted several areas for further research, which are reflected in the following questions:

1. What is shared control? Is it related to accessing important resources, other than distribution of controllers between companions? How does the interplay between controllers functionality (what controllers do) and temporally (when to use them) impact on shared control?

2. How does equality play out between companions? How frequently are different resources used? How powerful are controllers? Are there primary and secondary desirable positions?
3. How does the exhibit create reliance between companions and encourage/enable visitors to support companions?

The findings from study 2 suggest there is value being involved in the activity by influencing the interactions with the exhibit, suggesting value beyond only constant interaction. Study 1 found indications of value in this way from the study of the Ark exhibit too.

5.5.2 Distribution of Control

The findings from this study partly answer RQ3, which concerns how control is distributed and the role this plays in companions' social and shared interactions at the exhibits. At both FF and GD control, was primarily distributed through the provision of multiple tangible controllers. Controllers were physically distributed at the exhibit, but the relationship between different parts of the exhibit also had an impact on how control was distributed between companions. For example, the different ways controllers functioned, their interconnectedness, and the appropriate and counterproductive moments at which visitors were required to use them, all had an effect on how control was distributed between companions. I will now discuss associated characteristics which relate to the distribution of control at GD and FF, including:

1. The relationship between different functioning controllers
2. Temporal distribution of control, or when visitors are required to use controllers
3. Physical characteristics such as size of controllers and actions required to interact at FF
4. Indirect secondary control at GD
5. Spatially separated controllers in fixed positions

1. The relationship between different functioning controllers

It is important to note that both exhibits had controllers that functioned in different ways. As such, the controllers did not have equal influence over the activity. Some directly controlled the digital content, while others controlled another visitor's ability to effectively manipulate digital content creating a dependent relationship between companions. In addition, FF was unusual in that one of the controllers moved part of the exhibit instead of manipulating digital content. Moving the ladder moved visitors standing on the ladder which enabled people on the ladder to manipulate digital content effectively.

At FF, visitors using controller 1, the hose, were dependent on companions using controller 2, the wheel. Unless a companion moved them to an appropriate location, visitors could not use the primary controller effectively, creating a relationship between controllers and companions. However, while companions at controller 1 were dependent on those at controller 2, those at controller 2 were not dependent on those at controller 1. The dependency only goes one way and companions are not co-dependent on each other. This type of dependence between different interactive and digital parts of an exhibit has been highlighted in previous research. For example, Hindmarsh's (2005) study at the Ghost Ship exhibit notes that the viewing of the digital content is unrewarding without a companion interacting with a different part of the exhibit (Hindmarsh et al., 2005), (Rogers et al., 2004), (Wise et al., 2015). It is important to note that dependency can be created in other ways than only distributing controllers but also distributing view points.

The function of the controllers at FF were **closely linked**, in that they both controlled aspects of the same activity and digital content. In contrast, at GD, the controllers used by different companions functioned in different ways and were less obviously interlinked in terms of what they manipulated and controlled. Understanding the relationship between different parts of an exhibit shares a parallel to HCI models which argue for good feedback, stimulus and response to support interaction between a user and the system (Norman, 1988). Accordingly, visitors should be able to understand how their actions relate to their companions, what they can and cannot do, how they can coordinate their actions together, and the resources they have access in order to support the social context of companions interaction at interactive exhibits.

The three controllers at GD manipulated digital content in different ways. At station 1, two controllers manipulated five different outputs: a screen in front of the controllers, several water and boiler lights display, and a pressure gauge located away from the controllers. At station 2, one controller manipulated one output: the mechanical steam locomotive. There appeared to be an imbalance between controllers at different stations, as some visitors had more influence over the activity than others, and it was difficult to immediately understand the connection between controllers and stations. Visitors at station 2 were reliant on visitors at station 1 to manage the coal and water. In contrast, visitors at station 1 did not appear to depend on visitors at station 2. Instead, they were reliant on information that appeared on screen 2 instructing them how to use controllers at station 1. Companions did rely on each other, but the relationship was complex. In contrast to FF, at which visitors were relating to companions interactions in the physical real world in terms of what they were manipulating, at GD, the relationship between companions interactions was mainly in the digital realm, and it appeared to be more difficult to understand how the function of different controllers related to others.

From these characteristics, an opportunity for future research and design is to consider how different **functioning** controllers can create relationships and can spark social interactions between companions.

2. Temporally, When to Use Controllers

At both GD ad FF, there was a distribution of control on a temporal level, by encouraging the use of different controllers at different moments. At FF, the exhibit guided visitors to use the two controllers sequentially. At specific moments, the primary controller (hose) was ineffective unless the secondary controller (wheel) had been used first. Additionally, use of the secondary controller (wheel) outside of these specific moments would have been counterproductive to aims of the overall activity, interrupting any ongoing use of the primary controller (hose). Thus control was distributed temporally at the exhibit, as usage of controllers at certain points was either appropriate, ineffective or counterproductive. Furthermore, companions were also dependent on each other at specific moments. At, FF the interrelatedness of the controllers and their sequential relationship was evident. The exhibit thus effectively guided visitors to use the two controllers in coordination with their companions.

At GD, the temporal relationship between the three different controllers was not as clear. Often, the exhibit involved simultaneous interaction with all three controllers. Companions could interact with a number of controllers simultaneously, without any counterproductive outcome for a companion. In addition, visitors at station 1 often used two controllers simultaneously, hampering their ability to coordinate their actions with companions at station 2.

GD to some extent attempted to encourage visitors to use controllers in a considerate manner, by displaying guiding messages on screen 2 and waiting for pressure to build up in the boiler. However, visitors' faced difficulty in understanding the appropriate and counterproductive use of controllers and were given limited time to respond effectively to guiding messages. While simultaneous use of controllers was possible at GD, the exhibit responded better to sequential use of controllers, and appeared to make more sense to visitors when controllers were used sequentially. As visitors were given limited time and resources to understand this, interaction with the exhibit could be frustrating for visitors.

<u>Interplay between controllers on a temporal level</u>

Overall, there appeared to be less cohesive activity at GD than at FF, partly due to simultaneous interactions. However, at FF, there was less independent exploration than at GD. Instead, FF encouraged greater coordination between companions and visitors often gave companions their sustained attention. As a result, it is important to consider whether cohesive activity and independent exploration are necessarily incompatible behaviours. Other researchers have suggested similar results where companions "do their own thing" engaging in independent interactions, if they can while in a museum space.

3. Physical Characteristics such as Size of Controllers and Action Required to Interact at FF

Distribution of control is often considered to be spreading control over multiple locations or objects to manipulate digital content. However, control can also be distributed between people, if these people are using the same controller together simultaneously, provided that a controller enables them to do so easily. This was observed at FF, at which companions shared the use of the hose. This allowed older siblings to support younger siblings and share the interaction together, coordinating their actions in synch with a companion rather than with the exhibit. The physical shape and size of the controller, along with the dual actions required to use it (pointing and pressing a button), and the gesture required (holding it in position), supported companions in sharing the interaction. The wheel controller appeared to be more difficult for companions to share simultaneously, most likely because the rapid movements and gestures required made it difficult for companions to synchronise their actions. These findings align with the work of Hornecker' (2010) conducted at the Jurascopes exhibit, which found that companions shared the use of a lever that required minimal movement and allowed for shared control and interaction. Visitors were not observed sharing use of a single controller at GD for any prolonged period of time, potentially because placing two sets of hands on the same small controller was awkward or uncomfortable. Furthermore, the controllers encouraged fast movements, and as a result visitors often pushed their companions' hands away.

4. Indirect Secondary Control

Considering the question of how control is distributed, at GD there was a secondary type of control happening, almost an **indirect way of controlling the digital content and activity.** In such instances, companions did not directly use a controller to control the digital content and activity, but instead guided companions in their use of the exhibit, and influenced others' interaction with the exhibit. Thus, I propose that two different types of distributed control were evident at GD: direct and indirect. At the exhibit, distributing valuable information and rewards (outputs) along the exhibits supported indirect control. Control was thus distributed in various ways as companions could participate and influence the overall activity beyond only the use of controllers.

The guiding information provided at GD did not enable control on its own. Rather the information had to be used in combination with controllers. As this information was separated from relevant controllers, important resources were divided between different positions at the exhibit, which encouraged companions to share this information. Thus, to effectively control the digital content, visitors had to access both the controllers themselves and the information on how to use these controllers. This arrangement therefore included companions who were not located at controllers to participate in the activity.

5. Spatially Separated Controllers in Fixed Positions

At GD and FF, control was distributed spatially by placing controllers in separate fixed locations, in effect physically separating controllers. This appeared to create desirable positions and encouraged visitors to move between different parts of the exhibits and between each other. Thus, in addition to their temporal relationship, at GD and FF there is spatial interplay between controllers which also has an effect on distribution of control. The ways control is spatially distributed at both exhibits is an important insight from this study, as it highlights the relationship between companions, based on the interplay between spatially separated controllers.

5.5.3 Main Insights Gained from the Study

The study of GD and FF provided a number of key insights which influence the final study in this research, and significantly shape the arguments I will outline in Chapter 7. Typical for this type of research I suggest design considerations, which previously have been called 'design sensitivities' (Ciolfi 2004), (Hindmarsh et al. 2005). 'Design Sensitivities' are not direct design recommendations for an installation but are considerations for future design and research which is concerned with supporting companions shared social interaction at THIMEs. These insights are outlined in the following considerations for future work:

1. Consider <u>how control can be distributed in different ways</u> beyond distributing physical controllers, such as companions having access to information and resources that guide the use of controllers.
2. Consider staggering interaction between controllers in a sequence and <u>distributing control temporally</u> at different locations and controllers so that there is interplay back and forth between controllers during the task, by implying that controllers can be used either appropriately or counterproductively at different moments

3. Consider **challenges for SSI that visitors face** when trying to interact with the exhibit and with other visitors at the same time, regarding the demand on their attention. It can be difficult for visitors to concentrate on several stimuli simultaneously at an exhibit while also engaging with companions.
4. Consider stimulating a desire to **step back from interaction** or to move between controllers, enabling companions to share different perspectives or roles
5. Consider **equality** between companions in terms of the influence over the activity, influence over digital content, accessing controllers that manipulate digital content in different ways and how frequently different controllers are used during the activity. Should companions be in equal position all the time?
6. Consider fostering situations in which visitors **rely on companions** and can support each other in their interaction. Consider controllers which do not manipulate digital content, but instead supports companions to use their controllers effectively to manipulate digital content, creating reliance and opportunities for companions to support each other
7. Consider how to **draw visitors' attention to their companions** during the interaction rather than only to the exhibit and their personal interaction with the exhibit
8. Consider controllers which recede into the background or are **understated** so they appear less inviting to children. This could help to filter children away from certain controllers and allow parents to interact with the exhibit along with their children

5.6 Conclusion and Summary

The findings from this study focused on the distribution of control and shared social interaction. The findings suggest that distribution of control involves not only the physical distribution of controllers between people, but also the function of these controllers, and their relationship to other controllers, including temporal and spatial aspects of their relationship. Thus, visitors' social experiences could be enhanced by design which considers distributing control in a range of ways, and it not limited to simply providing multiple access point to manipulate content. The main insights from this chapter outline a number of considerations for the development of exhibits which provide multiple tangible fixed controllers with different functionality.

In recent years, an increasing number of interactive exhibits have embraced the perspective that visitors acting independently and shaping their own narratives, by for example generating their own, is beneficial for social and personal engagement (Snibbe and Raffle, 2009), (Taylor et al., 2015). However, as the findings of this study demonstrate, there is still value in structured collaboration in the context of museum interactive exhibits which prioritise social interaction. Indeed, there are different types of social experiences. For example, being in close proximity to a companion, or sharing and socially interacting by coordinating actions with companions during an activity can both be considered social experiences. This argument supports the work of Benford *et al* (2000), who argue there is a spectrum for how systems shape collaborative activity. It proposes that interactive systems can enforce, encourage or enable collaboration by the configuration of resources between group members. The way in which companions collaborated with each other at the exhibits outlined in this chapter is representative of enforced collaboration on the spectrum Benford et al (2000) developed.

In addition to the research findings discussed in this chapter, the study was vital to the PhD research, in that it allowed me to develop a relationship with the Riverside Transport Museum which was crucial when undertaking the subsequent study, 'Razzle Dazzle', outlined in greater detail in Chapter 6.

Chapter 6

Study 3: Razzle Dazzle

6.1 Introduction

The final study carried out during this PhD research concerns an interactive museum installation as part of a Knowledge Transfer Partnership (KTP) between the University of Strathclyde and the Riverside Transport Museum in Glasgow. The project involved both the design and evaluation of an installation, and had two overarching goals. The first goal was to conduct the research in a relevant context while gathering valuable insights into the museum design and evaluation process. The collaboration with the museum allowed the study to be conducted in a real museum with real visitors (i.e. "in the wild"). This real-life setting thus provided a highly valuable perspective to the PhD research, as the context provides the ambience of the museum, the competition between exhibits, real museum visitors who have their own agendas, expectations, moods and various group configurations that are impossible to recreate outside of the context, as discussed in chapter 2. The second goal was KTP-oriented; the project aimed to provide the museum the opportunity to gain experience of prototyping techniques and evaluation methods from product design and an HCI perspective. As such, the project had two main parts:

Part 1: Design and Development

The design process of the installation is not discussed in this chapter as it is not in the focus of the PhD thesis. However, it is important to note that the installation was shaped by adopting a combination of the museum's design processes with an iterative user-centred design approach and elements of co-design (Clarke et al., 2015). This design process is described in greater detail in Chapter 3: Methodology. During the collaborative design process, museum curators, gallery assistants and museum visitors were involved in brainstorming and iterative concept development, as shown in Figure 6-1. In particular, the voice of curators heavily influenced the final design. The story of Razzle Dazzle Ships was decided upon for development of a THIME in collaboration with museum curators. Prior to this collaborative process, the museum had already earmarked Razzle Dazzle Ships as a topic to be developed into an interactive exhibit.

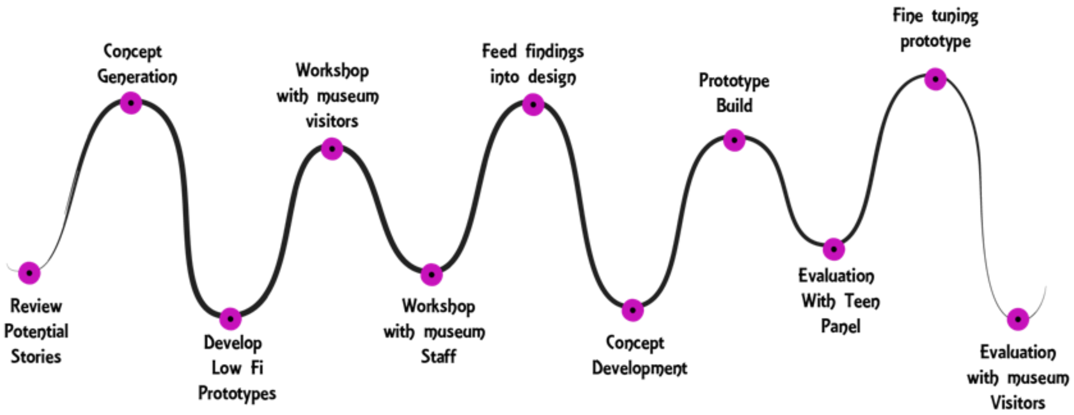


Figure 6-1: Different Stages of the Design Approach and Project Overview

Part 2: An evaluation of the final prototype

The final Razzle Dazzle exhibit was installed in the museum for two weeks. The installations narrative centred around warships, which had been painted with distorting camouflage colours, and posed challenges to groups on a large screen (shown below in Figure 6-2). Razzle Dazzle ships are explained in further detail later in the chapter. Four large buttons, representing four options that visitors could choose from, were located in front of the screen. When challenges were posed on the screen, pressing one of the buttons selected a single option for the group.

Figure 6-2: Final Razzle Dazzle Installation

Throughout the two weeks when the installation was displayed, I carried out an evaluation regarding the installation with museum visitors. The evaluation involved video-audio recording; post-interaction interviews; and questionnaires that focused on companions' social interactions, visitor behaviour, and interaction with the exhibit. The evaluation had a particular focus on concepts relating to a distribution of control, which relate to RQ3, and social shared interactions that unfold between companions, which relate to RQ2.

The study revealed that companions engaged in a number of common social activities at Razzle Dazzle. These activities included: (1) visitors focusing their attention on companions during the activity for example what they can do, what they say, where they are, and responding to it; (2) visitors sharing decisions with multiple companions before interacting; and (3) visitors

coordinating the groups' actions, by, for example directing others to press buttons, or asking others to wait, in effect pausing the interaction and bringing the groups focus together.

While these are seen as behavioural outcomes from the study, I am particularly interested in how one specific aspect of the tangible controllers related to these behaviours: namely, the distribution of control. The study findings suggest the potential value of considering different characteristics of distributed control. In the case of Razzle Dazzle control was distributed in a number of ways. These could be configured to complement or enhance each other, presented in Section 6.5. For example, how distributed control can be achieved and supported:

1) Through the physical distribution and separation of multiple tangible controllers
2) By presenting a choice of controllers to visitors and limiting the choice to one
3) By presenting a choice which: is based on visitors' opinions rather than the exhibit guiding visitors to use a particular controller; is based on a challenging consequence-based question; and is to be made from a selection of equal options. In the case of Razzle Dazzle this was supported by the provision of **equal functioning** controllers.
4) By using an unpredictable pattern of moving the 'desirable' controller throughout most of the task, which prevented any single visitor from dominating control
5) Through the display of the digital content embedded within controllers, which elicited more social behaviours than a version of the installation without embedded screens in the controllers
6) By reducing or staggering moments of interaction
7) By allowing visitors to be in control of *when* to interact

Overarchingly, the relationships between the controllers encouraged companions to rely on each other. In particular, the configuration of physical, functional and temporal distribution of control at the exhibit fostered companions to rely on each other. This sense of reliance between companions and the interplay between different controllers were already central points of interest to the research, having been observed in study 2 (GD + FF). The study examines how control is distributed and the different associated characteristics of distributed control beyond only the provision of multiple access points, such as constraining interaction, contributes to an understanding how social experiences can be fostered at interactive museum exhibits. This knowledge can help both designers and CHPs to use different attributes to support companions' social interactions and shared experiences. Such attributes can help visitors focus on the same activity at the installation, and support tangible interactivity for more than one person.

6.1.1 Motivation & Focus of Analysis

This chapter builds upon key areas of interest which were highlighted in the previous two studies, primarily relating to tangible and physical interactives, distribution of control and the connection to shared social interaction. The study, and the design of the installation itself, was motivated by the following considerations:

1) Providing multiple tangible controllers that are physically separated
2) Encouraging an interplay between the use of different controllers at different moments in time
3) Allowing for joint control over the interaction with the exhibit, during which companions guide, mediate and negotiate interactions
4) The mapping of tangible controllers in relation to their digital counterparts
5) Prioritising coordinated actions over quick interactions or simultaneous interaction by multiple companions
6) Including companions in the overarching activity, in ways which do not include physical interaction with the exhibit but involves active participation
7) Guiding the focus of the group to one central activity
8) Developing the idea of reliance between companions and understanding how one visitor's actions relates to their companions

With these considerations in mind, in this chapter I analyse and describe groups' 'social shared interactions' (SSI) at the Razzle Dazzle exhibit, and the various features which played a role in companions' shared and social interactions. In particular, the chapter focuses on the following questions:

1) <u>What is the nature of SSI that companions engage in at the exhibit</u>? What kind of social activities did visitors carry out. For example, did they point things out to each other, discussions, engage in dual interaction, coordinate or plan together? In what ways do visitors

relate to their companions based on both their own and their companions' interaction with the exhibit?

2) <u>How is physical interaction with the exhibit managed and shared between companions?</u> The question is multifaceted and comprises the following elements: how does the control of interaction transition between companions? What factors play a role in visitors shared physical interaction? Who or what is in control of how physical interaction is distributed among companions over the course of their interaction with the exhibit? The question also considers the digital distribution of control, considering how the interactional structure mediates visitors' use of tangible controllers and the groups' influence over the physical interaction with the exhibit.

3) <u>How do physical controllers relate to each other?</u> The question considers whether controllers are used simultaneously or in sequence. Do the controllers have equal functionality? How does the arrangement of the controllers relate to elements of equality? For example, does the arrangement impact the level of influence the controllers have over the interaction, and are there privileged or unprivileged positions for visitors to occupy?

4) <u>How does direct social interaction between companions relate to distributed control</u>? The questions concerns the effects that distribution of control has on companions' direct interaction with each other while using the exhibit.

5) <u>How do the physical and spatial qualities of distributed tangible controllers relate to companions SSI?</u> In particular, this concerns the physical mapping of tangible controllers to their digital counterparts.

6.2 The Razzle Dazzle Installation

I now give a brief overview of the installation that was designed and evaluated during the project. I firstly describe the backstory of Razzle Dazzle Ships, followed by an outline of the Riverside Museum's guiding principles when designing for teenagers. Finally, I provide a description of the final Razzle Dazzle installation which is evaluated in this study.

6.2.1 Topic of the Installation

Working with both the content curator and the digital media curator, the topic of Razzle Dazzle Ships was chosen as the narrative for developing a hands-on interactive exhibit . During World War I, British and Allied ships were being attacked at an alarming rate by German submarines. A marine painter, Norman Wilkinson, came up with the idea of breaking up the form of a vessel with highly contrasting colours and lines, thereby destroying the visual outline and general shape of the ship (Holt, 2015), (Rodriguez McRobbie 2016). Ships were painted with geometric patterns in contrasting colours as a type of camouflage. The patterns mimicked optical illusions and disruptive patterns similar to camouflaged animals such zebras, making it more difficult for U-boat commanders to target by sight and torpedo ships.

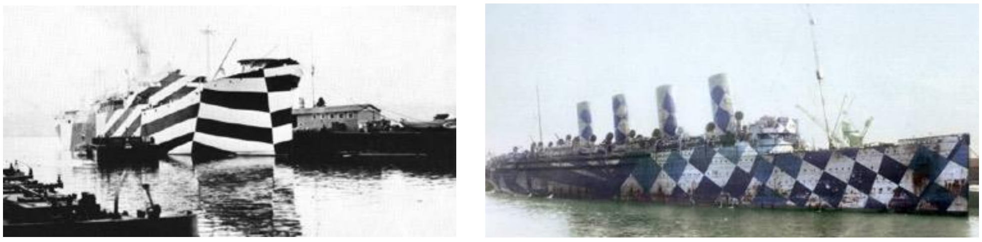


Figure 6-3: Razzle Dazzle ships. (Holt, 2015)

These radical designs were intended to cause confusion around the course and shape of a ship, as well as its speed and size, thus preventing successful attacks by enemy submarines. The technique's actual effectiveness is still unclear. There was a decrease in torpedoes sinking British and Allied ships, however the Navy also started travelling in convoy around this time, which also made it more difficult to torpedo ships. Therefore, it is difficult to determine whether the decrease can be attributed either wholly or partly to the use of the technique.

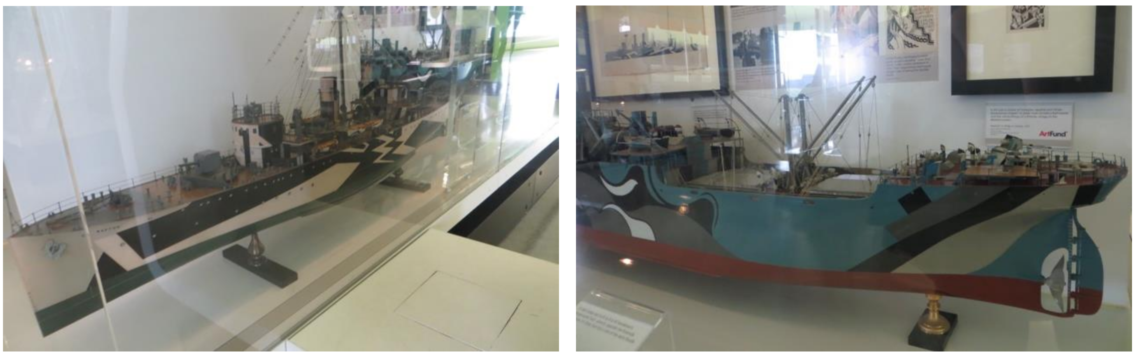


Figure 6-4: Razzle Dazzle Ships at Glasgow Museums, Riverside Transport Museum

6.2.2 Target Audience and Corresponding Design Considerations

The museum's traditional design approach involves considering a specific target audience and following a set of recommendations developed by the museum. Criteria include: different learning styles, audience characteristics and potential learning outcomes. For 'Razzle Dazzle' ships, the museum selected a teenage audience and its recommendations for this audience were taken into account during development of the exhibit.

When reviewing these recommendations, I highlight some of the points which relating to social interaction from the museum's set of recommendations for the teenage audience. For teenagers, the social context of an exhibit can be more important than the display itself. Interpretative methods should support discussions and encourage social interaction, and offer challenging or competitive interactions. The encounters should provide opportunities for debates, discussion, and allow visitors to question or express opinions both independently and as part of a group.

Considering both the museum's guiding criteria and the aims of the PhD research, the development of the installation prioritised the following:

1) Encouraging a shared experience while using interactive exhibits, such as discussion and collaborative activities, and allowing companions to engage in an activity during which they can consolidate bonds
2) Supporting tangible interaction with multiple, physically separated controllers
3) Communicating a key message about Razzle Dazzle Ships by presenting information linked to artefacts in the museum collection
4) Enabling comparative views of the ships by displaying them with and without Razzle Dazzle painting

6.2.3 The Final Installation

The final exhibit was a tangible hybrid interactive which showed how visual illusion tactics were used on ships to make it more difficult for submarine commanders to determine a ship's speed, size, shape and direction before a launching a torpedo at a ship. The exhibit gave visitors four challenges relating to optical illusions and visual distortion tactics used by Razzle Dazzle Ships. Each challenge posed a question to the group on a large screen in front of four buttons, as illustrated in Figure 6-5. Groups could use one of the four buttons placed in front of the large screen at a time to select an answer. Upon pressing a button, the content on the screen merged their answer with a patterned ship, showing how the optical illusion was applied. Each challenge had a predetermined format that staggered passive viewing of information about the ships at specific moments, inviting physical interaction. I will now outline the format of the exhibit, beginning with how the exhibit appeared in its resting state.

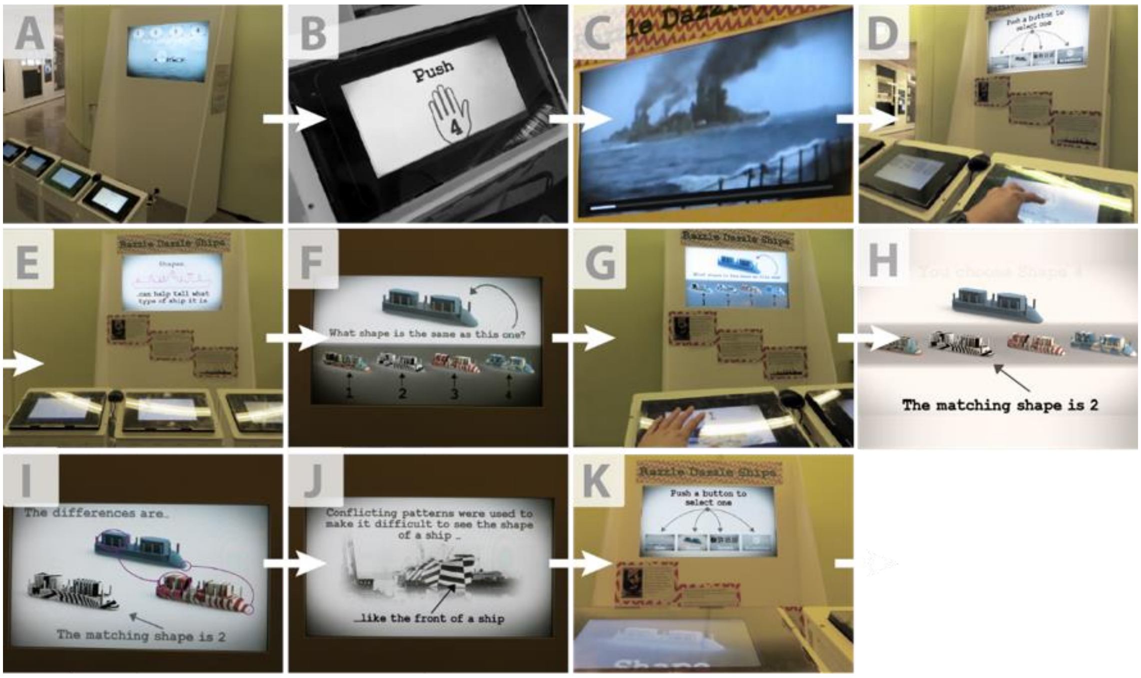


Figure 6-5: Interaction flow of the Razzle Dazzle Installation

When approaching the exhibit in its resting state, visitors were invited to ‘press a button to play’ on the large screen and individual buttons (parts A & B in Figure 6-5). Pressing a button started a video which lasted 44 seconds. The video introduced Razzle Dazzle Ships, outlining why they existed, and how they worked (part C in Figure 6-5). During the introduction, the smaller screens embedded in the buttons prompted visitors to watch the large screen. After the introduction video, a selection menu invited visitors to select a challenge (part D in Figure 6-5). When visitors selected a challenge, a short video snippet played introducing the challenge. For example, if they chose 'Shape', the video (part E in Figure 6-5) explained how submarine crew used the shapes of ships to identify the different types of ship, determining if it was an enemy ship they wanted to bomb or an innocent passenger ship. The Razzle Dazzle painting helps to distort the shape of the ships. Visitors were then presented with the challenge shown on the main screen (part F in Figure 6-5). To answer the question, visitors could use one of the four buttons located in front of the large screen, each representing one of the choices (part G in Figure 6-5). Screens embedded within the buttons changed to represent the answer during the challenges (part G in Figure 6-5).When visitors answered the question, information about the patterns and the answer were displayed on the large screen (parts H & I in Figure 6-5). Then, some final content was displayed relating their answer to patterns used on real Razzle Dazzle ships (part J in Figure 6-5), before returning to the selection menu (part K Figure 6-5).

The overall design intention was to create an interactive installation that enabled visitors to share an activity in which companions could act as a team, and during which each visitor could contribute to interaction with the exhibit and the activity, thus stimulating discussion. The exhibit gave visitors time to contemplate content or to debate and discuss. Control was also distributed at the exhibit. The design did not allow for, parallel simultaneous interaction, and aimed to make it difficult for one person to take control of the exhibit.

The final installation exhibited in the museum had two different variations. As described in the preceding paragraph, the first arrangement had screens in embedded within buttons. This arrangement aimed to explore the mapping of physical controllers in relation to their digital counterparts. When the controllers were inactive and no interaction was required, the embedded screens directed visitors to focus on the large shared screen (see Figure 6-6). The second arrangement of the exhibit was largely the same as the first, except in this variation screens were not embedded in the buttons. Instead, the buttons were simply numbered, as illustrated in Figure 6-7.

- **Setup 1:** Screens embedded within buttons
- **Setup 2:** No screens within buttons

The decision to evaluate versions with and without embedded screens was made for two reasons. Firstly, the decision concerned the aims of the PhD research. Secondly, the decision was driven by the museum's interest in evaluating the cost-benefit of adding screens, since these require additional resources including cost, time, development and advanced technology.

Figure 6-6: Set up 3

Figure 6-7: Set up 4

Figure 6-8: Close up of screen content

Screens embedded within the buttons aligns with traditional conceptions of tangible exhibits (Ullmer and Ishii, 2000), at which physical objects both control and represent digital content. Considering the analysis of the Glen Douglas study and related usability literature, it is evident that clear feedback is vital for meaningful interaction, and the visual changes on the button screens aimed to support this. At Glen Douglas, people struggled to understand how their input related the overall exhibit. Embedding screens within controllers aimed to make the relationship between each button and the overall exhibit and activity more explicit. Moreover, configuring viewpoints and actions points, both inputs and outputs, has been found to stimulate social activities and to encourage different forms of participation (Hindmarsh et al., 2005).

6.3 Study Setup & Analysis Approach

Teenagers were the target audience for the exhibit. However, aside from school groups, teenagers are the least likely age group to attend museums. Consequently, family groups were considered to be the most likely users of the exhibit, as they are the most frequent visitors to the Riverside Museum.[6]

As in Study 2, video and audio recording equipment was placed around the Razzle Dazzle exhibit, along with signage informing visitors of the study. Any visitors in the space and interacting with the installation were considered to be participants in the study unless they specified that they would like to opt out. Visitors were approached after using the exhibit, inviting them to respond to questionnaires and to take part in semi-structured interviews.

In order to conduct a detailed analysis of the video and audio data, the dataset was filtered to 16 groups: 8 groups with setup 1 (screens embedded in controllers), and 8 groups with setup 2 (no embedded screens). The 16 groups consisted of 59 visitors, including 8 children aged 11-18 years, 18 children aged 5-10 years and 33 adults, as illustrated in Figure 6-9. Filtering the dataset followed a criteria that prioritised visitor groups the study was to focus on and aimed to include a broad variety of such groups, in particular groups who had participated in interviews and questionnaires. The filtering process involved identifying groups with teenagers, families, and larger groups in order to represent a variety of visitor groups. Single visitors were removed from the data. Group types were defined based on the groups which were most prominent at the exhibit. For example, under 5s and toddlers are not accounted for in the dataset as they were not

[6] GLASGOW MUSEUM OF TRANSPORT. VISITOR RESEARCH FINAL REPORT. July, 2003 by Scotinform.ltd. RM02 audience development plan. (2003)

observed interacting with the exhibit or with their companions, other than during brief encounters before moving away from the exhibit. The lack of interaction from this group was possibly due to the type of installation and content, as well as the physical configuration of the installation, with the buttons placed out of sight of toddlers.

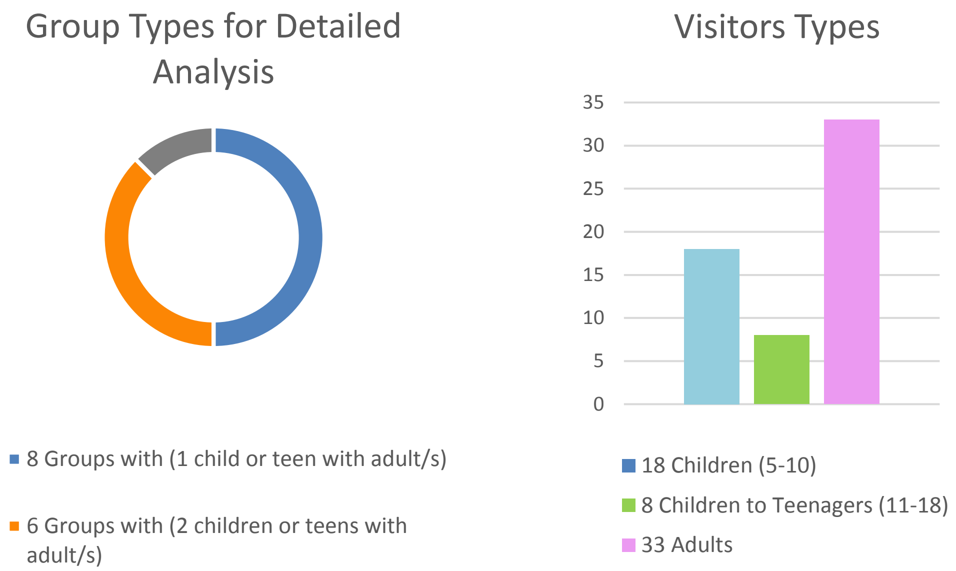


Figure 6-9: Breakdown of groups for Study 3

6.3.1 Data Analysis Approach

Video and audio analysis was the primary approach taken, with interviews and questionnaires used as a secondary source of data where appropriate. The analysis process of video-audio data is described in greater detail in Chapter 3: Methodology. The analysis of Razzle Dazzle differed slightly from the analysis of previous studies in that it also involved the creation of a catalogue honing in on specific snippets of video at particular stages of interaction. As the study specifically focused on social interactions in relation to control, sequences during which the exhibit invited visitors were to use controllers were collated into a catalogue for detailed analysis. Creating a catalogue of snippets of data is common practice when conducting an analysis of video or audio data which focuses on specific behaviours (Heath et al., 2010). Thematic analysis was then utilized following interaction analysis to derive themes and categories.

The analysis prioritised investigating the role of distributed control, including digital means of distributed control, upon companions' social interaction and shared use of the installation, relating to RQ3. To investigate this, I firstly sought to understand the types of social interaction that emerged while companions interacted with the exhibit. This is outlined in greater detail in Section 6.4 of this chapter, and relates to RQ2. Subsequently, I focused on the sequence of events and emerging patterns, questioning the relationship between features of the exhibit in order to consider the role which individual elements and attributes of the exhibit played in social activities. This is outlined in greater detail in Section 6.5 and relates to RQ3. Secondary associated qualities relating to distributed control are also considered in the analysis, as these have been identified as strengthening or counteracting the role that distributed control has upon visitors 'shared social interactions'. Furthermore, the analysis takes a holistic view of the interactions which took place at the exhibit, and includes factors which did not directly relate to the RQs. These factors were included because it was considered that only outlining factors related to the RQs would present an unrealistic representation of the exhibit.

To aid the analysis process, a set of empirical questions were developed. These questions considered the different means of participation that people undertook, such as verbal or physical participation. The following questions acted as operational indicators, helping to focus the analysis on particular behaviours and situations relating to the overarching RQs:

1. Did companions make <u>**joint and shared decisions**</u>, and if so, how did they make these? Indicators for this question included: companions voicing their opinions in relation to the available options, seeking and giving approval, agreeing with companions' suggestions, engaging in discussions before using a controller, and pausing before using controllers while possibly considering another person's suggestion. This is answered specifically in Section 0
2. The current section (section 6.4) is divided into three subsections, each of which deals which the themes shown above in Table 6-1. Theme 1 concerns how visitors shared decisions and contributed to answers. Theme 2 concerns how visitors shared physical interaction with the exhibit and how control transitioned from one person to another. Theme 3 concerns how individuals tried to dominate physical interaction with the exhibit or maintain control.

3. Theme 1: Groups Sharing Decisions.

4. Did the groups share the physical interaction with the exhibit, and if so, how did they share this? Indicators for this question included: directing a companion to use a particular controller, more than one companion pressing buttons throughout the course of the whole interaction, companions explicitly dividing up control of physical controllers, and companions coordinating and aligning their actions. This is answered specifically in Section 6.4.2 Theme 2: Sharing Physical Interaction.

5. What happened in situations in which companions dominated or tried to dominate the physical interaction? How did the exhibit restrict or support dominating behaviour? Indicators for this question included: situations in which companions tried to use the exhibit alone but had to compromise or found it difficult, companions reaching in front of others to use a controller, companions physically restricting or blocking companions from the exhibit or quickly pressing buttons without discussions. This is answered specifically in Section 6.4.3 Theme 3: Dominating Physical Interaction with the Exhibit.

6.4 Interactions Between Companions at Razzle Dazzle

In this section I discuss findings from analysis. During analysis it became evident there were no prominent behavioural differences between the two setups of the exhibit (with and without embedded screens). An example of a prominent behavioural differences is if people behave in strikingly different ways in trying to dominate interaction. Another example would have been if there was a contrast in people spreading out among controllers, between the two set ups. As the two setups resulted in no prominent behavioural differences, the findings cluster the behaviours from all 16 groups across the two set ups. However, where differences were found between set ups, these are noted throughout the findings.

This chapter is primarily concerned with the relationship between attributes of the exhibit, and how these attributes relate to visitors' social behaviours and shared interactions with the exhibit. To appropriately evaluate these factors, I will firstly outline the different social behaviours which were observed at the exhibit. In Section 6.5, I then examine how these behaviours and situations are connected to various attributes of the exhibit. This is followed by Section 6.6, which outlines some general observations which do not directly relate to the main research question, but which are nevertheless important in understanding the context of interactive museum exhibits.

Behaviours	Indicators
Sharing Decisions	Multiple contributions
	Considering other people's opinions
Sharing Physical Interaction	Transitions of control
	Dividing up controllers
	Coordinating actions together
Dominating behaviour (e.g. not sharing)	Reaching in front of companions to press a button the companion is closer to
	Interacting without conferring with companions
	Physically restricting companions from the exhibit

Table 6-1: Overview of the Themes related to shared control

The current section (section 6.4) is divided into three subsections, each of which deals which the themes shown above in Table 6-1. Theme 1 concerns how visitors shared decisions and contributed to answers. Theme 2 concerns how visitors shared physical interaction with the exhibit and how control transitioned from one person to another. Theme 3 concerns how individuals tried to dominate physical interaction with the exhibit or maintain control.

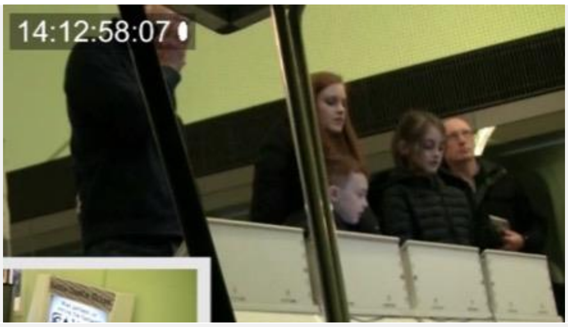
6.4.1 Theme 1: Groups Sharing Decisions

In this section, I discuss how visitors shared decisions together while interacting with the Razzle Dazzle exhibit. Before physically interacting with an interactive exhibit, visitors firstly decided which actions to take, either consciously or subconsciously. Of particularly interested is whether visitors made these decisions alone or with companions. To examine this, I focused on snippets from the dataset in which the exhibit presented options to groups and visitors were faced with making a choice. I found that the majority of visitors shared the decision-making process when deciding the answer to a question. However, when selecting a challenge, visitors were less likely to share the decision-making process. Visitors shared decisions in a variety of ways. For example, multiple companions made verbal suggestions and voiced opinions while deciding what the answer might be and what controller to use; visitors considered and acted upon their companions' opinions; visitors made agreements and sought the approval of their companions before using controllers; and visitors made decisions through group discussions. I will now discuss these variations in more detail, with direct reference to vignettes from the dataset.

Sub-Theme 1.1 Multiple Contributions

Companions shared decisions by multiple people putting forward their opinions and suggestions during the challenges. Challenge questions were posed to the whole group on a large screen and not directed at any single visitor or any single part of the exhibit, prompting companions to openly make suggestions to each other. With no timer setting the pace or putting pressure on groups, visitors decided how and when to interact, which created opportunities to make contributions and share decisions. A typical example of visitors within a group making multiple contributions is described in Vignette 12 below. A family consisting of Mum, her daughter Fiona (8-10 years old) and her son Alex (under 8 years old) interact with the exhibit. Dad and toddler stay close by, occasionally taking part in the activity. The group has already carried out 2 challenges and is now on their third challenge: speed.

Vignette 12: Multiple Contributions
Group 2B: C3-G11- Challenge 3 Speed
Mum, Fiona (8-10) and Alex (under 8) Dad and baby



Challenge 3 Speed

The challenge question appears on the screen and Mum reads it out *"what pattern is moving the fastest?".* Alex suggests, *"it looks like the stripes".* Alex looks at the corresponding button (button 4) and then moves to it. Dad is pointing towards button 1. Mum comments, *"I think one".*

Fiona starts pointing at the main screen. Mum looks towards button 1: *"yeah, I think it's one".* Fiona and Alex look towards button 1 that Mum and Dad have suggested. Alex points to the main screen. Fiona agrees. Dad makes more suggestions *"one or four".* Fiona is at button 1 but hasn't pressed yet. They all look back at the main screen after Dad's comments. Alex repeats Dad's *"one or four"* while looking at the main screen. Mum looks down to button 1. Fiona standing over button 1 ponders and then proposes, *"let's go for one".* Fiona looks back towards Mum to confer with her. Mum responds, *"let's go for one .... stripes fastest."*

Dad comments, *"they all might be going at the same speed".* Fiona presses button 1. At the same time Alex repeats again *"one or four"* while looking at the main screen. Alex still hasn't decided. Fiona points to the main screen turning to Mum saying something inaudible. Alex comments, *"it's gonna be four". Alex* looks at button 4, repeating *"it's gonna four. I know. It's gonna be four I think"* as they watch information on the main screen and wait for the answer.

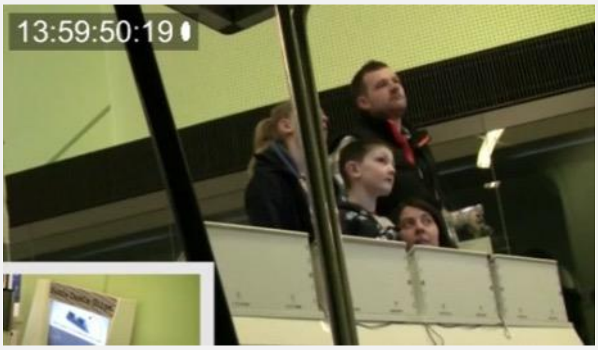
While considering the answer to select, the whole group debated with each other, shared thoughts on what the answer could be, commented, made suggestions, voiced their opinions and pointed to the options. They took their time to do so, and did not rush to a decision. The group continued behaving in this way when making the rest of their choices at Razzle Dazzle. The vignette reveals how deciding the answer and what button to press involved contributions from many companions. Both visitors who were and were not located at controllers gave their opinions and made suggestions. Interestingly, visitors who were not standing at the controllers were found to contribute more than their companions who were standing at the controllers. This may be similar to GD in Study 2 of this PhD, where stepping back from interaction enabled a better overview and seemed to allow for a more reflective stance. All of the groups were found to share decisions through multiple contributions from companions to some extent. Only 2 out of 16 groups had only minimal signs of multiple contributions, indicating the prevalence of shared decisions with multiple contributions for most groups.

This behaviour suggests that visitors felt that they could contribute meaningfully to the activity verbally, creating situations in which companions socially shared decisions. The exhibit therefore increased opportunities for visitors who were not physically interacting with controllers to contribute and influence decisions indirectly by guiding and influencing their companions' actions (RQ2). A more detailed discussion of how certain attributes of the exhibit relate to this behaviour in Section 6: Key Elements of the Exhibit that Relate to Groups' Social Shared Interactions .

Sub-Theme 1.2 Considering Other People's Opinions

Groups also shared decisions when visitors considered the opinions of their companions. The behaviour was identified in instances when visitors moved to a controller suggested by a companion, when visitors looked towards the suggested controller, or when visitors repeated what their companions said to them. Vignette 12 demonstrates visitors considering their companions' opinions. For example, Alex looked and moved to the first button when it was suggested, both children looked towards the button their parents suggested, and Alex repeated Dad's suggestions. Similarly, in Vignette 13 shown below, Allen moves to the controller that a companion suggests.

Vignette 13: Considering other People's Opinions
Group: 4A. C4-G10 Challenge 1 Shape
Gran, Mum (25-34), Dad (25-34), Susie (13), Allen (8-10)



After deciding what challenge to take on, the group watches as information and a question for their first challenge (shape) appears on the large screen.

Challenge 1 Shape

Mum reads out the question: *"right, what shape is the same as that one.... which one of those pictures is the same... what one do you think?"* Allen looks down to button 2 in front of him. Susie voices her opinion: *"I think four"* while she is looking at the main screen, shown in the image above. Upon hearing his sister, Allen moves towards button 4: *"eehhh".* Allen stands at button 4 with his hands either side of the button looking at the main screen again.

In this vignette, a visitor listens to a companion's opinion and acts upon it. This is one example of many instances in which visitors listen to suggestions from their companions. Both companions acted as a team, carrying out different actions related to their shared activity. The structure of the interaction and spatial arrangement of the controllers, the visibility of digital content and the actions of companions enabled a companions to separate their actions, and supported multi-visitor activity with the exhibit. Allen's involvement is enabled by his ability to move closer to the button that his sibling suggested, ensuring he has possession of the controller and increasing the likelihood that he will be able to execute the group's answer. In this way, the distribution of controllers through the space, in tandem with the interaction structure, allowed the activity to be shared by more than one person. In addition, button 4 was still free, as it was not clear from the outset which would be the correct answer.

Sharing Decisions with Embedded Screens or No Screens within Controllers

Every situation in which visitors were invited by the exhibit to press a controller was coded as either involving social interaction or not involving social interaction in deciding what controller to use. The setup with embedded screens was found to encourage more social interaction than the setup without screens. At the setup with embedded screens, 38 out of 55 instances (69%) involved social interaction between companions while making the decision. At the setup without screens in the buttons, only 21 out of 54 instances (39%) were coded as involving social interaction between companions while making the decision. This suggests that embedding digital content within controllers added a dimension to the exhibit that increased social interaction. From an HCI perspective, the embedded screens provided a better understanding of the exhibit, as they clearly showed the current state of the system and the activity, and gave more concrete instructions. However, it should be noted that there were only three groups with more than one child who used the set up without screens, while five groups with more than one child used the setup with screens. These group configurations may have had a significant effect on the pattern of interaction and decision making, with parents possibly taking on a moderating and facilitating role prompting discussions in an attempting to include all children in the activity. It is also possible that having embedded screens created a novelty effect, which drew more attention to the exhibit, and led to more visitors wanting to be involved in the interaction. The findings reflected upon here are thus inconclusive.

Summary of the Theme 1: Sharing Decisions

The findings discussed in Theme 1 respond to RQ2, as they reveal the social activities which companions engaged in while interacting with the Razzle Dazzle interactive exhibit. These activities included making suggestions, listening and responding to suggestions, and various forms of facilitation by adults.

In answering RQ3, the social activities relating to groups sharing decisions were influence by following aspects of the exhibit:

- Posing a question to the group. This invited group members to contribute to controlling how the exhibit was interacted with.
- Asking a challenging opinion-based question which elicited opinions from visitors. As such, controlling and influencing the outcome was not solely based on having possession of a controller.
- Allowing visitors to control the pace of their interaction, with no time pressure imposed by the exhibit. This allowed time for discussions.
- Giving visitors a choice without the exhibit constraining or suggesting suitable controllers prompted shared decisions. Thus, visitors had control over what happened with the exhibit, as this control was not directed by the exhibit, as seen at the installations in Study 2 (Chapter 5).
- By limiting the use of controllers to only one at the moment of decision, which was either correct or incorrect, and represented the answer for the group provoked shared decisions.
- Physically distributing controllers, which prompted visitors to move to another controller in response to their companions' suggestions. This helped individuals to be aware of others' intentions, which was important for sharing decisions and control of the exhibit.

Thus, companions' shared discussions at Razzle Dazzle demonstrates how the distribution of control, such as which controller is used, and when to interact, is not only related to the physical separation of tangible controllers. Rather, control can also distributed throughout a group by engaging them in verbal decision making.

Table 6-2 summarizes how features and attributes of the exhibit influenced the behaviour of shared decision-making in relation to the central PhD research question 'what are the different attributes of THIMEs that should be considered when designing to support companions' shared social interaction and the shareability of the interaction'.

Behaviour	Variations	Link to the Exhibits' Features & Attributes
Sharing Decisions	Multiple Contributions	• There was a lack of clarity as to what the answer was. The system posed a challenging question; it is difficult to identify the correct answer is and thus what controller to use. • Visitors were presented with a decision to make with multiple options to chose from, and were given no prompts from the installation as to which particular controller to use. • The question was asked on a large screen to the whole group, not to any one visitor. • The question had consequences, creating a desire to answer correctly. • An opinion-based question allowed everyone in a group could contribute. Companions did not need controllers to give their opinion. • Large movements or glances to buttons created awareness of which buttons companions were considering and thus meant that visitors could react to their companions' actions. • Only one button could be selected, meaning that only one answer could be put forward by a group.

	Considering other people's opinions	The visitor who selected the answer had the responsibility of choosing for the whole group. • The physical separation of the different options created a situation which enabled companions to be involved in the activity together. For example, visitors considered companions' opinions because they can act upon it. If they were located closer to the button suggested, then they could press it. • The structure of interaction with the exhibit constrained the use of controllers to certain moments, such as selecting a challenge or answer. This encouraged visitors to be mindful of the use of controllers, and sparked the desire to get the answer right. • No time pressure was imposed on making decisions; the pace was set by visitors and not the exhibit, allowing time for discussions and debates.

Table 6-2: Mapping behaviours to characteristics of the exhibit

6.4.2 Theme 2: Sharing Physical Interaction

I will now discuss how companions shared the physical interaction with the exhibit with each other. During the challenge, the questions and selection menus invited visitors to use the tangible controllers, but the exhibit only permitted the use of one controller to select a choice at these moments. This aspect led to a number of questions which guided analysis, including: would visitors share the physical interaction or dominate? Would control transition between companions? If so, how did this happen and how did the exhibit relate to their social behaviour?

I found three variations in how groups shared physical interaction with the exhibit, shown in Table 6-3. Firstly, situations in which physical control transitioned between companions. Secondly, situations in which visitors divided and assigned controllers between companions. Finally, situations in which visitors coordinated and aligned the actions of themselves and their companions while interacting with the exhibit.

Behaviour	Variations
Theme 2: Sharing Physical Interaction	Transitions of Control
	Dividing up Controllers
	Coordinating & Aligning Actions Together

Table 6-3: Themes related to sharing physical interaction

Sub-Theme 2.1 Transitions of Control

One of the ways physical interaction was shared within groups was through transitions of control between companions. During the design process, it was intended that the spatial layout, with its physical distribution of controllers, would encourage the use of the physical buttons to transition between companions over the course of the interaction. Whether and how this happened will be discussed in this section. There were various ways in which physical control transitioned between companions: visitors directing companions to use specific controllers, visitors requesting a turn and parents facilitating turn-taking.

Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller

A key behaviour used to identify transitions of control was visitors directing a companion to use a controller. For example, visitors would inform companions of the answer or direct a companion to use a particular controller, asking them to "press the button". Typically, this happened when this controller was not easily accessible to them, being out of their physical reach. Visitors then pointed to specific controllers, suggesting it was to be used or that it was the answer. This behaviour shows how visitors considered not only how they alone could interact with the exhibit, but also how their companions could interact with the exhibit. There were 17 instances from 8 of the 16 groups in the dataset in which visitors explicitly directed a companion to use a controller. There were also instances in which parents encouraged or invited children to press a button. These are not included in the 17 instances, as they were not coded as 'directing companions', but rather as encouraging and supporting children, as a form of scaffolding and facilitation. In contrast, 'directing' was considered to be a situation in which a visitor attempted to ensure that a particular button was selected as the answer.

I now refer to Vignette 14, which depicts two siblings, Susie and Allen, in order to demonstrate how control transitioned between visitors when a companion was directed to use a specific controller. In the vignette, Susie and Allen are at two separate controllers and control transitions between them as they direct each other to use the controller at which the other person is standing.

Vignette 14: Directing Companions to use a specific controller
Group 4F: C3-G10 Question 2 Speed
Gran, Mum (25-34), Dad (25-34), Susie (13), Allen (8-10)

Challenge 2 Speed
We join the group while Susie, Allen and Mum debate if the answer is one or four.

Allen: *"I think ......* (he pauses and moves his hands over to place them onto button 4 then starts talking again): *....four".* Both Allen and Susie look at button 4. Mum encourages him to press his suggestion: *"right press four".* Susie voices her opposing opinion: *"mmmm......I bet ya it's going to be one"* while making a funny face. Mum and Allen start to look at the main screen again. Allen's hand is on button 4 but he's doesn't press it. Susie directs him to select it: *"right go".* Mum also encourages Allen to press it: *"just do it".* Allen points to his sister at button 1 and says: *"no you ......"* (shown in the left images.) Mum encourages him again to press button 4 in front of him: *"you push.. you push that first".* Allen doesn't press it but keeps his hands on it. He looks at Susie and says: *"no, I want Susie to do hers first......"* Susie presses button 1 and they all look to the main screen to see the change.

The two siblings stand at either end of the exhibit debating which button to choose while directing each other to use a controller. The situation highlights a number of features which encourage this shared activity between companions: firstly, how controllers relate to each other; secondly, the physical distance between each suggested controller; and thirdly, how the desire to be right influenced sharing of physical interaction with the exhibit. When the siblings begin to debate whether the answer is one or four, both children assume positions at button 1 and button 4. They physically move to access the respective controllers. But there is no race as to who presses first; instead the group wants to come to a shared, correct decision. When they finally decide which answer to go with, Allen instructs his sister to press the button she is at, rather than moving over to button 1 and pressing it himself. In order to select the answer that Allen believed to be right, he communicated with a companion and handed over physical control.

In a different observed situation, visitors were side-by-side and could reach to use their companion's controller, but instead directed their companion to use the controller. In Vignette 15 below, Lucy explicitly directs her friend Holly to press her controller, even though Lucy would be within reach of the controller.

Vignette 15: Directing Companions to use a specific controller
Group: 5E. C4-G8 Selection Menu 2
Family & friend of daughter:
Mum, Dad, daughter Lucy (8-10 with hat) and daughter's friend Holly (under 8 blonde)

Selection 2: Second time using the selection menu to choose a challenge
Lucy (with hat) reads out screen *"push a button to select".* The two children confer with each other while standing at button 3 and 4. Holly looks at button 3 where Lucy is standing. At the same time, Lucy looks to button 4 where Holly stands. Lucy points to button 4, saying *"direction"* (shown in above left image). Then Lucy directs Holly to *"press yours."* Holly takes on Lucy's suggestion and presses button 4.

This behaviour occurred frequently between the two girls. One child explicitly directs their companion to use the controller they are at, rather than reaching in front of their companion, even though the button is within reach.

There was a difference in visitors directing companions to use controllers between the two setups. A setup 1, with screens embedded in the controllers, there were 11 instances of visitors directing companions as to what to press. However, at setup 2, without embedded screens, there were only 6 instances of visitors directing companions as to what to press, suggesting that the visual representation of the digital content embedded in the controllers encouraged transitions of control between companions. The screens may have given visitors a greater understanding of what the buttons represent, and how the individual controllers related to the overall activity. It is also possible that controllers with screens embedded in the buttons appeared to be owned by individuals, and therefore deterred companions from using controllers which other visitors were located at, instead directing their companions to use these controllers. Again, there are multiple potential explanations, including how different demographics interact. For example, with less children in the groups.

Sub-Theme 2.1.2 How Transitions of Control Occurred in Other Ways

It was not only the structure of the exhibit which prompted transitions of control between companions. Parents also facilitated turn-taking, and individuals initiated transitions of control by requesting a turn. In many groups, parents often mediated turn-taking. While turn-taking may have been instigated by individuals or may have occurred when a button was out of reach, parents often played a role in mediating these transitions of control. They facilitated and scaffolded both verbal and physical turn-taking in a number of ways, such as asking what others think, inviting children to press buttons, and forming agreements. One of the largest groups observed at the exhibit appeared to struggle with control, with several children wanting to interact simultaneously, making it difficult for the mother to facilitate and attend to a number of children putting forward their suggestions. Scaling up and down exhibits to support both larger and smaller groups is a common challenge in museums (vom Lehn and Heath, 2016).

Children also prompted transitions of control by requesting a turn. In the dataset, this was observed three times. In all three instances, this occurred with boys under age 10 who were using the exhibit with an older female sibling. After the transitions of control occurred, companions were still actively involved in the activity, influencing the manipulation of digital content, and verbally and physically controlling what happened with the exhibit. This is illustrated in Vignette 16, in which a younger sibling, Mike, requests a turn while using the exhibit with his older sister, Sara. After transition of control, Sara is still involved, actively influencing the interaction verbally.

Vignette 16: Transitions of Control Occurred in Other Ways
Group: 10D: C4-G10 Challenge 4
Family Group: Dad, Sara (8-10) and Mike (under 8)

Mike returns from the bathroom to join his sister Sara, who's been using the exhibit while he was in the bathroom close by.

Selection 4
When the selection menu appears, Sara moves her hands on button 4 saying: *"then direction"* smiling (shown in lefthand image above). Mike wants to have a go saying: *".... can I not have a go"* . Sara says: *"we're doing direction"* and keeps looking at the main screen. Dad puts his hand up to Mike's back saying: *"let Mike do it. Let him press it".* Dad encourages Mike to move to stand between button 2 and 3 (shown above) and Sara moves to button 4, shown in the righthand image. Mike stands beside his sister between button 2 and 3 looking at the main screen.

Challenge 4: Direction
Sara reads out information coming up on the screen out loud: *"fire torpedo..........bomb".* She reads out the question as it comes on the screen: *"can I tell what ship is closest to me ... YES! It's one".* Sara looks at Dad and asks: *"do you think the closest ship is one Dad?"* This time Sara is not able to reach the suggestion she is making and Mike has just requested a turn, which Dad supports.

Sara walks up to the main screen saying: *"look".* Dad responds, but it's inaudible. Sara starts running her fingers along the main screen underneath the ships. Dad says: *"Sara"* as if to tell her to stop. She turns back to them while standing at main screen saying: *"yeah, the closest ship is one."* She walks back to button 4 while pointing at button 1, telling her brother: *"press one Mike".* Mike looks at button 1 and presses button 1 down hard with one hand.

Soon after, the answer comes up on the screen and they got it right. Mike looks down at button 1. Sara looks at Dad smiling and then back to the main screen. Dad congratulates: *"well done."* Sara celebrates: *"y...e.....a......h.....we won"*

In Vignette 16, Mike asks Dad for physical control. The transition of physical control happens relatively easily with the help of a parent. After handing over physical control, Sara, who mainly used the controllers, is still involved in the activity. She influences the interaction with the exhibit by encouraging and directing Mike as to which controller to use. Sara continues as an active participant influencing the physical interaction through verbal and gestural guidance. An element of team effort is evident when Sara shouts *"we won"* after the exhibit has confirmed that they answered correctly.

Verbal contributions and being right proved to be important factors in participation. Therefore, making suggestions as well as physical interaction influenced the use of particular controllers. Interestingly, verbally asking for a turn was successful for children at the exhibit. The request led to a child handing over physical control, but maintaining their involvement in the decision-making process and guiding a companions' use of controllers. Thus, visitors could change their way of participating in the activity; handing over physical control to companions did not mean being excluded from the activity.

Sub-Theme 2.2 Dividing up the Controllers

One of the ways in which companions managed their physical interaction with the exhibit was to assign controllers to individuals both implicitly and explicitly. This only happened in groups with more than one child, whereas groups with adults and one child did not assign controllers to members of the group. It is possible that this was due to the fact that facilitating is more common in groups with more than one child. The explicit division of controllers was rare. Instead, implicit, unspoken division and ownership of the controllers was more frequent.

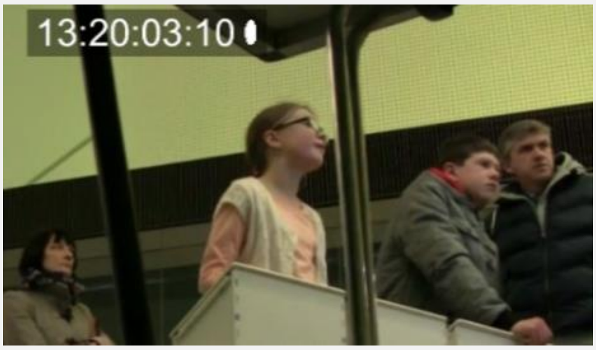
Sub-Theme 2.2.1 Inexplicitly Dividing up Controllers: Standing and Moving to Different Controllers

Visitors typically divided controllers between the group implicitly as the interaction progressed. Usually, no verbal agreement was made regarding who should use particular controllers. This behaviour manifested itself in several ways. For example, visitors repeatedly stood at specific buttons without any verbal allocation. If visitors moved to use a controller, they would often return to the controller they had been standing at, in effect maintaining possession of a controller and thus also maintaining their involvement. Visitors referred to controllers as "yours" when suggesting companions use particular buttons. There was an unspoken form of ownership over the controllers at which visitors were located.

Sub-Theme 2.2.2 Explicitly Dividing up Controllers

Only three groups explicitly divided up the controllers, by verbally suggesting to split up the controllers in the group. The suggestion was only made by boys, and only happened when there was more than one child in the group. Vignette 17 describes how 2 children went about explicitly dividing up controllers. As we join them at the vignette, they have just selected their first challenge.

Vignette 17: Explicitly Dividing up Controllers
Group: 7A. C4-G2.
Family: Mum, Dad, Lily (8-10) and Malcolm (11-13)



Challenge 1: Speed
When the information for the challenge comes up on the screen Lily reads "speed". Malcolm starts to read the screen out: *"to hit a moving ship……."* Lily moves to place her hands on button 3. She presses button 3 before the question is even on the screen. Malcolm starts giving the exhibit attention and gives Dad his drink to free up his hands. Malcolm says to his sister: *"right I'll do 1 and 2. You do 3 and 4"*.

Malcolm divided up the controllers at the start of their interaction, just after he observed his sister using a button for the first time to select a challenge. It is possible that at this point Malcolm realised how to interact with the exhibit using the buttons, which encouraged him to be involved. Even though they divided the controllers between themselves, there was hardly any discussion between Malcolm and Lily. The first four times they selected answers, they quickly pressed the buttons without conferring with each other. Selecting their third challenge was the only time Lily communicated with her brother, encouraging him to select button 1 at which he was standing, but only after she had quickly pressed button 3 without considering the options. It appears that, by explicitly assigning controllers, Malcolm and Lily divided the interaction into their individual separate activities at the exhibit, using different controllers. While interacting with the exhibit, the group engaged in individual, uncoordinated activities. In adopting this strategy to explicitly assign controllers between each other, the children may have been trying to ensure their own physical interaction with the exhibit and a way to share the exhibit with their companions.

Malcolm and Lily used the exhibit in setup 2, which had no screens in the buttons. In contrast, two other groups used the exhibit in setup 1, with screens in the buttons, and explicitly divided up the controllers later in their interaction. For these groups, the suggestion to divide control appeared to be a strategy to align their actions and coordinate their actions following this division of control, unlike Malcolm and Lily in Vignette 17.

Thus, constraining the interaction to only one of four possible controllers, along with the spatial distribution of controllers, enabled groups to divide the controllers explicitly. This behaviour was rare, and did not appear to necessarily support collaborative and joint decision-making. It appeared to be connected with more explicit leading roles, in which specific children would mediate the group with phrases like *"don't press unless we say Naomi"* rather than negotiating and considering the options along with companions. This behaviour was particularly noticeable with Malcolm and Lily in Vignette 17.

Sub-Theme 2.2.3 No Dividing the Controllers Between People

Groups with only one child and an adult or adults typically did not stay located at any particular controller. Instead, children moved freely along the buttons when using the exhibit. The position at which visitors spent most time was between button 2 and 3. This was observed for 6 out of 8 groups who had only one child. This position provided the easiest to access all of the controllers, and very little movement was required to reach buttons when standing between button 2 and 3. The behaviour reveals children only divided up controllers with other children, not with adults.

Sub-Theme 2.3 Coordinating & Aligning Actions Together

The next sub-theme concerns situations in which visitors coordinated and aligned their actions while using the exhibit. Two particular behaviours indicated visitors coordinating in this way. Firstly, they verbally requested that companions “wait”, pausing the group’s interaction with the exhibit and re-grouping visitors’ focus together. Secondly, they established agreements and developed protocols for how to interact with the exhibit together. In some situations, companions used the same controller together. I will discuss these behaviours in detail below.

Sub-Theme 2.3.1 Pausing the Interaction … “Wait”

Visitors were observed pausing the group’s actions with the exhibit by requesting that the group “wait”. The request had a substantial impact. 11 instances of the behaviour were observed from 5 groups. This predominantly occurred when visitors were presented with the challenge selection menu or a challenge question. At this moment, the 4 controllers become active, inviting use. Vignette 18 demonstrates the behaviour. In this vignette, a Mother and teenage daughter are using the exhibit together. The father and toddler in the group only remain at the exhibit for one challenge.

Vignette 18: Pausing the Interaction … “Wait”
Group: 12A. C4-G4 Selection Menu 1
Mum, Dad, Toddler, Kate (11-13) – Mainly Mum & Kate play

Selection 1: First time using the menu to select a challenge
The menu comes up on the screen. Kate says: *"wait, wait wait".* Kate reads out the options: *“size, speed, shape”* and suggests: *“shape.”* Then she presses button 2 (shape) down.

Kate asks the group to wait, displaying awareness of her companions and their ability to progress the task without her input. The arrangement of physical controllers, and constraints of the exhibit which meant that only one controller could be used, created a situation in which group members were in equal positions to control the digital content. Group members were thus encouraged to be mindful of their companions and to consider how their actions might impact on the interaction. Kate verbally tried to synchronise the group's agenda and pace, reducing the possibility of a quick decision and interaction. Visitors requesting that the group *"wait"* slow down the pace and actions of the group, giving them more time to think and discuss choices. Susie and Allen from Vignette 13 also paused the group's interaction by asking the group to *"wait"* at different points during their time at Razzle Dazzle. The request to *"wait"* demanded people's attention, bringing the group's focus together, and encouraging them to progress together, rather than individually. At Razzle Dazzle, the controllers were not active all the time. When the exhibit invited interaction and the controllers were active to interact, visitors attempted to coordinate with companions, attempting to mitigate unwanted interactions or exclusions, while striving to use the desirable controller.

<u>Sub-Theme 2.3.2 Establishing Agreements and Protocols</u>

The exhibit constrained visitors to the use of only one controller for each challenge or selection menu. This constraint, along with the physical separation of controllers and the reduced ability to restrict co-visitors from interacting due to the size of the exhibit, encouraged companions to establish protocols for how to interact with the exhibit and each other. These dynamic of these factors also prompted visitors to establish agreements in relation to how they shared physical interaction with the exhibit and aligned their actions with each other. Forming protocols rarely occurred explicitly. Rather, protocols emerged through visitors' shared activity. Protocols involved waiting for agreement and opinions of others before physically interacting, and visitors trying to ensure that companions did not act without considering their suggestion. Vignette 19 outlines a situation in which a mother established an agreement as to how the group would interact with the exhibit based on Allen trying to coordinate his own desires with his sisters actions. It was the first time the group used the exhibit.

Vignette 19: Establishing Agreements and Protocols
Group 4C: C3-G10 Selection Menu 1
Gran, Mum (25-34) , Dad (25-34), Susie (13), Allen (8-10)

Selection 1: First time using the menu to select a challenge
When the challenge menu comes up on the screen, Mum points to the screen and reads out *"push a button to select one."* Allen starts looking down at the buttons. Allen starts to move and look at other button screens too. Susie does the same and says: *"mmmmm".* Allen seems disrupted by Susie saying: *"ehhhh".* Susie and Allen both want to choose.

For a moment, Susie touches Allen's hand physically restricting him from moving towards button 3. Mum tries to focus Allen's attention: *"right look look this one... look look this one."* Allen is looking at buttons, focusing on them.

Allen starts to say: *"iiiiiii"* choosing while looking at the main screen. Mum points to the buttons explaining them: *"this one's size, that one's shape, that one's speed and that one's direction."* Susie reaches with her arm across Allen, with her finger out towards button 2 as if using it as a touch screen. It agitates Allen: *"no, it's still me"* thinking his sister will take over. Mum asks him calmly: *"what one do you want?"* Susie is pointing to the button 2 reaching across brother. Mum states: *"Susie is not going to press it."* Allen starts to look at buttons again. Mum asks him *"what do you want?"*

Allen is looking at buttons and moving along them. Then he glances up at the main screen. Susie points to button 2 and 1 suggesting: *"I would say these 2 are the most exciting".* Allen still looks towards button 3 and 4, taking his time.

Mum encourages Allen to go with Susie's suggestion: *"yeah....... go for shape."* Allen is still looking at the buttons deciding. He starts focusing on button 2, Shape challenge. Allen puts his hands on button 2 saying: *"yeah".* Crouched down at button 1, Mum encourages Allen to press it: *"push it down".* Allen presses button 2 as his sister Susie watches him. Mum reassures Allen when he's pressing it: *"that's it".*

This situation came about at the very start of the group's interaction, as they were exploring how to use the exhibit. Both children had equal ability to progress the task, but only one visitor was able to do so. Allen asked for a turn, causing the group to form an agreement on a way to use the exhibit together. With the aid of the Mother, an agreement on how to share the interaction was made, setting an informal rule that Susie would not use the controllers without Allen being involved. This pattern of working together continued for the rest of their interaction. The configuration of control put companions equally in control and equally not in control, meaning that there was no easy way for either child to maintain control and exclude other children. Groups made agreements and developed protocols to share the exhibit together. Being unable to prevent their siblings from becoming active prompted verbal agreements and encouraged children to negotiate how to share the use of the exhibit together. As a result, there was more complex verbal interaction between companions when sharing decisions.

Sub-Theme 2.3.3 Using the Same Controller Together

Occasionally situations occurred in which companions pressed the same button simultaneously or together. Only 8 instances of this behaviour were observed from 5 of the 16 groups in the data set. Simultaneous dual use of a button only happened between children and adults, never between two children or two adults. Typically, parents helped to press a button that a child did not fully push down, or acted when children were commenting on what they wanted to select but were not yet acting upon it. Parents then jumped in, moving the interaction forward by pressing the button along with children (see Figure 6-10). In other, less frequent situations, companions ended up pressing a button together because they both went to press a button at the same time.

Figure 6-10: Mum & Claire pushing a button together

The ability to press buttons simultaneously gives parents the opportunity to physically interact with the exhibit along with their children beyond verbal participation. It shows how the configuration of the exhibit enabled parents to break away from their typical behaviours, such as verbal scaffolding or facilitating, and physically play along with the children.

The presence of embedded screens within the buttons appeared to influence simultaneous use of the same controller. 4 out of the 5 groups observed undertaking the behaviour did so when screens were embedded, suggesting that adults' physical interaction with the exhibit increased when controllers were enhanced with a digital representation of the content.

Coordinating and Aligning Actions Together with Embedded Screens or No Screens in the Controllers

The presence of digital content embedded within controllers appeared to be instructive and to influence how companions coordinated and aligned their actions. The questionnaire handed out to groups that had used the exhibit included a semantic differential scale, in which participants were asked to rate 'when you were using the exhibit you work with others' on a scale of 1 to 7, with 1 meaning 'not at all' and 7 meaning 'all the time'. The results reveal, having embedded screens in the buttons received higher ratings in this question, with a greater number of people feeling that they worked together while using the exhibit, as shown in Figure 6-11. This supports the finding that there were more instances of social interaction when people were choosing what button to select when there were screens in the buttons, rather than buttons with no screens, suggesting that this feature helped visitors coordinate with their companions.

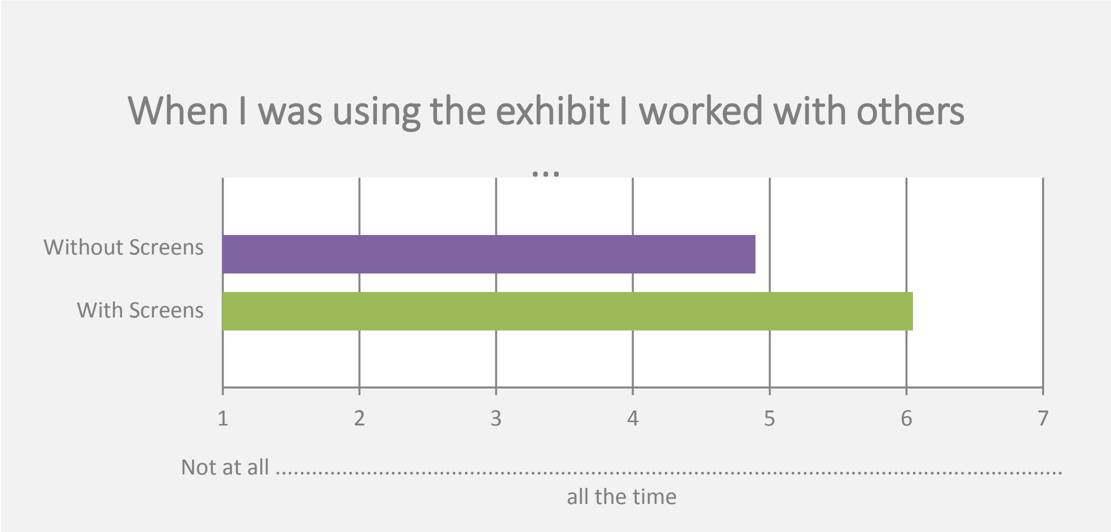


Figure 6-11: Working with others

In one such situation, illustrated in Vignette 20, a Grandmother moved to look directly at the screens in the buttons as all three members of the group put forward their suggestions.

Vignette 20: Embedded Screens in the Controllers
Group: C3-G8 Challenge 1 Size
Tom (under 8) , Mum (30-40), Gran (over 55)

Challenge 1: First time selecting an answer to a challenge
Gran reads out the question: "*What one's the smallest?"* while pointing to the main screen. Tom responds: *"up... over here"* as he moves to button 1. Mum disagrees: *"no, no look at the screen"* as she points to the main screen. Gran starts to make a suggestion while moving to look at the buttons shown in the images above *"I think it's numbeeeerrrrrrrrr........"*

In the vignette, the Grandmother refers directly to the buttons, suggesting that the screens guided people through the interaction as they considered the options. Visitors could use the screens in the buttons to make sense of the activity, allowing them to join in and contribute to joint decisions. During interviews, the Grandmother commented on noticing the screen changes during the activity. The screens appeared to guide visitors' attention. Only when the buttons were active would they show their digital counterpart, the choice that controller would select. Otherwise, the screens directed visitors to watch the big screen, which helped to prevent companions from focusing their attention on individual screens. Overall, visitors rated the setup with the embedded screens in the buttons more highly in terms of being satisfaction, entertainment, feeling active rather than passive, and feeling they were 'doing it (the activity) together'.

Summary of Theme 2: Sharing Physical Interaction

Similar to Theme 1, there were variations in how visitors shared physical interaction including: 1) transitions of control; 2) dividing up controllers, either inexplicitly and explicitly; and 3) coordinating and aligning actions together. Here, I give a brief overview of the findings relating to transitions of control.

Summary of Sub-Theme 2.1 Transitions of Control

Transitions of control transpired in different ways, and were supported by the features of the exhibit. One of the most telling behaviours of companions sharing the physical interaction was visitors directing companions to use particular controllers. This indicates how the distribution of control supported companions to share the activity as active participants, both verbally and physically participating. The configuration of control prompted situations in which visitors invited companions to use specific controllers, and in so doing, included their companions in the activity. Visitors influenced their companions' physical interaction with the exhibit, sharing control and the activity with them. Less frequently, transitions of control occurred was by children actively requested a turn. In these instances, rather than physically interacting with the exhibit to enter the activity, a small number of children entered the activity by verbally asking for a turn. It is important to note that these situations were successful, in that both the child who handed over control and the child who gained control remained involved after physical control was handed over. As previously research has noted (Hornecker and Nicol, 2012), at interactive exhibits, parents often facilitate transitions of control. However, at RD for larger groups, facilitation appeared to be more difficult for parents. There was only one large group in the dataset, yet the data provided by this group suggests that the arrangement did not scale up for larger groups, a challenge faced by many exhibits.

Regarding RQ2, the study offered a number of insights into social activities relating to transitions of control. For example:

- It was rare for companions to verbally request a turn, but when this did happen it led to transitions of control between siblings.
- After a transition of control during which siblings asked for a turn, both companions remained involved actively in deciding and guiding the interaction with the exhibit, conversing with each other.
- Parents mediated and facilitated turn-taking.

Regarding RQ3, I found that the social activities noted above related to the distribution of control in the following ways:

- Through physical separation and distribution of controllers.
- Through a lack of time pressure. Without time pressure imposed by the exhibit, visitors were in control of the pace of the interaction at key interaction points and thus could invite others to interact or discuss.
- Through the active and inactive status of the controllers. Transitions of control often occurred when controllers became active and inactive during the course of the interaction.
- Through controller constraints. Limiting the use of controllers to one controller per decision played a role in how physical interaction transitioned between companions located at different controllers.
- Through the varying desirability of the controllers. Various controllers became the desirable controller at different moments during interaction, shifting control between different members of the group over the course of the interaction.

Summary of Sub-Theme 2.2 Dividing up the Controllers

Children in a group with at least one other child tended to assign or divide the controllers either explicitly or implicitly between members of the group. The groups which made the decision implicitly engaged in a greater amount of collaborative behaviours and joint decisions . They appeared to collectively develop a protocol for working together, whereas the groups who explicitly divide controllers seem to have one child who led or imposed rules. It is possible that the manner in which an exhibit implies explicit or inexplicit ownership or assigns controllers to individuals is an important factor in encouraging joint decision-making and collaborative behaviours. The findings demonstrated that the less explicit the process of dividing controllers between companions, the more freeform the decision-making and shared interactions became. This raises the question of whether exhibit design should aim to avoid creating situations in which groups have to explicitly assign controllers to companions, thereby allowing for a more fluid, implicit process. Groups with only one child did not assign themselves to any particular controllers, and instead the child moved between controllers, with the parents often participating, physically and verbally.

Regarding RQ2, the nature of visitors' social activities, the findings demonstrated that typically, companions divided physical controllers in very subtle, unspoken ways. This implicit division was associated with companions sharing decisions. More rarely, companions explicitly divided up controllers. In these cases, groups tended to make decisions more quickly, and were less likely to make joint decisions.

The findings around companions dividing up controllers corresponded with RQ3, highlighting a connection the distribution of control and the following characteristics:

- The spatial distribution of tangible controllers
- Unprivileged positions
- Interconnectedness of controllers - the relationship between controllers
- The digital distribution of control. In particular, the ways the interactional structure responding to the use of only one controller

Summary of Sub-Theme 2.3 Coordinating & Aligning Actions Together

The study revealed a number of different situations of interest relating to visitors coordinating and aligning their actions. Firstly, in some situations visitors were mindful of how their companions' actions influenced their personal interaction with the exhibit. This was particularly noticeable when visitors asked the group to "wait" before interacting. Secondly, in other situations visitors understood and objected to their excluded from the activity. The situation seemed to happen more with younger children, such as in Vignette 19. This exclusion involved both physical interaction and decision making. Rather than companions having equal control, they were equally not in control, which sparked companions coordinating together.

Thirdly, the exhibit did not reward random quick button pressing and guiding the groups' attention to a singular focus, drawing companions' attention collectively together. That there was only one possible answer and visitors were unable to dominate all of the controllers, encouraged companions to verbally coordinate as a group so that visitors did not press a button randomly.

Regarding RQ2, companions aligned and coordinated their actions in different ways, such as requesting that their companions *"wait"*, establishing agreements, and directing others to use certain controllers. The behaviours reveal not only how visitors coordinated their actions, but also how visitors were guided to focus on their companions beyond their own individual interaction with the exhibit.

Behaviour	Variations	Link to the Exhibit's Features & Attributes
Sharing Physical Interaction	Transitions of Control Dividing up Controllers Coordinating & Aligning actions together	• Separation of controllers • Fixed controllers • Ambiguity as to which controller is the desirable controller – difficult to know immediately or predict, linked with posing the group a challenge opinion-based question • Controller located at different companions, leading to situations in which a companion is at the desirable controller • Being right or wrong – the motivation to be right rather than be the button presser • Ability to influence the interaction with the exhibit even after handing over control • Limiting the interaction to use only one controller at a time • Digital content embedded within the controllers (screens in the buttons) • Implication that the exhibit is multi-user with 4 separate controllers • Hard to press buttons from the side • Large buttons – easy to press together

Table 6-4: Sharing physical interaction and features or attributes of the exhibit

In relation to RQ3, there were many aspects of the exhibit relating to the configuration of control which influenced communication within groups and coordinated actions such as: the spatial distribution of controllers; the inability to restrict companions from interacting; screens embedded within controllers; moments of inactive and active controllers; the ability to only use one controller combined with a challenge question for the group with an unclear answer; and putting companions in equal positions for actions, so that anyone can comment or suggest an answer.

Parents and children occasionally shared physical interaction through control of the same controller. This shared use of the same controller between parents and children was encouraged and facilitated by the physical distribution of controllers, screens embedded within controllers, the large size of the buttons.

6.4.3 Theme 3: Dominating Physical Interaction with the Exhibit

While the PhD thesis considers how exhibits support or hinder social interactions between companions, it is also important to investigate antisocial behaviours which occur. For example, when visitors exhibit dominating behaviours, do not coordinate with companions, or ignore or exclude companions from the activity. It is important to consider both the outcome of these situations and the manner in which features of the exhibit influence these conflicts when developing installations in order to avoid supporting dominating behaviours, and to help visitors to resolve conflicts easily and quickly. It is of course unrealistic to expect these behaviours not to emerge in groups contexts, but exhibits should aim to diminish dominating behaviours, particularly when supporting group interactions and social activities.

Younger children often naturally dominate during hands-on activities, or attempt to interact alone. Collaboration and sharing can be difficult, especially for younger children (Stanton et al., 2001). This section considers situations in which visitors tried to dominate and maintain dominance of the physical interaction with the exhibit in order to investigate how aspects of the exhibit hindered or enabled this domination. Three indicators were used to identify how visitors attempted to and succeeded in dominating physical interaction with the exhibit, as shown below in Table 6-5. The theme is related to the other themes in that these behaviours may happen before or after behaviours which appear in the other themes. However, they are distinct as they relate to dominating the interaction. For example, a child dominating the interaction (theme 3) may lead to a child requesting a turn and a hand over of control occurring (theme 2). The behaviours themselves are connected in they happen before or after each other but are different in their nature and therefore are organised under separate themes.

Behaviours	Indicators
Dominating (e.g. not sharing)	Reaching in front of companions to press a button the companion is closer to
	Interacting without conferring with companions
	Physically restricting companions from interacting with the exhibit

Table 6-5: Indicators of dominating behaviour

Sub-Theme 3.1 Reaching in Front of Companions to Use Controllers

Both children and adults frequently reached in front of others to use a controller. Children would reach in front of adults without hesitation. Similarly, parents were observed reaching in front of children to use the controllers without any objection from children. Given the context of these instances, it seems apparent that parents did this in order to progress the task. However, when children reached in front of other children, there were two outcomes. Firstly, in three instances, children were unable to successfully use the controller which was not located directly in front of them.

Figure 6-12: Pressing Buttons

Due to the construction of the buttons, the easiest way for visitors to use the exhibit was by placing a hand in the centre of the button. As a result, it was difficult to press the controller unless visitors stood directly over the button. Therefore, effectively prevented companions from dominating the physical interaction by reaching over to access this controller. Three of these instances, prompted a transition of control transitioned to the companion standing at the controller. This enabled visitors to act upon their companions' intentions, and to be involved in the activity rather than being excluded. For example, in Vignette 13, Allen acted on his sister's suggestion to press button 1, which she was standing at. Allen moved behind his sister to press button 1, as show in Figure 6-13. This overt, physical behaviour, moving behind Susie, allowed her to become aware of Allen's intention, react to him, and use the controller before Allen could do so. In this way, we can see how aspects of the exhibit prevented visitors from dominating the interaction, and helped companions to be included in the activity and physical interaction.

Figure 6-13: Allen moves behind Susie to press a button

The second observed outcome was children verbally reacting to dominating behaviour, such as a sibling invading their space at a controller, which triggered handovers. Referring back to Vignette 16, Mike asked *"...can I not have a go"*, which led to a transition of control from Sara to him. Before Mike made the request, Sara had just reached in front of Mike to use the controller at which Mike was standing.

Figure 6-14: Mike and Sara at the installation during their third challenge, Speed

In this group, Sara dominated button pressing while Mike was in the bathroom. She conferred with her father about the answers. When Mike returned, he stood at button 1, as shown Figure 6-14. Sara then moved in front of her sibling, to which he objected, and this then triggered a transition of control. When Sara did not invade Mike's space, there was no request for a turn. It is therefore likely that invading Mike's space to use the button in front of him led to him requesting control. As demonstrated in Vignette 16, this request prompted a transition of physical control for the next challenge.

Sub-Theme 3.2 Interacting Without Conferring with Companions

In some situations, one individual significantly dominated use of the controllers. These situations were rare, and typically occurred in groups with only one child and adults. Lily and Malcolm's group were the only group in which children continuously and quickly pressed buttons without conferring with companions, as illustrated in Vignette 17. In this group, the visitors explicitly divided up controllers to one another at the start of their interaction and proceeded to press buttons as quickly as they could without conferring with their companions. Usually, companions discouraged each other from such quick button pressing without group discussion and coordination, as demonstrated in section entitled 'Coordinating and Aligning Actions Together with Embedded Screens or No Screens in the Controllers' on page 248.

Sub-Theme 3.3 Physically Restricting Companions from Using the Exhibit

In some cases, children tried to maintain physical control of the exhibit by physically restricting their companions from using the exhibit. This was a rare occurrence, and did not usually continue for any prolonged period of time. This was because it was impossible to do physically restrict their companions for an extended period, owing to the configuration and location of the controllers. Typically, older children tried to restrict younger children from interacting with the exhibit. For example, as Figure 6-15 illustrates, children sometimes put up a hand or arm in front of a sibling to prevent them from using the controllers. Typically, this behaviour occurred at the start of groups' interactions and dwindled out quickly.

Figure 6-15: Preventing a sibling from accessing controllers

While some children initially tried to prevent their younger siblings from using the controllers, the physical configuration and nature of the installation made it impossible to do so for any prolonged period of time. The controllers were distributed over a wide space, making it physically difficult for children to restrict others. Furthermore, it was not possible to predict the next location of the desirable controller, meaning that it was not possible to continually prevent a companion from using the desirable controller. Controllers were only active at certain points, and visitors had limited time to physically interact with them, meaning that when controllers became active, the desirable controller may have been inaccessible to a visitor who wished to dominate the interaction.

Summary of Theme 3: Dominating Physical Interaction with the Exhibit

The majority of groups decided which controllers to use together. However, as expected, on occasion children attempted to dominate the physical interaction by using controllers by themselves, even when these were located in front of their companions. The behaviours which occurred between children, rather than between adults and children, were of particular interest. In these cases, it was evident that the dominating behaviour of reaching across companions to use a controller was generally unsuccessful. This limited success was the result of to two factors. Firstly, it was difficult to press a button from the side of the exhibit; instead, to easily use a controller, a visitor had to be located directly in front of the button. Secondly, if a visitor's space was encroached on by a companion, this usually triggered a reaction from the visitor.

Both situations lead to (1) a transition of control, as visitors moved to press the button themselves, and to (2) an explicit request to share the current or subsequent activity. In all cases, companions responded to dominating behaviours in a way that mitigated physical conflicts around control. The situations where visitors felt excluded from the activity were resolved with verbal negotiations and agreements rather than physical interventions. Disruptive behaviour and conflicts were, overall, surprisingly rare, indicating that the exhibit design was successful in encouraging productive social interaction and enabling visitor groups to establish their own patterns of sharing.

Along with physical distribution of the controllers, the structure of the interaction constrained the physical interaction so that visitors could use only one controller per challenge. This structure therefore hindered attempts by individuals to dominate physical interaction and limited opportunities for visitors to engage in separate independent activities with the exhibit. All four buttons became the desirable controller at some point during interaction, in no predictable sequence. This gave the activity a dynamic and unpredictable quality. Combined with the physical distribution of controllers, this interaction structure mean that visitors were unable to maintain the desirable position, for every challenge question. The structure therefore created opportunities for visitors to share the physical interaction.

In response to RQ2, the nature of social activities between companions, the following insights regarding dominating behaviours have been determined:

- Children did try to dominate physical interaction intermittently throughout their use of the exhibit.
- Adults and children did reach in front of each other to use controllers. Such attempts generally prompted verbal and physical responses.
- Children did not physically fight but did engage in verbal negotiations and agreements to manage dominating behaviour or conflicts.
- Children reacted to being excluded by asking to be included or by physically carrying out actions for other children, when other children invaded their space to use a controller.
- Physical blocking of companions at the exhibit was rare and never lasted for a long time.

Dominating behaviours were more prevalent in groups with only one child but, given the opportunity, parents interacted too. Dominating behaviours between children were rarely sustained.

In response to RQ3, ways in which control is distributed between companions, the following insights have been determined in relation to dominating behaviours:

- Children's attempts to use companions' controllers failed for three primary reasons: (1) controllers were out of reach for the child attempting to gain control; (2) it was difficult to reach and successfully press controllers from the side of the exhibit due partly to the physical mechanism of the buttons; (3) and children often noticed companions moving to use a controller the child is closer to and used the controller before their companion could. Successfully
- The distance between all of the controllers made it difficult for visitors to restrict companions from interacting with the exhibit.
- As only one controller could be used at a time, and the location of this controller was not predictable, it was difficult for individuals to dominate the physical interaction.
- The movement of the desirable controller between the four controllers prevented visitors from maintaining constant control of this desirable controller and, in turn, prevented them from easily dominating the interaction.

For most groups with two or more children, dominating behaviours were mediated by both the exhibit and companions. Attempts to resolve conflicts frequently led to companions sharing the activity through verbal and physical activities. It was difficult for children to interact with the exhibit by themselves if they wanted to succeed in the challenges.

Behaviour	Variations	Link to the Exhibit's Features & Attributes
Dominating Behaviours	Reaching in front of companions to press a button the companion is closer to Interacting without conferring with companions Physically restricting companions from the exhibit	• Difficulty in using controller unless standing right over the button • Physical distribution of the controllers • Limitation to use only one controller at interaction moments • Unpredictable and dynamic movement of the desirable controller as different controllers at different interaction moments • Challenging opinion-based question. Creating opportunities for companions to meaningfully influence the interaction with the exhibit through verbal participation • Large buttons • Distance between the controllers, and the ease of moving between them

Table 6-6: Dominating behaviours & features or characteristics of the exhibit

6.4.4 Summary of Interactions between Co-visitors while using the Exhibit

A number of relevant behaviours and situations were evident while groups were using the exhibit. For example, it was found that groups used controllers thoughtfully, and engaged in calm, slow interactions, rarely rushing to press buttons as quickly as possible. Group members were encouraged to hand over control to others during the activity, which led to the sharing of physical participation. As well as sharing physical participation, groups also shared decisions through discussions, debating the different available options to choose from, and actively influencing how their companions interacted with the exhibit. In these discussions, there was a noticeable focus on what companions were saying, what the group were currently doing and what they could potentially do with the exhibit. The activity encouraged group members to expand their focus beyond their own solo interaction with the exhibit being mindful and inclusive of their companions. Co-visitors also aligned their actions with each other and coordinated their interaction with the exhibit. Situations in which individuals were excluded from the activity and wanted to be involved were resolved quickly and easily. In these cases, even when an individual's means of participation changed, all parties continued to strongly influence the interaction with the exhibit. Unusually for an interactive exhibit and on occasion at RD, parents participated in the activity on a peer level, offering contradictory suggestions and physically interacting themselves. It was difficult for individuals to dominate physical interaction with the exhibit when there was more than one child in the group. Individuals were aware of the intentions and actions of others, and visibility of the status of the activity, which supported the group's engagement with the activity and interactions with each other.

The setup of the exhibit also made it difficult for children to restrict their companions from using the exhibit. At some exhibits, limiting visitors ability to maintain control can cause disruption. For example, the use of a controller by a companion can interrupt the current visitors interaction with the exhibit. At Razzle Dazzle, children developed ways to use the exhibit together, and adopted coordination strategiessuch as seeking approval before pressing, asking the group to "wait", and verbalising their suggestions and opinions. These acted as protocols they adopted in order to share interaction with the exhibit.

6.5 Key Elements of the Exhibit that Relate to Groups' Social Shared Interactions

This PhD research is centrally interested in understanding how the design of an interactive exhibit and its specific features can influence a group's experience of using the exhibit and, in particularly, the impact these features have on social interactions between group members while they are using the exhibit. So far, I have discussed the findings in terms of companions interactions which occurred while they interacted with RD. I will now consider the data from a more abstract perspective, considering particular characteristics of distributed control, in response to RQ3. I will then attempt to map these with the observed interactions or behaviours.

This mapping presents an alternative conception of the behaviours and situations discussed in section 6.4. The discussion in this section specifically considers aspects associated with the distribution of control. These are mapped between characteristics associated with distribution of control, shown in the left hand column of Figure 6-16, and outcomes which were observed at RD, shown in the right hand column of Figure 6-16. Between these two categories is a transactional space in which interactions occur between companions and with the exhibit. In this conception, visitors occupy this central space between characteristics and outcomes; interacting with characteristics on the left of Figure 6-16, leads to the situations or behaviours on the right. I have categorised the connections between the features of the exhibit and outcomes in order to present an interpretation of the interaction. However, it should be noted that if a connection is not present in the diagram, it should not be inferred that this connection does not exist. Only those connections that have been derived from the data are presented here.

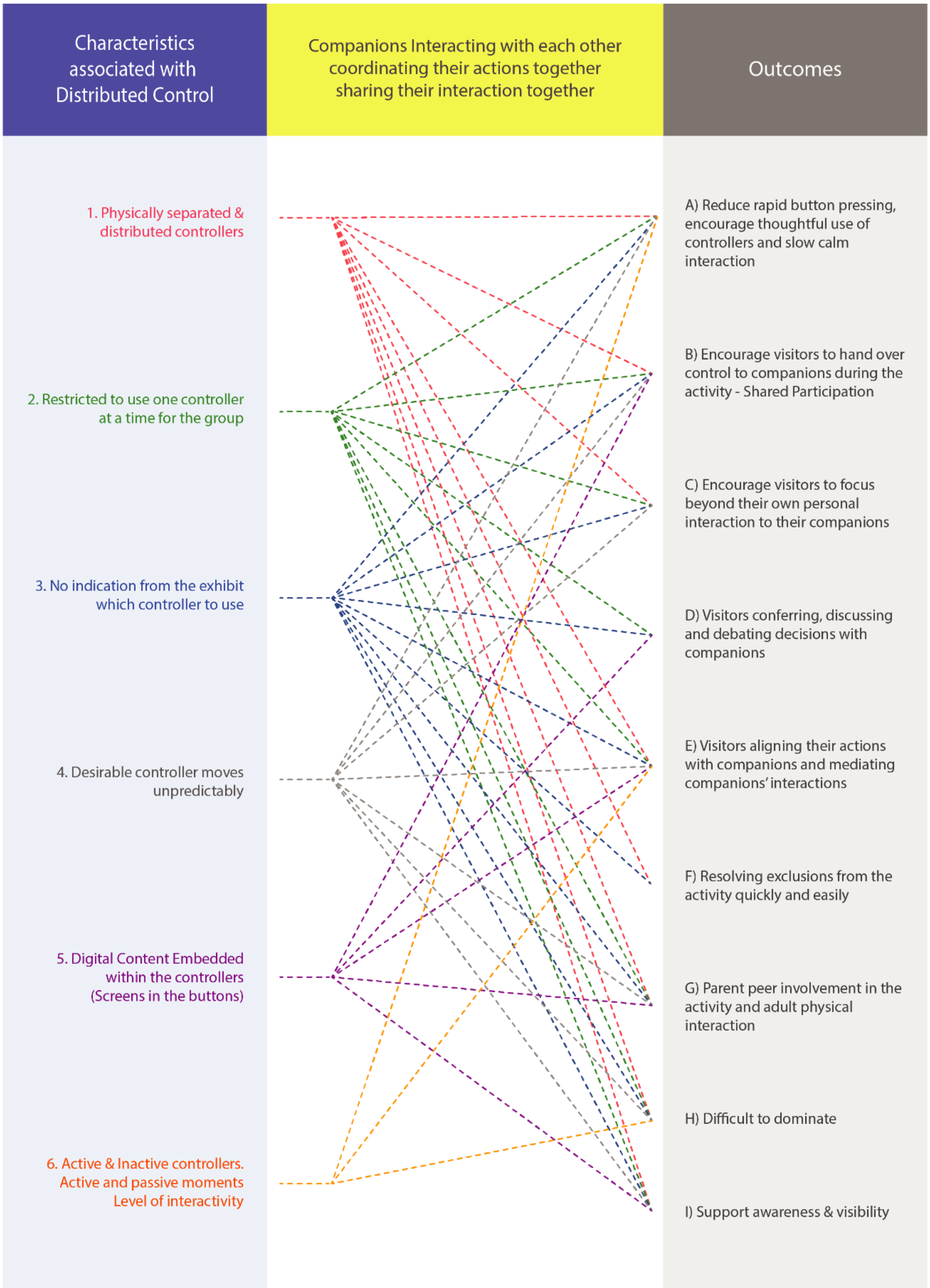


Figure 6-16: Mapping of characteristics and observed outcomes in terms of behaviours

The characteristics listed in Figure 6-16 are not considered to be factors that independently foster the behaviours and situations listed on the right of the diagram. Instead, they are understood to collectively contribute and work together to support such outcomes. Removing one of these factors alters the overall balance. The factors work together to strengthen each other and enhance out different qualities in each other.

Furthermore, other aspects relating to the nature of the activity have also played a role in the companions shared social interactions at RD. However, these are not mapped out in Figure 6-16 as they do not align with the central research focus on distribution of control. Nevertheless, two attributes were observed to influence the nature of social shared interactions and therefore should be noted before discussing the characteristics of distribution of control (Figure 6-16) in more detail. Firstly, the prospect of visitors being right or wrong and, secondly, the lack of time pressure imposed by the exhibit.

Firstly, as a result of the nature of the activity at RD, visitors either answered a question correctly or incorrectly, which gave their actions an element of consequence. Having to answer the question correctly created situations in which visitors directed and encouraged their companions to use specific controllers (Sub-Theme 2.1.1) and mediated group interactions (Sub-Theme 2.3.1), demonstrating how visitors worked as a team to answer the question correctly. Groups debated and decided together their answers and who would use a controller, based primarily on what they believed the right answer to be, not on equality of turn taking. The drive to be correct appeared to distract from potential conflicts, so that groups chose controllers based on the right answer, rather than on whose turn it was to use a controller.

Overall, the prospect of being right or wrong appeared to be a primary motivator for social interaction between companions, which led to the shared use of the controllers and triggered transitions of control (Sub-Theme 2.1). As described in ‘Sub-Theme 2.3 Coordinating & Aligning Actions Together’, companions coordinated and aligned their actions in a number of ways, including mediating each other’s interactions with the exhibit.

Secondly, there was no time pressure imposed at the exhibit to use controllers within a certain time frame. During the co-design process, it was suggested that a timer could be introduced to gamify the exhibit. Museum staff in particular were keen to introduce a timer to create excitement and a competitive element. However, based on personal observations from the gallery floor of people's interactions with gamified exhibits which have timers, it was ultimately decided that a timer would not be appropriate. In support of this decision, prior studies have suggested that time pressure reduces visitors' ability to reflect on the situation or to have discussions (Hornecker, 2016). At RD, without time pressure imposed by the exhibit, companions took their time discussing the options (Theme 1: Groups Sharing Decisions), organising their collective actions ('Sub-Theme 2.3 Coordinating & Aligning Actions Together' and 'Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller'), engaging in thoughtful and considered use of controllers (Theme 1: Groups Sharing Decisions and 'Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller') and gaining awareness of their companions' involvement in the activity.

Now I will move on to breaking down the points in the above Figure 6-16: Mapping of characteristics and observed outcomes in terms of behaviours') individually discussing six characteristics associated with distribution of control and how these played a role in visitors' shared social interaction.

6.5.1 Physically separated & distributed controllers

Of particular interest to this research is to understand the distribution of controllers in relation to the "social ongoings" of companions. In particular, the research focuses on controllers that manipulate the digital content which are physically separated from each other. In the case of Razzle Dazzle, four buttons were located in a line alongside each other, but were physically divided by a visual and physical gap.

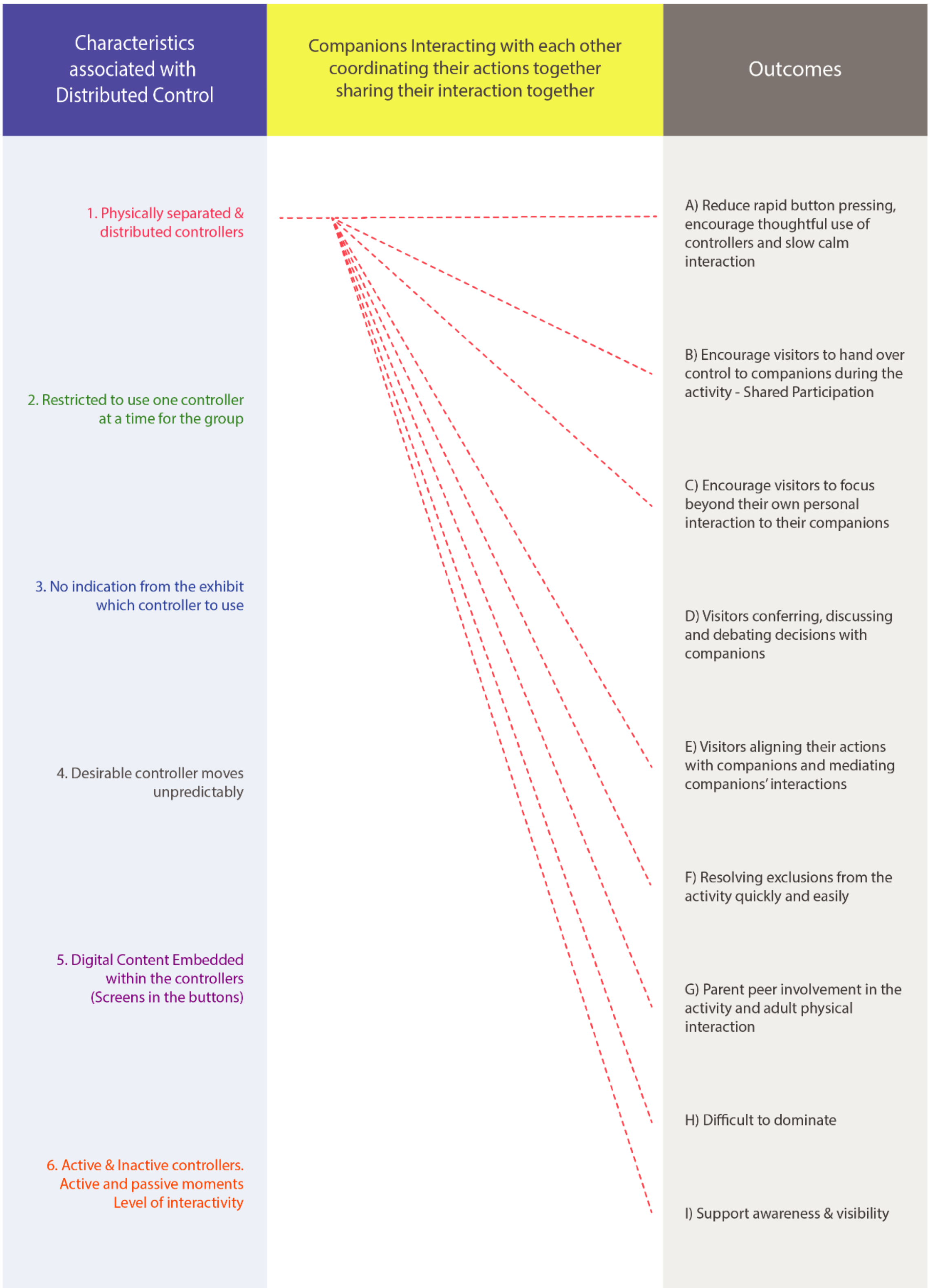


Figure 6-17: Outcomes connected to physical distribution of controllers

The physical distribution of controllers had a number of key outcomes at RD. This distribution:

Outcome A) ...made it difficult for individuals to immediately press a button if it was located away from them, which slowed down physical interaction (Theme 1: Groups Sharing Decisions & Sub-Theme 2.1 Transitions of Control). With four distributed controllers to consider, visitors took time to consider which controller represented the answer they have decided upon.

Outcome B) ... meant that using a controller located in front of a companion required handing over control (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller) or invading their personal space (Theme 3: Dominating Physical Interaction with the Exhibit), which frequently triggered transitions of control (Sub-Theme 2.1 Transitions of Control).

Outcome C) ... encouraged individuals to consider their companions' ability to interact with the exhibit, rather than focusing exclusively on their own interaction with the exhibit (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller & Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome E) ... encouraged visitors to align their actions with companions and mediate the interactions of the group. Visitors who were located closer to the desirable controller could act upon their companions' suggestions, and the group could collectively share the selection of answers (Sub-Theme 2.2 Dividing up the Controller, Theme 3: Dominating Physical Interaction with the Exhibit and 'Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome F) ... aided handovers during which children did not need to move away from the exhibit, as there were four separate controllers and no single controller of which to maintain possession (Theme 3: Dominating Physical Interaction with the Exhibit). The design of the exhibit implied that it was a multi-user activity, as it had multiple separated controllers. This prompted situations in which individuals initiated turn taking.

Outcome G) ... invited adults to physically interact with controllers located close to them (Sub-Theme 2.3.3 Using the Same Controller Together & Theme 1: Groups Sharing Decisions).

Outcome H) ... limited opportunities for individuals to dominate the activity. Visitors were unable to physically restrict companions from all of the controllers distributed over the large exhibit space. Occasionally, controllers were blocked by companions, reducing the ability for individuals to dominate the physical interaction. This created opportunities for companions to be included in physical interaction and to share the activity (Theme 3: Dominating Physical Interaction with the Exhibit).

Outcome I) ... elicited large movements, making visitors' intentions and interaction with the exhibit evident to co-visitors, thus increasing awareness and visibility of companions activities (Theme 3: Dominating Physical Interaction with the Exhibit).

6.5.2 Restricted to use one controller at a time for the group

Another key aspect of distributed control was the constraint to only use one controller at a time. The exhibit reacted to only one button being pressed during the challenge questions and selection menus. Thus, selecting one option or answer. It should be noted that this structure directly relates the nature of the task, which required visitors to choose only one answer or challenge to take on. However, here I focus solely on the distribution of control relating to the controllers, rather than the task itself.

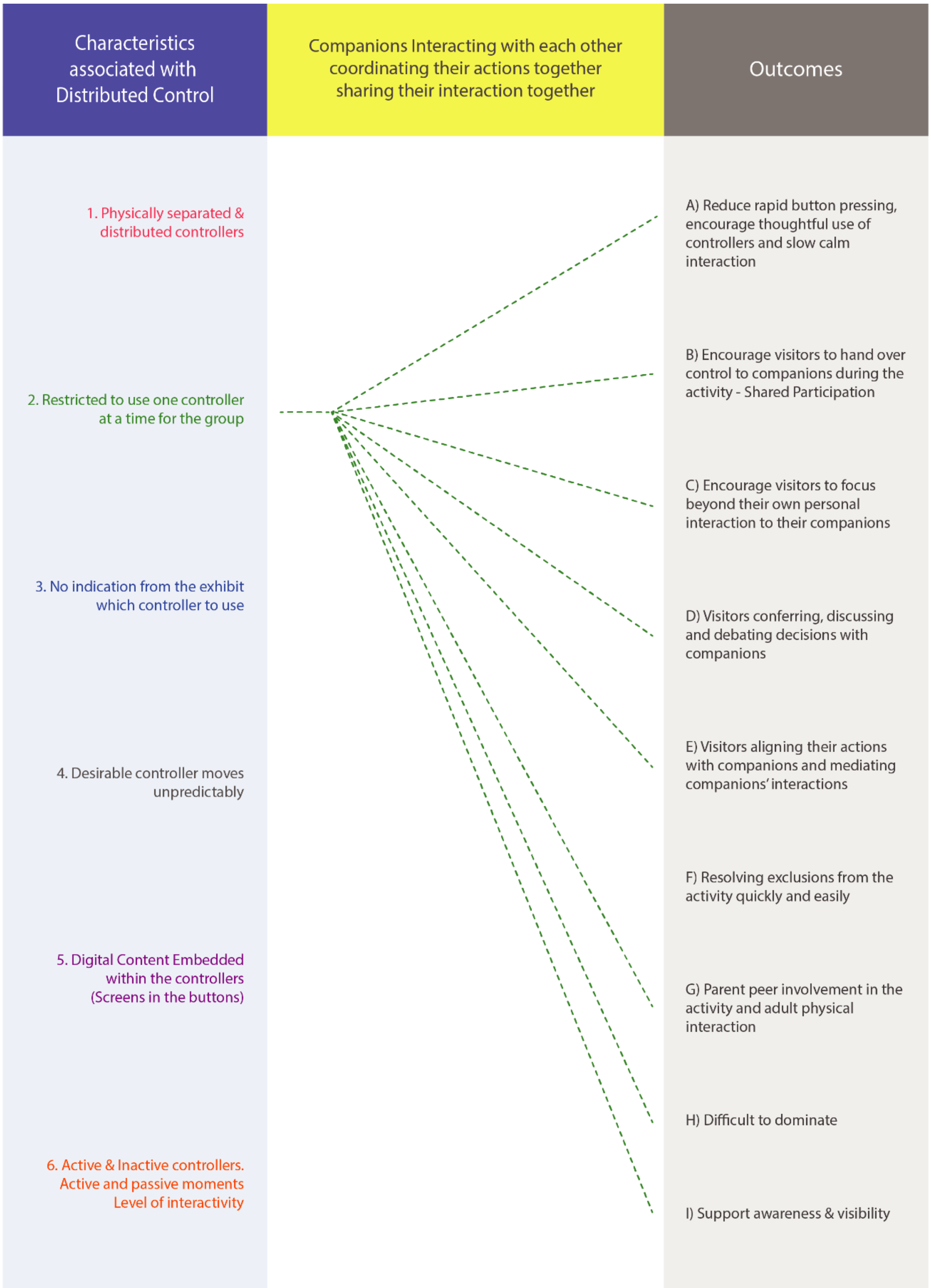


Figure 6-18: Outcomes connected to restricting the group to choose and interact with only one controller

Restricted interaction with controllers, allowing a group to select only one controller to use, had a number of key outcomes at RD. This restricted interaction:

Outcome A) … appeared to encourage careful and thoughtful use of the controllers, which in turn discouraged quick button pressing and slowed down the pace of visitors' interaction (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller & Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome B) … appeared to prompt transitions of control between companions (Theme 1: Groups Sharing Decisions). It was impossible to be located at all sections of the exhibit at the one time, and thus when companions were located at the desirable controller, others frequently handed over control, sharing the activity.

Outcome C) … encouraged visitors to consider suggestions put forward by their companions and the controllers which they could access. It was possible for companions to use the wrong controller or interact without the contribution of others, potentially reducing the groups chance to succeed at the challenge. With only one controller to select, visitors shifted their focus from how they could personally interact with the exhibit to also consider how companions could interact. Visitors asked companions to wait, demonstrating a heightened awareness of each other's actions and how their companions actions could impact upon their involvement in the activity and the overall activity. (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller & Sub-Theme 2.3 Coordinating & Aligning Actions Together)

Outcome D) … triggered group discussions and debates that were frequently driven by choosing an answer and a single controller for the group (Theme 1: Groups Sharing Decisions).

Outcome E) … led to situations in which visitors coordinated their actions when trying to select one answer and use the appropriate controller (Sub-Theme 2.3 Coordinating & Aligning Actions Together)

Outcome G) … brought about situations in which parents physically interacted with the exhibit along with children, using the same controller together (section 'using the same controller together').

Outcome H) ... made children's dominance of controllers obvious. Companions reacted, either physically or verbally, to the dominating behaviour which hampered further dominating behaviours (Theme 3: Dominating Physical Interaction with the Exhibit).

Outcome I) .... encouraged visitors to consider all of the options available, increased awareness and visibility of the task, guided the groups' focus to a central activity and aided visitors' awareness of their companions' (sections discussions 'sharing decisions', 'directing others' and 'coordinating and aligning actions together').

6.5.3 No Indication from the Exhibit Which Controller to Use

Similar to restricting interaction to the use of only one controller, making a choice as to which answer to choose also appeared to engender shared social interactions between companions. The challenging opinion-based questions groups gave no guidance as to the appropriate controller to use. The exhibit did not explicitly direct visitors as to which controllers to use. Thus, groups had to decide together which single controller to use.

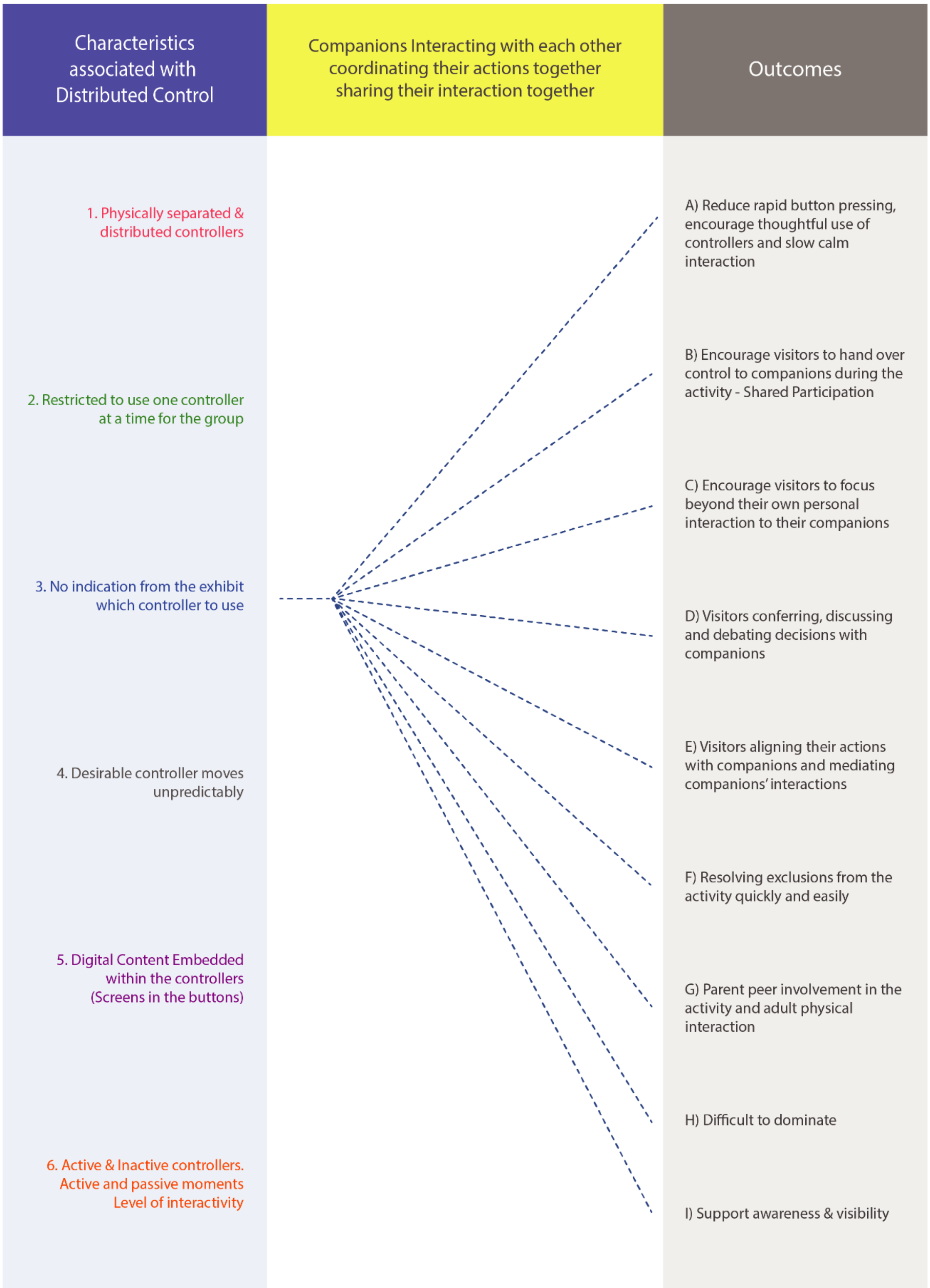


Figure 6-19: Outcomes connected to no guidance from the exhibit which controller to use

This lack of indication as to which controller to use had a number of key outcomes. With no guidance from the exhibit which controller to use...

Outcome A) .... individuals took time to consider and debate the options, which in turn engendered slower, calmer interactions and use of controllers (Theme 1: Groups Sharing Decisions & Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome B) ... control in the form of consent was passed between companions (Sub-Theme 2.1 Transitions of Control), and companions directed each other to use controllers while still deciding which controller to use.

Outcome C) ... deciding which controller to use was based on opinions, with multiple members of the group in equal positions to contribute verbally to the decisions as to which controller to use. Companions' opinions and suggestions helped groups to choose the appropriate controller, encouraging visitors to listen to each other (Theme 1: Groups Sharing Decisions, Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller & Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome D) ... the choice was based on opinions, thus inviting multiple contributions by group members and prompting discussions and debates between companions (Theme 1: Groups Sharing Decisions).

Outcome E) ... visitors were observed coordinating and aligning their actions (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller & Sub-Theme 2.3 Coordinating & Aligning Actions Together) and mediating their companions interaction with the exhibit. The opinion-based choice created opportunities for any member of the group to participate and influence the interaction of the group, regardless of access to controllers.

Outcome F) ... choosing a controller was based on opinions, reinforcing the notion that verbal contributions were highly influential to some extent influenced the activity more than the physical participation of individual members (Theme 1: Groups Sharing Decisions & Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller). This helped to resolve conflicts, as children could still participate in a highly influential way, through verbal contributions and directions, without maintaining physical interaction with the exhibit.

Outcome G) … adults appeared to be engaged by the challenge, considering and proposing possible controllers themselves. This supported situations in which parents participated in the activity as peers as well as in the role of facilitators (Theme 1: Groups Sharing Decisions & + Sub-Theme 2.3.3 Using the Same Controller Together).

Outcome H) … the interaction was heavily orientated around group members' opinions. Restricting individuals from sharing their opinions was difficult, if not impossible (Sub-Theme 2.3 Coordinating & Aligning Actions Together & Theme 3: Dominating Physical Interaction with the Exhibit). Furthermore, the ambiguity of knowing which controller to use made it awkward for visitors to predict and monopolise the appropriate controller.

Outcome I) … visitors often took a step back from interaction to consider the appropriate controller to use, aiding in their visibility and overall awareness of the task and of their companions.

6.5.4 The Desirable Controller Moves Unpredictably

The dynamic and unpredictable movement of the desirable controller also influenced social interaction. During the overall interaction, the location of the most desirable controller changed between the four different buttons at different moments during the interaction. This process was entirely random, which made the activity dynamic and unpredictable. The impact of this unpredictability was reinforced by the previous characteristic 'No Indication from the Exhibit Which Controller to Use', as there was ambiguity around which controller to use. I will now highlight how the movement of the desirable controller influenced the situations observed at RD.

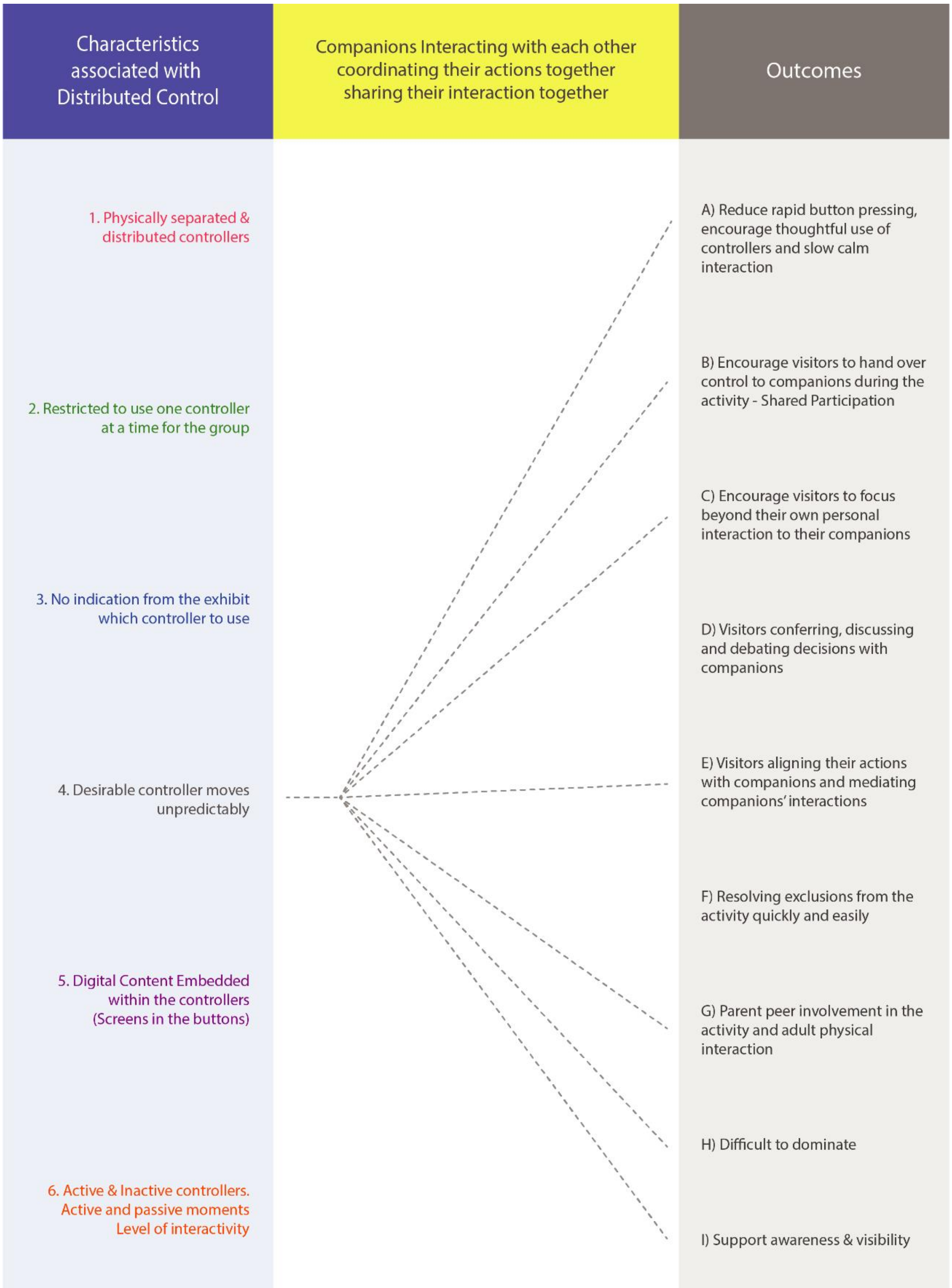


Figure 6-20: Outcomes connected to the unpredictable and dynamic nature of the desirable controller being located at different controllers throughout the activity

The unpredictable and dynamic nature of the desirable controller had a number of key outcomes. This unpredictability…

Outcome A) … slowed down visitors' interaction and encouraged thoughtful use of the controllers (Sub-Theme 2.1 Transitions of Control & Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome B) … led to situations in which visitors handed over physical control to companions as visitors could not predict where to stand in order to assume control of the desirable controller (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller & Theme 3: Dominating Physical Interaction with the Exhibit).

Outcome C) … prompted visitors to focus on their companions' interactions with the exhibit beyond their own personal interactions, and encouraged visitors to consider controllers that the whole group would access (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller & Sub-Theme 2.3.1 Pausing the Interaction … "Wait").

Outcome E) … encouraged companions to coordinate their actions. The unpredictability created a lack of control, as visitors did not know where the next desirable controller would be. Visitors responded to this uncertainty by asking companions to 'wait' (Sub-Theme 2.3 Coordinating & Aligning Actions Together), giving the group time to figure out the answer and thus the desirable controller to use. The exhibit therefore created situations in which groups were encouraged to work together to solve the problem and coordinate their actions to interact with the exhibit (Sub-Theme 2.1 Transitions of Control).

Outcome G) … occasionally located the desirable controller at parents, instigating situations where parents interacted physically themselves (Sub-Theme 2.1 Transitions of Control).

Outcome H) … made it impossible for visitors to maintain possession of a single essential controller, making it difficult for any one person to dominate physical interaction at the exhibit (Theme 3: Dominating Physical Interaction with the Exhibit).

Outcome I) … distributed visitors' focus throughout the exhibit space and prompted individuals to move between controllers (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller) Such movements were noticeable to companions in the space, which increased visitors' awareness of the intentions and actions of their companions and increased visibility of the buttons.

6.5.5 Digital Content Embedded Within the Controllers

This study also focused on how and where the digital content visitors interacted with is represented in the exhibit. As such, I considered the interactions which took place in relation to the digital content embedded within the controller, both in the setup with screens embedded within the buttons, and the setup without.

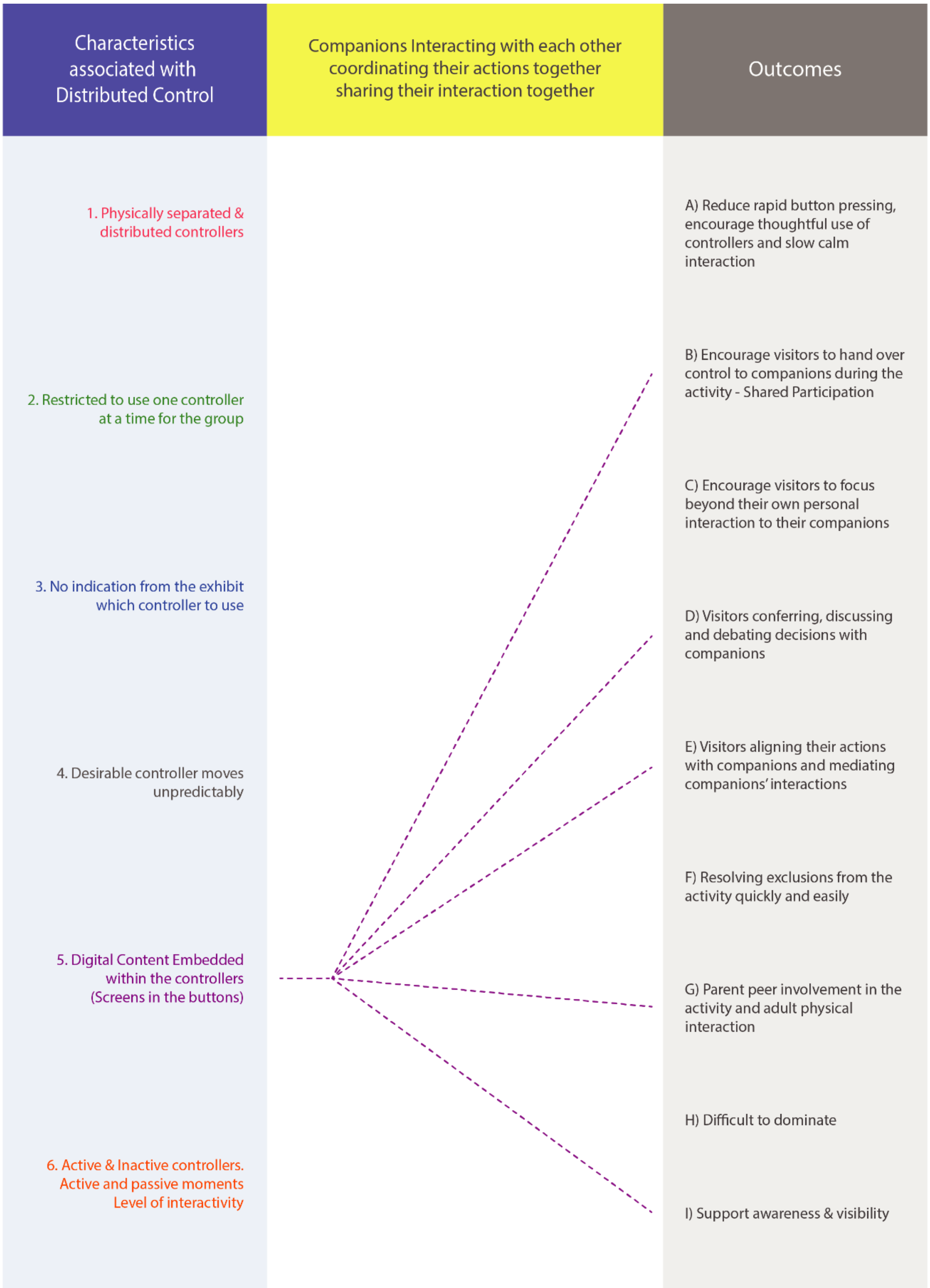


Figure 6-21: Outcomes connected to digital content embedded within controllers

Embedding digital content within the controllers had a number outcomes. The embedding of this content:

Outcome B) … stimulated shared participation and prompted visitors to direct their companions to use controllers during the activity more than was the case for the setup which did not have screens embedded in the buttons (Sub-Theme 2.1.1 Directing Companions to Use a Specific Controller).

Outcome D) … encouraged visitors to discuss and confer with their companions more than the setup which did not have screens embedded in the buttons (Sub-Theme 2.1 Transitions of Control). The screens may have enabled a greater understanding of what the buttons represented and invited visitors to be actively, rather than passively, involved.

Outcome E) … aided in companions feeling as though they were doing the task together (Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome G) … appeared to provide support for adults to physical engaging with the exhibit (Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome I) … created explicit mapping of what digital content visitors were manipulating by using the buttons, increasing awareness of their own and their companions' actions (Sub-Theme 2.3 Coordinating & Aligning Actions Together).

6.5.6 Active & Inactive Controller

The controllers were active and inactive at different moments during the activity. Challenge questions or selection menus invited visitors to use the controllers but, outside of these moments, the controllers were inactive; pressing a button did not trigger any change in digital content during these periods. This switch between active and inactive controllers structured visitors' interaction with the exhibit, and created a mixture of passive and interactive moments. Here I highlight how this related to situations that arose while companions used RD.

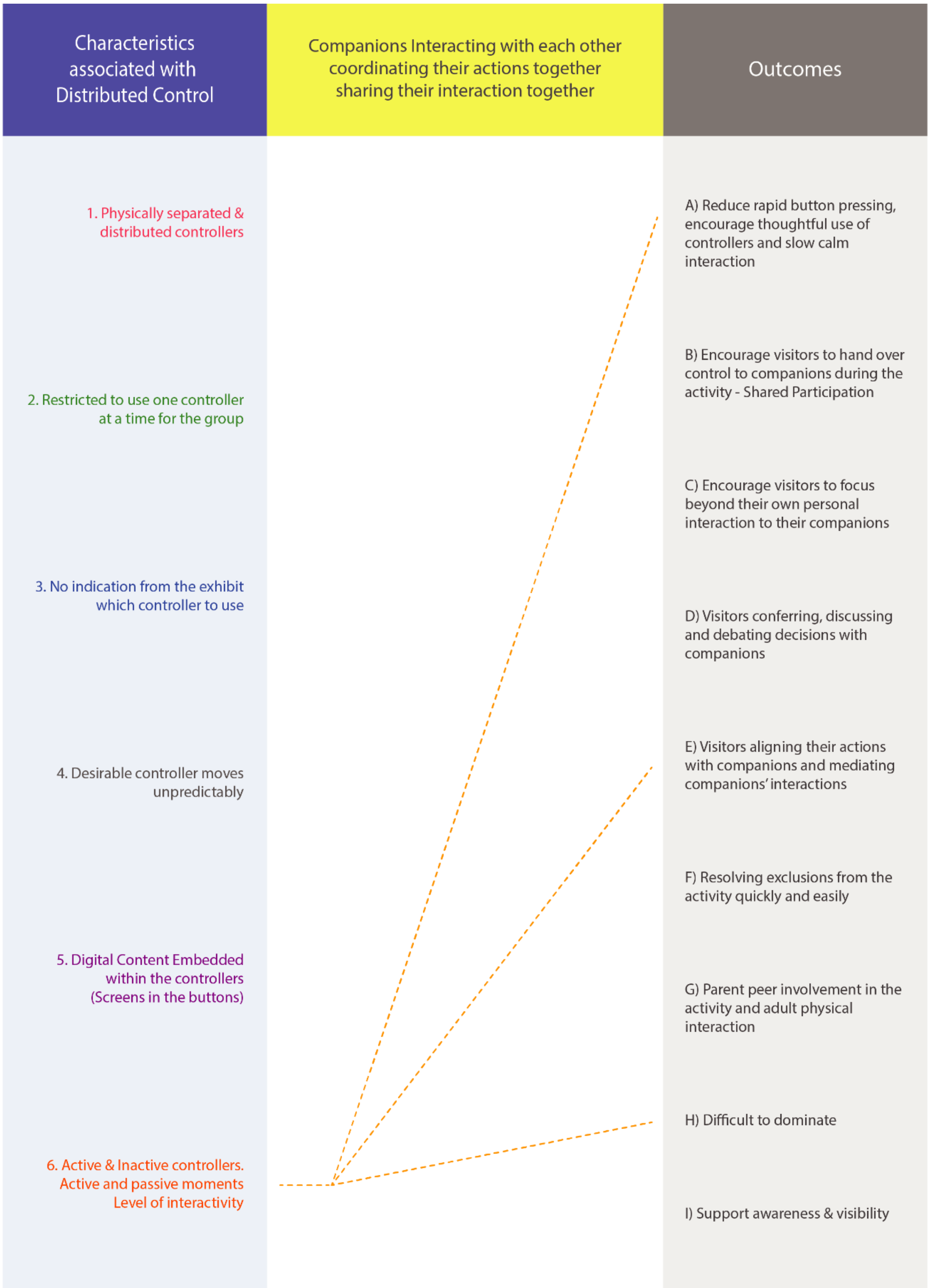


Figure 6-22: Outcomes connected to controllers being active and inactive at various points during the activity

The controllers varying active and inactive status at various points during the activity had a number of relevant outcomes. This varying of active and passive states:

Outcome A) … limited visitors' physical interaction to particular moments; rather than interacting quickly, they often took time to consider the use of controllers before undertaking their interaction with the exhibit (Sub-Theme 2.3 Coordinating & Aligning Actions Together).

Outcome E) … prompted visitors to coordinate their actions (Sub-Theme 2.3 Coordinating & Aligning Actions Together) and share physical interaction with the exhibit when the controllers became active (Sub-Theme 2.1 Transitions of Control).

Outcome H) … made it more difficult for people to dominate physical interaction with the exhibit. Firstly because there was limited time during which a person could manipulate the digital content, but secondly because when the controllers were active the desirable controller may have been inaccessible and located in front of a companion, rather than the visitor looking to dominate control (Theme 3: Dominating Physical Interaction with the Exhibit).

6.5.7 Summary of Key Elements of the Exhibit that Relate to Groups' Social Shared Interactions

This section highlighted the close relationship between the characteristics associated with distribution of control and companions' shared social interactions. It outlined a complex ecosystem which led to particular social interactions and behaviours, and demonstrated how visitors shared the physical interaction at the Razzle Dazzle exhibit. With varying degrees of influence, features of the exhibit either instigated or subtly supported shared social interaction between companions. Features which instigated shared social interaction include: the physical separation and distribution of controllers; having only one active desirable controller at any one time; a challenge which motivated visitors to achieve a goal, by selecting the right answer; and the unpredictable location of the desirable controller over the course of the activity. In contrast, features such as a lack of time pressure, embedded digital screens within controllers, and staggered interaction with active and inactive controllers supported, rather than instigated SSI.

Many of these characteristics are closely linked and in some respects cannot exist without each other. For example, the unpredictable movement of the desirable controller is in part created by the physical separation and distribution of the four controllers. In part, this desirability is also created as groups are limited to use only one controller which represents one of four answers. It is therefore important to view these characteristics in conjunction, rather than in isolation, in order to fully and accurately understand how to design for SSI.

6.6 Observations Outside the Main Scope of the RQs

Before discussing the overall findings of this study, it is important to consider two observations which are not directly related to the main research question, given their relevance to communicating narratives relating to collections, one of the core purposes of exhibits in museums. Thus, this section briefly discusses observations relating to the impact of the introduction video which was triggered when visitors began using the exhibit, and indications that visitors connected with the narrative of Razzle Dazzle Ships while using the exhibit. This is a challenge that many interactive exhibits struggle to overcome.

6.6.1 Introduction Video

The exhibit had a 44-second long introduction video. During the study, it was noted that a number of groups did not watch introduction video before the challenges yet still understood the narrative of the exhibit. In fact, in some cases it appeared that visitors had an easier, less frustrating and more enjoyable experience at the exhibit because they did not watch the long introduction video. However, the introduction video was deemed as an important feature of the exhibit, particularly in terms of the museum's educational goals. During the co-design process, we deliberated on the value of the video; though it prevented visitors from interacting immediately, it gave background information which was useful in understanding the narrative of the exhibit, and context to the artefacts themselves. Consequently, it was decided that a shorter introduction video would not impart sufficient information and thus would not fulfil the museum's educational goals.

44 seconds is a considerable period of time for children to wait and refrain from interacting with an exhibit. I observed children randomly pressing buttons throughout the introduction video and, in some cases, visitors thought that the exhibit was broken. Despite this, groups did remain with the exhibit, possibly as the screens in the buttons provided some guided information which invited them to watch the video on the main screen. Overall, the value added by the introduction video was questionable, as groups that did not see the introduction video still demonstrated a high level of knowledge attainment from simply working through the challenges.

6.6.2 Connection to Content and Narrative

Of all of the exhibits considered in this thesis, Razzle Dazzle elicited the most comments about the content and narrative of the exhibit. Companions frequently discussed Razzle Dazzle ships with each other. This level of engagement with the story was not evident at the exhibits in Study 1 and Study 2. The story behind the exhibit is interesting and surprising, which may have been a factor in the distinct level of engagement and desire to discuss it with others (Simon, 2010a). The interviews also revealed that visitors gained knowledge of the story. Vignette 21 illustrates one such situation.

Vignette 21: Connection to Content and Narrative
Group: 9C: C3-G4 Question 4 Speed
Family: Mum, Dad, Gordon (11-13), Allister (14-16)

Challenge 4 Speed – While the answer and information is coming up after answering the Question
Mum is standing beside Gordon at button 4. After answering the speed question, Gordon starts to tell Mum: *"did you know they used to put different patterns on the ship.........direction...."* . Mum responds: *"no I didn't know that ... no... but I seen that there now"*

In the vignette, a child shares information about the story with his mother. This indicates a connection to content, and also that the content encouraged side-line social interaction as visitors wanted to share information with their companions about the exhibit. This engagement with the story could be attributed to the mixture of inactive and active moments at the exhibit. Telling the story of Razzle Dazzle ships was integrated into the exhibit in the moments between interaction and as such the exhibition to some extent balanced activity with storytelling.

6.7 Discussion

To conclude the chapter, I will present a discussion of this study. The discussion consists of an overview of the study; a discussion of the nature of the shared social interactions between companions, addressing RQ2; and a discussion of how control was distributed at RD, addressing

RQ3. I will then outline some key considerations for design and research concerned with encouraging shared interactions and supporting social interactions.

6.7.1 Overview of the Study

The study aimed to explore arrangements of control that encourage companions to rely upon each other and which fosters social interaction. The significance of reliance at such exhibits has been discussed in Computer Supported Collaborative Learning (CSCL) literature (Wise et al., 2015). Furthermore, reliance was central to both GD and FF in encouraging companions to work together. The study also considered factors such as the interplay between controllers, visitors' movements between controllers, and swapping of the primary controller during the interaction. Based on the previous PhD studies, the design of the exhibit was underpinned by the idea of distributing control physically, functionally and temporally between companions.

Themes which arose in the previous two studies prompted me to investigate the role that shared physical interaction with an exhibit plays in fostering interaction between companions and to examine the nature of the social activity at these exhibits. (Hornecker, 2008), (Snibbe and Raffle, 2009), (Hindmarsh et al., 2005). The researchwas thus motivated by a consideration of how companions are included in visitor interactions with THIMEs, focusing on how the interaction is shared between companions, and the social interaction between these companions.

The findings are divided into two sections. Firstly, I discuss the various ways in which companions shared interaction with the exhibit, and the social interactions that occurred between companions at exhibits. Secondly, I offer an interpretation of how elements of the exhibit relate to companions' social shared interactions. I will now present a brief summary of the main findings and discuss how these contribute to the overarching PhD research questions.

6.7.2 Nature of the Shared Interaction and Social Interactions Between Companions

The insights offered by the study concerning the nature of the social activities between companions using THIMEs are directly relevant to RQ2. At the exhibit, social interactions between companions were predominately based around verbal exchanges (Theme 1: Groups Sharing Decisions) and the coordination of actions (Sub-Theme 2.3 Coordinating & Aligning Actions Together). In particular, I found that interactions between companions involved visitors turning their attention to companions; sharing decisions; participating on equal terms; coordinating actions, including turn taking; and handling conflicts.

Companions frequently participated in verbal debates and discussions at moments when the exhibit invited visitors to physically interact. The majority of visitors decided which controller to use together during challenges, with multiple members of the groups voicing their opinions and speculating about which answers and controllers to select. The observed behaviours indicated that visitors not only verbally participated, but also listened to and considered the opinions of their companions. Visitors collectively agreed and approved actions before using a particular controller. Listening to and considering companions' opinions is a valuable behaviours to encourage at exhibits, and can significantly support social experiences at exhibits.

Visitors Turning Their Attention to their Companions

At the exhibit, it was notable that visitors frequently focused their attention on their companions, rather than only focusing on the exhibit. Furthermore, visitors listened to and acted upon their companions' comments and suggestions (Theme 1: Groups Sharing Decisions & Sub-Theme 2.1 Transitions of Control). At exhibits that aim to support multiple companions, encouraging visitors to focus their attention on each other rather than on their own interaction can be challenging. The exhibit gave visitors sufficient time and provided extrinsic motivation to focus their attention on their companions during the activity. Overall, this finding suggests re-thinking the balance of visitors' attention between the exhibit and their companions at museum interactive exhibits (Warpas, 2014). Previously, exhibits have achieved this balance by overlapping a focus on companions and interaction with the exhibit (Hindmarsh et al., 2005). For example, displaying digital representations of visitors as the digital content at the exhibit (Hindmarsh et al., 2005), (Snibbe & Raffle, 2009). Thus, overlapping visitors focus on companions with their interaction with the exhibit. At RD, the structure of the exhibit had an effect on this balance through the distribution of; companions were only able use one of four controllers, and the collective decision-making of which controller to select appeared to encourage visitors to turn their attention towards their companions as well as towards the exhibit itself.

It is rather unusual for visitors activities at interactive exhibits to result in **companions listening to each other** (Warpas, 2014), (Hornecker, 2016). Typically, multi-user exhibits prioritise simultaneous co-participation or co-exploration (Snibbe and Raffle, 2009), (Dindler et al., 2011) with fewer exhibits encouraging or enabling companions to listen to each other (Warpas, 2014). Enabling non-interactors, such as spectators or bystanders, to have a **meaningful impact upon** on the activity is a key challenge for public interactive exhibits. In sharing a social activity, it is important that group members feel that they are listened to and have an impact on the activity. At RD, the challenging opinion-based questions posed by the exhibit appeared to be an effective way of engendering verbal contributions from members of a group, stimulating social activity between companions and prompting active participation in the overall activity beyond physical interaction. At RD, the exhibit motivated visitors to select the correct answer, which encouraged them to listen to their companions. It also enabled companions to feel that they could contribute to the activity in a useful and meaningful way, without physically interacting with the exhibit. Often, when using interactive exhibits, interactors focus solely on their personal interaction with the exhibit. However, at RD, visitors spent time conferring with their companions, listening to their advice, discussing options, and handing over control to them so that the right answer could be selected. Prior research regarding tangible interaction has also highlighted the importance of these behaviours (Antle et al., 2011a), (Antle et al., 2011b). Engagement and listening between companions was also encouraged by other features of the exhibit such as the ambiguity as to which controller to use to achieve the desirable outcome and the possible consequences of using controllers, including acting on behalf of the group.

The type of social activity and listening to companions that RD encouraged is closely related to Battarbee's idea of 'cognitive intimacy', a part of 'co-experience' (Battarbee, 2004) . Battarbee defines cognitive intimacy as "thinking about and awareness of another, sharing values and goals" (ibid). At RD, encouraging visitors to share decisions together fostered cognitive intimacy. This cognitive intimacy is similar to ways which visitors engage socially at traditional non-interactive exhibits, by for example showing one another aspects of the exhibit, listening to each other, and discussing aspects of the exhibit or artefact (Hornecker, 2016). Overall, these behaviours are more closely linked with non-interactive exhibits, and it is unusual for a hands-on interactive exhibits to encourage or enable them, as RD did.

Verbal Contributions, Sharing Control and Participation through Making Decisions Together

Often the most common way to manipulate digital content at an interactive exhibit is by interacting with a controller. However, at RD, verbal contributions greatly influenced the outcome of the task, which prompted contributions from companions who did not possess controllers. Importantly, the exhibit therefore encouraged and enabled visitors to transition from passive observers to active participants (Reeves et al., 2005), albeit not interactive participants. Researchers have suggested that the frequency and fluidity of transitions between companions are important considerations when designing exhibits which support group interactions (Hornecker et al., 2007), (Reeves et al., 2005). However, opportunities to <u>share decisions</u> about the interaction are frequently overlooked in the design of interactive exhibits. In such instances, non-interactors can be involved as both viewers and as active participants, influencing the activity and the manipulation of digital content through social interactions. In support of this, Study 1 highlighted how encouraging visitors to make decisions and choose controllers can prompt discussions between companions. In future designs, distributing physical controllers at an exhibit and considering how visitors make choices about their interaction are techniques and considerations which could be drawn on to prompt social, human to human interactions (Reeves et al., 2005). At RD, the simple activity of <u>making decisions together</u> was highly social, encouraging companions to debate the available options and also to make suggestions to each other. It is important to note that being asked a challenging question, which was either right or wrong and had an associated controller distributed within the group, encouraged this collective decision-making.

Companions Being in Equal Positions

When considering group interaction at TUIs, an aspect that has been highlighted previously is the notion of **equality**, specifically considering access points and power positions (Hornecker et al., 2007), (Rogers et al., 2009, Marshall et al., 2008), (Hornecker, 2005). As at GD and FF in Chapter 5, at RD, the **desirable position and controller shifts** spatially between different controller during the activity. This movement enabled companions to be included in the activity and, at different moments, interact with the desirable controller, progressing the task for the group. Furthermore, the **unpredictable nature of the movement** facilitated sequential interaction that was unpredictable, thus aiding equitable participation, giving group members equal opportunities to participate.

Prior research has suggested that activities in which companions participate on equal terms, particularly involving turn taking and individuals offering their opinions and ideas, are valuable in supporting visitors experiences at exhibits (Allen and Gutwill, 2009). This idea was supported by RD, which gave companions equal standing in the activity, so that any member of a group with a controller could be included or excluded from the task. In addition, equitable participation transpired through verbal contributions which heavily influenced the interaction and unpredictable turn taking prompted by the exhibit.

A number of aspects of the exhibit supported a sense of equality between companions. These included (1) controllers with equal functionality; (2) equal opportunities for companions to interact including companions being equally in positions which lacked full control; (3) that there was no single vantage point to ensure interaction with the desirable controller; (4) that the activity was strongly influenced by verbal contributions and the nature of the activity itself, invited multiple people to contribute their opinions by posing a challenging question.

Overall, it was crucial that, as well as equality of control, companions at RD were often equally not in control, as the opinion based nature of the questions meant they didn't know what the answer was or had doubts. This equal lack of control is unusual for an interactive exhibit, and is supported by research regarding 'the juicy question' which exhibits pose in order to prompt group inquiry (Gutwill and Allen, 2017),(Allen and Gutwill, 2009). While The exhibit aimed to try to support equality of participation and the inclusion of many groups members, I would argue that it was their lack of control which placed them in equal positions and led to coordination of actions and social interactions. Importantly, this lack of control placed companions in **equally unprivileged positions**. Future studies could investigate how designs may deliberately give all participants no control over the exhibit, and subsequently examine how they collectively decide who should be in control.

A personal lack of control and being in equal positions appeared to encourage visitors to be mindful of companions and to negotiate the actions of their companions with their personal actions. This supports findings from prior research such as Allen and Gutwill (2009) and Horneck (2005) who suggest there are benefits for companions to participating on equal terms (Hornecker et al., 2007), (Hornecker, 2005).

Allen and Gutwill (2009) suggest the specialised roles for visitors do not support companions as effectively as visitors participating on equal terms. This argument is supported by the findings of the study, as when visitors at RD did lead the group by explicitly dividing up controllers between companions, shared decision making and coordinated actions appeared to be diminished. In these situations, before interacting fewer discussions and negotiations took place than in situations in which no group members explicitly led the group or divided up the controllers. This raises questions for future designs to consider companions being placed in specific roles. Future designs should therefore consider the value and appropriateness of assigning specific roles to visitors. While many exhibits currently support visitors to assume different roles and positions of leadership, it is possible that future installations could benefit from re-evaluating this structure so that companions are no longer given explicit positions. In doing so, exhibits could engender social interactions through a sense of equality and autonomy, without relying on competition-based interactions between companions or parallel simultaneous individual interactions to do so.

Coordinating with Companions, Including Turn Taking

Coordinating actions with companions, taking turns and negotiation are integral aspects of shared interaction (Block et al., 2015), (Piscitelli and Weier, 2002), (Davis et al., 2015). At RD, visitors negotiated and coordinated each other's interactions, directing companions to use particular controllers, debating the correct answer and corresponding controllers, and asking companions to "wait" before interacting. Research carried out by Horn et al at tabletop surfaces categorises this request to "wait" as pacing (Horn et al., 2012a). Similarly, at RD, the request mediated companions' actions at the exhibit and brought the group together.

Block et al (2015) highlight how turn taking, when compared to simultaneous interaction, is beneficial in terms of prolonging dwell time and supporting visitors' engagement with content. Even in conversations, taking turns is a basic structure in how people engage with each other. Previous research has indicated the importance of the fluidity and frequency of transitions of control between members of a group (Reeves et al., 2005), (Block et al., 2015). Reflecting this, at RD, the exhibit encouraged transitions of control without explicitly dictating that control must be handed over to a particular person, or in a particular way. While RD prompted companions to take turns to interact physically with the exhibit, visitors themselves mediated the specifics of the turn taking process between each other. Moreover, it is important to note that, unlike the exhibits in Study 2, the specific controller to use and the person who was to operate it were factors decided by the group, and not by the exhibit. The decision over which member of the group was to be next to use a controller stimulated conversations, negotiations and encouraged companions to coordinate their actions.

Individuals handing over control of a controller to companions were not excluded from the activity and still maintained some influence over the activity, as illustrated in several vignettes throughout the findings. Instead, verbal participation was highly influential in guiding physical interaction. As such, visitors could assume the role of suggestor or leader after handing over physical control, thereby continuing to contribute to the activity in a meaningful way, often by directing their companion to select the answer they believed to be right. The motivation to be right when answering questions at the exhibit appeared to distract people from the fact that they were giving up physical control, alleviating typical issues encountered with turn taking, which is often managed by parents. However, scaling the interaction up for bigger groups was challenging, as it was difficult for larger groups to gain awareness of which group members were operating the controllers. Supporting awareness and visibility is a widely recognised challenge at systems which support multiple people interaction at the one time (Krogh and Petersen, 2008), (Kreijns et al., 2003), (Block et al., 2015).

At RD, parents appeared to facilitate turn taking and transitions of control with relative ease. Often, mediating turn taking for parents can be stressful [ref], particularly if children do not want to hand over control, or if they feel they are excluded from the interaction after handing over control. At RD, rather than investing time in mediating turn taking, parents often concentrated on supporting children's interaction with the content and following the activity at hand. This also gave parents time to make sure that all of the group were included, by asking their opinions and voicing their own. The exhibit therefore supported parents as facilitators, reducing time spent mediating turn taking. For parents, rather than managing turn taking, it is important to be able to spend time doing an activity together and supporting their children's' activities during their time in a museum in order to support bonding.

Many exhibits support group co-participation by encouraging parallel interaction or through predetermined turn taking, during which specific controllers must be used in a set sequence. At RD, the physical distribution of the controllers, combined with the fact that there was only one appropriate controller which moved unpredictably, created a sense of spontaneity and autonomy, which was not observed at the exhibits in study 2. Offering some level of autonomy provoked social interaction through shared decisions and shared physical interaction. Physical turn taking was largely decided firstly by the agreed possible answer and corresponding controller, and secondly by the arrangement of the group at the exhibit at that particular moment, and which member was located in front of the relevant controller. In this way, the group, rather than exhibit, at that particular moment is determining the use of particular controllers. While a number of exhibits use this type of sequential turn taking, RD is distinct in that the choice of the controller to use is not guided by the exhibit. As such, companions often interacted socially with each other in order to decide what controller to use and who uses it.

Rapid button pressing is a common issue at hands-on interactive exhibits. However, at RD, interactions were typically reserved and coordinated, rather than fast-paced. This was in part because random button pressing was unrewarded and discouraged. The exhibit constrained interaction in a way that created co-dependency between companions, meaning that it was not to beneficial to the overall activity to use inappropriate controllers or interact without conferring with the group (Wise et al., 2015). GD, FF and RD all gave visitors the impression that interacting with controllers could be counterproductive to the overall activity. As such, all three exhibits encouraged coordination, negotiation and mediated companions' interactions.

Limited prior research has suggested rewarding joint simultaneous interaction with enhanced digital content in order to encourage shared coordinate interaction with exhibits (Ciolfi and Bannon, 2007). RD had almost the opposite incentive which encouraged visitors to give away control in order to gain a reward (the right answer), rather than use the controllers themselves. The shared decision-making process around which controller to use and the motivation to be successful in the activity alleviated the potential issues children face in sharing interaction. Overall, it was evident that the desire to interact with the exhibit was secondary to the desire to overcome the challenge at hand.

Conflicts and Resolutions

The study revealed how conflict was dealt with and managed by visitors and by the exhibit. Conflicts are rarely discussed in literature, even though they occur frequently between children in museums and are a challenge in supporting multi-user interaction (Marshall et al., 2009). Furthermore, understanding how exhibits relate to conflicts exposes a broad picture of social interactions and offers a rich understanding of all social interactions between companions visiting the museum, encompassing both negative and positive behaviours. Managing conflict and negotiation is a natural aspect of social interaction. Conflicts often occur when people are using multiple shared resources (Marshall et al., 2009), (Krogh and Petersen, 2008). Marshall et al's (2009) research concerning multiple tangible controllers indicates that children should be supported in trying to mediate conflict in unaggressive ways (Marshall et al., 2009). Such conflicts and dominating behaviours were managed in number of ways at RD.

Firstly, at RD, visitors were unable to easily restrict companions from the activity or from the whole exhibit as the buttons were spread and in fixed positions along a large area. As such, it was difficult for one person to occupy this space constantly. Similarly, the unpredictable re-location of the desirable controller also prevented any one person from maintaining dominance.

Consequently, visitors were unable to possess all the controllers at once or to predict which controller would be desirable to use during the next interaction. Furthermore, the exhibit made it counterproductive to exclude companions and difficult to maintain independent physical interaction with the exhibit. As a result, rather than restricting their companions at the exhibit, visitors adopted protocols and ways of working together.

Design guidelines often suggest interactive exhibits should limit behaviours that can interrupt a person's interaction with an exhibit. In some respects, RD encouraged visitors to confront and negotiate companions' potential disruptive behaviours, such as pressing a button quickly. Instead, companions used interpersonal skills to agree and coordinate, prompting situations in which companions engaged in social negotiations while interacting (see Sub-Theme 2.3 Coordinating & Aligning Actions Together). The exhibit explicitly mediated interrupting interactions by companions through constrained interaction. This mediation and negotiation of turn taking was built into the game play disguised as a decision-based question with a consequence. Instead of restricting the interaction of companions, the risk of being wrong and causing an undesired effect deterred companions from randomly button pressing and potentially interrupting ongoing interaction.

6.7.3 Distribution of Control

In this section, I discuss what the study revealed in relation to distribution of control in response to RQ3. Creating interactive exhibits that include multiple companions and clearly communicate content is a challenging task. In particular, it is important to understand how control can be distributed in such a way which hamper individuals from engaging in prolonged independent use of the exhibit, while at the same time fostering inclusion of companions in the activity. Specifically, the present research has examined how this may be enacted through physically separated and distributed controllers; restricting use to one controller; giving visitors no indication which controller to use; dynamic and unpredictable movement of the desirable controller moves; the embedding of digital content within the controllers; and the status of controllers changing from active to inactive during the activity, which creates passive and interactive moments and staggers interaction with the exhibit. Distributed control at RD was supported by a number of different mechanisms that can be categorized in three themes: functional, temporal, and physical distribution of control. Overall, there were six different characteristics relating to distributed control which this section will reflect upon: 1) the constrained use of the controllers; 2) the unpredictable movement of the desirable controller; 3) equal functioning controllers; large, 4) large physically separated controllers in fixed positions; 5) control distributed between the exhibit and visitors; and 6) a mapping digital content to controllers achieved by displaying digital content on screens within the buttons.

Restricted and Constrained Use of Controllers

While some researchers have argued that unstructured interaction supports simultaneous parallel interaction by multiple companions, others have highlighted that simultaneous interaction raises a number of challenges, such as individuals focusing on their own personal interaction without collaborating or engaging in social interaction with companions (Benford et al., 2000). The interaction at RD was structured and constrained by the use of controllers in two ways. Firstly, interaction was limited by controllers as they were only active at certain moments during the interaction, and, secondly, visitors were only able to use one of the four available controllers at the moment of interaction.

Modern interactive exhibits, and especially THIMEs, tend to support high levels of interactivity, allowing visitors to constantly manipulate digital content. In contrast, at RD, interaction was only invited at specific moments. Limiting interactivity appeared to support companions to socially share the activity and meaningfully connect with the narrative. This raises questions as to whether a very high level of interaction reduces possibilities for sharing at exhibits and making meaningful connections with the narrative. Perhaps there is a balance to be sought here. Reducing or staggering interaction could have a number of benefits, such as increasing the number of discussions and enhancing visitors' reflective experience.

Reducing interaction at interactive exhibits may seem counterintuitive, particularly from a HCI perspective, but it is important to understand and question the specific ways interactives support or hinder their intended purpose in a particular context. In addition, Warpas's (2014) research has indicated that replacing high interactivity with subtle connections between sensors and digital content can aid companions' social interaction with each other, and help them more consciously relate to the digital content, rather than focusing their energy on interacting with the exhibit.

Staggering moments of interaction may also address the issue of quick button pressing and a lack of mindful connection at interactive museum exhibits. At RD, physical controllers were deprioritised as they were inactive for prolonged periods of time. Furthermore, verbal, rather than physical, participation was central to controlling the digital content. In some ways, limiting interactivity may be seen as an uncharacteristic step away from current trends in interactive exhibit design. However, it does align with research in the field of HCI which moves towards encouraging mindful interaction (Rogers, 2014) and discouraging mindless interaction with museum exhibits. Furthermore, limiting interactivity is supported by a range of research which suggests that exhibits with lower interactivity have a range of benefits (Warpas 2014), (Hornecker, 2010), (Hornecker, 2016). While an exhibit may create excitement and faciliate physical interaction for a prolonged time, it may offer very little value in communicating a historical narrative or enabling groups to engage in discussions while interacting. In the case of RD at the Riverside Museum, the museum staff remarked on how it was surprising and powerful to simply encourage groups to collectively stop interacting and watch digital content. De-activating controllers for a large portion of time helped to guide companions' attention to a single point of focus, aligning their attention and fostering a slow paced interaction (Simon, 2010a), (Povis and Crowley, 2015) (Rogers, 2014).

Secondly, visitors were limited to the use of only one of four controllers. Rarely do interactive exhibits distribute controllers among a group but permit only one of these controllers to be used at a time (Peter and Plénacoste, 2016). However, in the case of RD, the constraint sparked a number of shared social interactions among companions, guided visitors focus to each other, and encouraged companions to coordinate their actions such as recommending controllers for companions to use. This limitation to use only one controller, combined with the challenge of the activity to make a choice with consequences encouraged considered use of the controllers in the groups. Allen and Gutwill (2009) previously offered the idea of constraining several companions delving into individual parallel activities as a valuable way to bolster social interaction during family enquiry at interactive science exhibits. However, thus far, the technique has rarely been adopted in practice.

Unpredictable Movement of the Desirable Controller

The exhibits in study 2 explored the effects of interplay between controllers, using different controllers at different moments during the interaction, and using different controllers in combination with each other. These characteristics have also been examined in a range of existing literature (Ciolfi and Bannon, 2007), (Wakkary et al., 2009), (Rogers et al., 2004). A consideration of these aspects and effects was developed in the study of RD. The format of RD disrupts the typical structure of an interactive exhibit, in that it had no obvious desirable position which could be occupied to maintain control. Instead, control was passed around the group during the activity, as the desirable controller changed. The interaction at RD also involved an interplay between different controllers. However, it was impossible to predict which controller would be desirable to use next during the interaction, introducing elements of unpredictability. This appeared to support a sense of equitable interaction in the groups, to prompt social interactions between companions, and made it difficult for individuals to dominate interaction. While some researchers argue that ambiguity makes exhibits more difficult to use, in certain situations ambiguity can be utilised as a design tactic (Gaver et al., 2003). The ambiguity around which would be the next desirable controller helped to eliminate any dominant vantage point, which can hamper sharing at an exhibit (Hornecker et al., 2007). Control was distributed over the space of the exhibit, between controllers, throughout the duration of the interaction, and by moving desirable controllers in the physical space. In some cases, there was an evident desire to use other controllers, which led to visitors handing over physical control but not necessarily handing over a physical object (Sub-Theme 2.1 Transitions of Control). This prompted shared activities and social interaction between companions. Similarly, at GD and FF, group members often had the desire to use other controllers that the exhibit suggested should be interacted with at that moment in time. Instead, at RD, visitors decided themselves which controller to use. As such, RD had qualities relating to decision making and choices that moves towards qualities associated with co-created exhibits at which companions choose the options for themselves (Taylor et al., 2015).

Equal Functioning Controllers

A range of literature has discussed the notion of equal participation in relation to social aspects of interactive systems (Hornecker et al., 2007), (Marshall et al., 2008) and family inquiry in science centres (Allen and Gutwill, 2009). However, at present, only a limited number of studies discuss the provision of equally functioning controllers (Ciolfi and Bannon, 2007), (Fernaeus et al., 2008). At RD, all of the controllers were equal in terms of their functionality. As such, companions debated how the controllers were to be used as they could only choose one from the selection of equal functioning controllers. Similarly, in both Study 1 and in a previous related research, it was found that providing equal controllers or options encouraged companions to discuss the merits of different controllers and to share this part of the activity (Rogers et al., 2009), (Marshall et al., 2008). The presence of several equal controllers also meant that visitors could not identify a single control position or vantage point from which they could dominate interaction. This prompted companions to socially interact with each other to identify the desirable controller and then coordinate their use of this controller.

Controllers that were Large, Physically Separated and in Fixed Positions

Controllers at RD were physically separated and in fixed positions, thus limiting visitors' ability to move controllers away from companions. Such restricting behaviours have previously been reported in studies such as those by Marshall et al. (2008) and Fernaeus et al. (2008), with individuals bringing all of the controllers together to prevent others from using them. Fixed controllers stimulated visitors movement around the exhibit, making it easier for visitors to notice and follow the actions of their companions. Furthermore, separated controllers gave visitors a sense of ownership of the controller and thus gave them personal buy-in into the activity. Often visitors stayed in near particular controllers and returned to them if they moved away momentarily. In this way, RD emulated the work of studies which have argued that individual territories on tabletop surfaces are important in allowing companions to manage their participation in the activity and limit aggressive confrontations (Antle et al., 2011a) (Marshall et al., 2008). Moreover, communicating with companions across a distance makes the action obvious to the rest of the group; visitors can observe others moving, looking and communicating, but do not have to hand over a physical controller.

Large separate controllers were easy for people to see. Additionally, the size also allowed two people to comfortably use the controllers together. Hornecker's (2010) study similarly observed large fixed controllers which require a single movement being used by more than one person (Hornecker, 2010).

Control of the Activity Distributed Between the Exhibit and Visitors

Control of the interaction is distributed between companions but also between the exhibit and the visitors. It is thus important to understand whether visitors or the exhibit control the pace and direction of the interaction. At RD, control was distributed both by the exhibit and by visitors, and this control often shifted. Two particular factors shifted control of the activity between visitors and the exhibit: (1) the choice of which controller to use; and (2) the time given for visitors to interact. Firstly, challenge or game-based installations, including GD and FF, often guide visitors to use particular controllers during the activity (Wakkary et al., 2009), (Rogers et al., 2004). At RD, the decision as to which controller to use was made by visitors, and was not guided by the exhibit. The opportunity of choice and the decision-making process is highly relevant to the present research, as it prompted several social activities at RD.

Secondly, no time pressure was imposed at RD when visitors were required to use controllers to make a choice. Imposing a timer can be beneficial as a strategy to increase excitement. However, at RD, the abundance of time gave visitors the ability to dictate the pace, which proved highly supportive of companions shared social interactions. Ample time enabled visitors to listen to companions, debate the answer, direct others to use particular controllers, align their actions and develop their understanding of the activity. Based on the insights gained from RD, and an understanding of how time pressure hindered companions coordinating interaction at GD, the present research supports the work of researchers such as Hornecker (2016), which argues against imposing time pressure on visitors. Time distributes control is between the exhibit and visitors, and enables visitors, rather than the exhibit, to assume control of the situation at hand. Additionally, I also argue providing ample time increases the ability for more people to become involved in the activity.

Mapping Digital Content within Buttons

A characteristic of tangible user interfaces, as defined by Ullmer and Ishii (2000), is objects which are both controllers and representations of digital content. Commonly, digital content is incorporated into a range of objects, camera tracking systems with projections or objects tagged with RFIDs and sensors. However, there is limited recent literature discussing TUIs which both control and represent digital content. After observing the challenges that visitors faced in relating controllers to digital content at GD, I deemed it important to include a close mapping of controllers to the digital content at RD. At RD, embedding digital content directly in controllers appeared to have several benefits. For example, when digital content was embedded within controllers companions were more likely to socially interact while making decisions; visitors directed companions to use particular controllers; and visitors reported that they felt like they had worked with their companions while interacting with the exhibit. Thus, embedding screens within buttons appeared to bolster the social dimension of visitor interactions.

This may have been for a number of reasons. For example, screens may have explicitly outlined the current state and goal of the task to visitors, thus increasing awareness of the relevance of the controllers; and supported the social context of the group interactions. In some cases, distributing visitors' attention between multiple distinct points can hinder collaborative activities. However, at RD, the screens had the opposite effect. This suggests that providing screens that reinforce information, rather than providing additional information, is an important quality of an exhibit in supporting collaborative activities.

6.7.4 Future Considerations Drawn from the Study

I will now outline a number of considerations based on the findings. These considerations aim to inform future research, designs for supporting social and shared interactions, and to advance an understanding of the nature of social shared interaction companions experience at THIME with several tangible controllers. As such, the following recommendations are offered:

1. Provide opportunities for companions to rely upon each other during the interaction. Reliance between companions was created through the division of controllers among companions; the physical distribution of the controllers; the presence of desirable and counterproductive controllers which companions had access to; and the necessity of eliciting and considering companions' opinions when answering a challenging question. As such, visitors were encouraged to focus on their companions as well as their own personal interaction, thereby engaging in social interaction and coordinating their actions with others.

2. Consider embedding digital content directly in controllers. This recommendation is linked to a traditional understanding of tangible user interfaces, in which digital content representing what the controller manipulates appears inside controllers (Ullmer and Ishii, 2000). This feature appeared to support social interactions such as aiding visitors' awareness of the task; increased visitors feelings of working together; encouraging visitors to guide companions to use particular controllers; increasing use of controllers; companions using the same controller together; and companions engaging in shared decision making. In addition, digital content embedded in controllers was rated more highly by visitors in terms of satisfaction, entertainment and feeling active.

3. Consider presenting visitors with choices or decisions as to which controller to use. Without the exhibit guiding visitors to use a particular controller when answering a challenging opinion-based question, companions shared decisions, which stimulated social dialogue between companions.

4. Consider ways to support equality among companions in their physical interaction and overall involvement in the activity. This can be enacted in a number of way. 1) Firstly, by removing the presence of a single primary control point or vantage point, in turn limiting dominating behaviours and inequality. 1b) By moving the desirable controller around during the task, so it is not associated with a particular person. This could be initiated by the exhibit or by visitors in terms of passing over the controller. 2) By providing controllers which have equal functionality for companions. 3) By creating situations in which visitors are in equal positions of not only control but also of a lack of control. Such situations guide the group to focus on a single focal point, limit parallel independent activities, and prompt visitors to coordinate with companions. 4) By encouraging visitors to value the opinions of others, by creating an activity which encourages visitors to share

opinions with each other. 5) By giving each member of the group equal standing, so that no single person can interact with the exhibit for any prolonged period with the others as onlookers. This was achieved by controller status switching between active and inactive for everyone during the activity. 6). Finally, by attempting to avoid situations that might encourage visitors to explicitly divide up controllers, as these may prompt dominating behaviours and diminish collaboration.

5. **Consider incentives to give away control, share and invite others to interact**. These incentives can be created by encouraging engagement with different controllers back and forth between companions. Turn taking of this nature could be dictated by either the exhibit or by visitors. In the case of RD, a desire for another controller to be used during the task prompted turn taking and provided an incentive to give away control to companions, sparking to sharing and social interaction.

6. **Consider time, attention and staggered interaction.** Consider guiding and supporting visitors' capacity to give attention to their companions by providing ample time for companions to interact with each other, and encouraging slow, considered interaction with the exhibit. Controllers which are counterproductive when pressed and the unpredictable location of desirable controllers can help to develop considered interaction and coordinated actions between companions. In addition, passive and active moments help to stagger interaction. Giving visitors **time** to think and discuss can support social interactions involving verbal dialogue and shared decision making. Other types of social interactions may not need this slower **pace**.

Typically, in the field of HCI, usability considerations suggest systems should be predictable in order for users to understand them and succeed their activities with them. However, there are application areas and contexts where predictability is not desirable. For example, in user experience, systems concerned with long-term engagement and games design would value systems that provide users with surprises and challenges. The insights from this study, in part, consider moving away from conventional HCI design recommendations and towards an exploration of what opportunities a degree of chaos might provide. For example, suggesting a lack of control and unpredictable movements of the controllers might be beneficial for particular experiences and contexts but would typically be viewed as poor designs features for HCI research that prioritises usability and efficiency.

It is important to note the insights which derived explicitly from this study which differ from study 1 and study 2. These insights are: (1) equality in a lack of control and unpredictable movements of the controllers and (2) embedding digital content directly in controllers supports SSI.

6.7.5 Main Contributions: Ending summary

As listed above, the chapter contributes a number of design considerations for supporting companions' shared interaction with a THIME and social interaction between companions at such exhibits. Supporting social interaction at interactive museum exhibits is often related to competition, role-playing scenarios or user-generated narratives. This relationship can limit the scope of content that museums can present at interactive exhibits. In contrast, the present study contributes to an understanding of arrangements which do not involve competition or simultaneous parallel individual interaction, but which instead provide companions with controllers which have equal functionality. This type of exhibit is unusual in a museum context, in providing multiple controllers and limiting visitors to the use of a single one of the controllers at any one time. Most commonly, multiple controllers can be used simultaneously in such contexts.

The primary contribution of the study is an understanding of the qualities of distributed control at THIMEs. The study has highlighted how distributed control works in such contexts, and how qualities of distributed control relate social interactions between companions, and their shared interaction with the exhibit (RQ2 and RQ3). The study identified a number of qualities which had significant influence over social and shared interactions. In the case of RD, social and shared interactions were underpinned by (1) the provision of multiple fixed tangible controllers which were physically separated from each other; (2) the constraint of only using one controller at a time; (3) visitors being presenting a difficult choice with consequences; (4) the unpredictable movement of the desirable controller during the activity; (5) the embedding of digital content within controllers; and (6) the provision of equal controllers.

While goal-oriented challenges have been subject to criticism, it has also been noted that they can create excitement and stimulate movement during interaction. In the case of RD, a goal-oriented task was one aspect which encouraged visitors to think before they interacted with the exhibit, rather than interacting immediately. During these moments of contemplation, visitors listened to companions, considered possible actions based on companions' suggestions, and coordinating their actions with companions. A number features of RD are similar to those at other multi-user exhibits which have been shown to engender playful collaborative activities. The exhibit is by no means the same but commonalities include (1) giving users a choice, which creates a degree of autonomy; (2) interlinking companions' actions; and (3) a reliance or co-dependency between companions while they are using the exhibit (Hindmarsh et al., 2005), (Snibbe and Raffle, 2009), (Ciolfi and Bannon, 2007).

In designing and considering RD as an exhibit which communicated a specific narrative around museum artefacts, the research offers an alternative format for set information-based narratives. The approach outlined in the present study is more didactic than exploratory hands-on interaction of modern interactive exhibits. The chapter draws on conceptions of distributed control at other exhibits, specifically relating to notions of reliance, equality and inclusion. Museums with interactive exhibits often struggle to link the nature of interaction with an interactive exhibit to key messages the museum would like to communicate. Previous studies have indicated that when exhibits support highly collaborative social interactions, making visitors aware of the narrative and artefacts relating to the exhibit can be difficult (Hindmarsh et al., 2005), (Snibbe and Raffle, 2009). However, as noted in section 6.6.2 'Connection to Content and Narrative' visitors at RD made connections with the narrative and indicated that they understood the overarching story behind the exhibit.

To some extent, RD constrains and prescribes interaction, which has previously been argued against (Hindmarsh et al., 2005), (Allen and Gutwill, 2009). However, many exhibits which are geared towards social interaction encourage unstructured, open co-participation, and have only a loose connection to the narrative around the museum artefacts. Hindmarsh et al.'s (2005) research on Ghost Ship argues that this loose connection is a drawback of such exhibits (Hindmarsh et al., 2005). Similarly, Warpas (2014) argues that interactivity distracts from artefacts and narratives relating to them. This argument broadly relates to the debates around the value and trade-offs of sequential, structured interaction over unstructured, open interaction. A number of researchers have recommended supporting dialogue between companions beyond “how to” conversations relating to usability and understanding how to use the exhibit at interactive exhibits (Hornecker, 2008). The present study has demonstrated that it is important strike a balance between interactive and non-interactive elements of an exhibit in order to encourage dialogue and interaction.

Overall, the study highlighted how exhibits such as RD can support shared and social interactions through a distribution of control. The study contributed to an understanding that control can be distributed in three main ways: consideration of what controllers do (functional distribution of control); when to use controllers (temporal distribution of control); and what and where controllers are (physical distribution of control). These three overarching ways of distributing control underpin the social interactions which occur between companions, and influence how companions share the interaction and are included in the overall activity with the exhibit.

As a minor methodological contribution, this study also developed a classification scheme: turning attention to others, signs of listening to others and being able to act upon their suggestions.

Chapter 7

Discussion

7.1 Introduction

This PhD thesis has presented interdisciplinary research which involved three studies focusing broadly on how technology-based interactive exhibits can support and encourage visitors to share their interaction with an exhibit with their companions while simultaneously engaging in social interaction. particular, the research has investigated the distribution of control at tangible hybrid interactive museum exhibits (THIMEs) which have several manual controllers that visitors can interact with, including levers, wheels, digital-physical paintbrushes and paint pots, and large buttons enhanced with screens.

Many interactive museum exhibits do not support hands-on or tangible interaction, and frequently, exhibits do not support social interaction between companions. A key motivation for the research was to aid future designs of tangible museum exhibits and to develop an in-depth understanding of how these exhibits can include and involve companions in each other's interactions with the exhibit, and support social interaction with each other. The discussion in the present chapter presents and synthesises reflections and insights gained from the empirical research conducted during three case studies.

Figure 7-1: Overview of Three Case Studies

Study 1 involved the design and evaluation of the installation Painting Patterns for Nature (see Figure 7-1) for a children's culture centre in Dublin, The Ark. The study of the installation involved video-recording family groups who had volunteered to take part in the study, while the installation was curtained off from the general public. The video was analysed using interaction analysis and thematic analysis. The study contributed to existing research on tangible interaction, and helped to define the focus of the PhD research, specifically around the social activities of groups at interactive exhibits, and how certain factors related to the exhibits support companions' social interactions.

Study 2 involved an 'in the wild' study of two existing tangible interactive exhibits at Glasgow's Riverside Museum, both of which are illustrated in Figure 7-1. Both exhibits shared a number of similarities: both used multiple tangible controllers, and both centred around an activity that required several people to work together, with dedicated roles and responsibilities assigned to them by virtue of which controller they were located at. The study involved video-recording the general public's behaviours at the exhibits, followed by detailed video analysis, which included a coding approach. The main contribution of the study was an understanding of how exhibits can create reliance between companions and distribute control through the interplay of different controllers companions have access to. The findings suggest that distributed control is complex, and influenced by a range of factors beyond multiple physical controllers.

Study 3 involved the design of an exhibit for the Riverside Museum, and a study of this exhibit involving museum visitors. The first two studies motivated and generated research questions for the final study. These research questions aimed to identify strategies for distributing control between companions, with a specific focus on eliciting shared social interactions in which visitors do not simply interact alongside companions in parallel, independent activities, but rather are encouraged to socially interact with one another and share the interaction. The methodology utilized in study 3 involved video-based observation and analysis, with addition data collected through questionnaires, short post-interaction interviews and semantic differentials. Overall, the study demonstrated ways which companions can be encouraged to share decisions, and how distribution of control between companions can contribute to increased equality of participation during interaction at exhibits.

7.2 Research Contributions

In this section, I outline the research contribution of this thesis. I begin by providing a summary of the research questions. Following this, the discussion is conducted in three sections, each corresponding to the research questions. Addressing RQ1, section 7.2.2 presents a definition of THIMEs. Addressing RQ2, section 7.2.3 presents an overview of the social and shared interactions observed during the three case studies, thus developing an understanding of the types of social and shared interactions which are typical or possible at interactive exhibits in a museum context. Addressing RQ3, section 7.2.4 discusses commonalities and differences highlighted throughout the three case studies regarding the ways in which control was distributed and how this distribution of control influenced companions' shared and social interaction. These include factors which instigate distributed control, such as providing multiple controllers, and factors that supported distributed control, such as providing ample time for visitors to coordinate their actions, in effect enabling groups to distribute control themselves. Finally, section 7.2.5 summarises key themes from across the research. These themes include 1) the inclusion of companions in the overall activity, (2) visitors' reliance upon companions, and (3) supporting equality between companions. From this, the research identifies a new design space in which various distributions of control between companions and their influence on companions' shared social interaction can be explored.

The nature of this research is interdisciplinary and as such contributes to various fields such as visitors and museum studies, Human-Computer interaction, and product and interaction design. The research contributions to visitors and museum studies in various ways. The PhD presents an example of how summative evaluations of existing exhibits can feed into future designs of interactive exhibits. Typically, evaluations conducted in museums are summative, for the purpose of reporting. A group of experts in museums studies has called for a change in this practice to use evaluations in more formative manor (Davies and Heath 2013). This PhD presents an example of how this might be achieved. In addition, study 3 implements a comparative study more typical for HCI (sort of AB testing), but extremely rare in visitor studies.

Contributing to the field of HCI, the research adds to a limited body of research focusing on social interaction between people in public spaces. Particularly unusual, is the focus on people outside of their core interaction, before and after interaction. As well as specifically focusing on companions in public spaces, rather than strangers. Beyond contributing to research concerning interactions in public spaces and research “in the wild”, the research contributes in unpacking the different types of distributed control. Previously control has been viewed as directly manipulating a system through a direct input. In this PhD research different types of distribute control are unpacked contributing to HCI, museum and visitors studies and product design.

In addition, the research contributes to the field of product and interaction design by drawing up design considerations for future products and installations when striving to support the social context of companions’ interaction and experience. In addition, the design considerations also present an opportunity for future research to investigate.

7.2.1 Research Questions & Motivation

The overarching research question of the thesis asked: what are the different factors to consider when designing tangible hybrid interactive museum exhibits concerned with supporting and fostering companions’ social interactions and shared interaction with the exhibit? This question was divided into three sub-research questions earlier in the thesis (see Chapter 1 Introduction). The first of these sub-RQs aimed to define the specific subtype of museum installation that this thesis focuses on, while the final two sub-RQs influenced the empirical research which was undertaken in the case studies. Chapter 1 contains a detailed outline of the RQs and an in-depth account of their development and motivation.

7.2.2 Defining Tangible hybrid interactive museum exhibits (RQ1)

In order to define the scope of the research and lend clarity to the subsequent discussion, RQ1 sought to accurately and lucidly define the type of exhibit examined in this thesis. Thus, in response to RQ1, the term Tangible Hybrid Interactive Museum Exhibit, or THIMEs, was proposed.

Tangible refers to a type of interaction which requires physical manipulation of real objects in order to manipulate digital content. This encompasses tactile, physical, or hands-on, interaction (Hornecker and Buur, 2006). **Hybrid** refers to merging the physical and digital, during which physical artefacts may be enhanced digitally or connected to digital content, which is controlled by people. Combining tangible and hybrid implies hands-on interaction with physical objects that manipulate digital content. **Interactive** refers an exhibit which changes as a result of a person's actions. Such exhibits respond to people, as *"change is under the visitors control"* (Bitgood, 2014, p.118). Interactive exhibits typically involve a longer sequence of visitor actions and system responses, than exhibits which use a simple on/off button or a start button. Used alone, the term 'interactive' does not necessary imply a link between technology or digital content. However, when combined with the term hybrid, the terminology indicates that digital technology is an aspect of the exhibit. **Museum** refers to the context in which the installation located, and thus specifies the exhibit's socio-cultural context. Finally, **exhibit** refers to an object or limited collection of objects on display, which have been curated to explain or relate to a particular topic, and are often displayed in public spaces. In summary, a THIME refers to a museum exhibit at which visitors use tangible interaction with physical objects to manipulate or control digital content.

7.2.3 Companions' social interactions at tangible hybrid interactive museum exhibits (RQ2)

In order to understand how distributed control relates to companions' social and shared interaction, it is first necessary to examine the nature of shared and social interactions (RQ2). The PhD research addressed RQ2 through a detailed review of existing literature (see Chapter 2), and by gathering empirical evidence on shared and social interactions between companions at interactive museum exhibits. Understanding the nature of SSI provides important knowledge for future creation of exhibits which aim to support this type of interaction. Furthermore, understanding SSI and identifying the different forms it takes, including action and activities, can provide guidelines for evaluating exhibits that aim to support SSI, an analysis which is often complex and resource-intensive.

In this section I present a brief overview of the social and shared interaction observed in the three case studies, as illustrated in Figure 7-2.

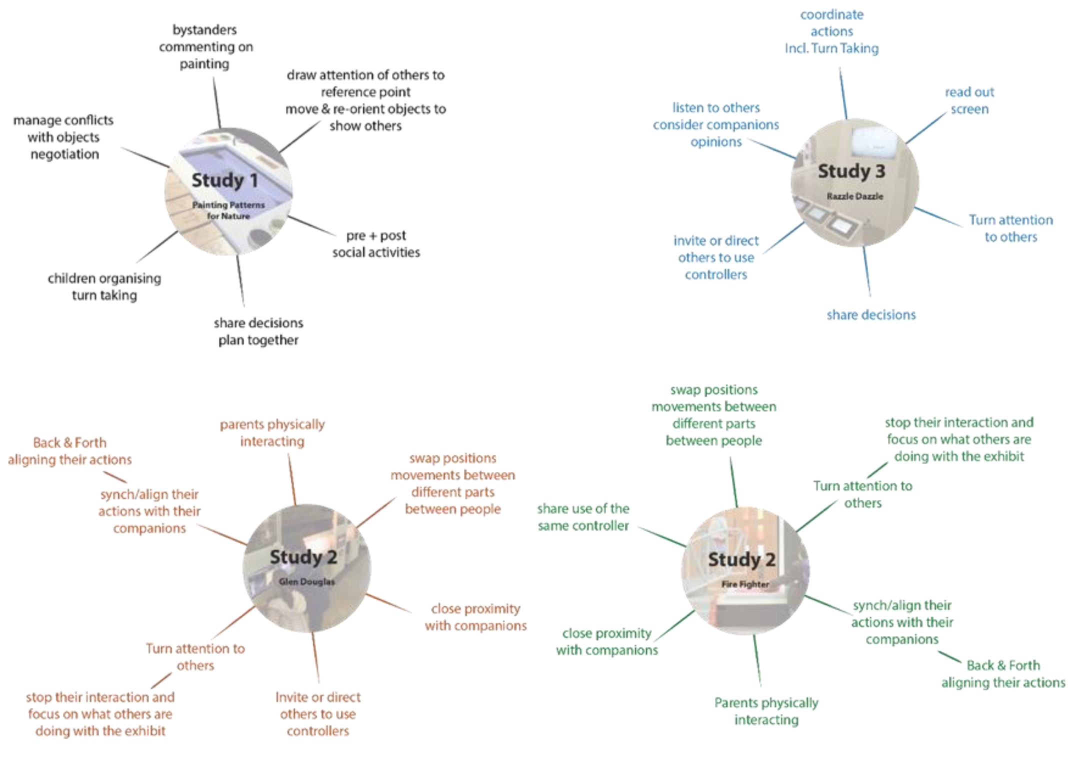


Figure 7-2: Social and shared interactions observed in the three PhD Case studies

Figure 7-2 gives an overview of the range and scope of the social situations observed. A number of these situations are of particular relevant to the present research, such as:

- Turn taking
- Supporting each other
- Sharing decisions
- Aligning actions with companions

At interactive exhibits, companions frequently engage in and negotiate turn taking. This action can lead to groups spending longer at exhibits and engaging in on-topic conversations (Block et al., 2015). The PhD research highlighted the variety of ways turn taking between members of the group can be encouraged. For example, in some instances, the exhibit itself structures the interaction, moving the desirable controller between several controller which helps to include various members of the group in interaction without requesting visitors to give up a physical controller (GD, FF & RD). In addition, the research highlighted how turn taking and hand-overs occur when visitors move into different positions. For example, stepping back from interaction at GD prompted people to intermittently take turns of the same controllers at station 1 back and forth between companions. Similarly at FF, moving from the hose controller to the wheel controller encouraged visitors to take turns of separate controllers. What is notable about the turn-taking in both study 2 and study 3 is the way it prompted companions to support each other in their interactions with the exhibits. These moments of support enabled companions to interact more effectively at FF, pass on useful guiding information at GD, and encouraged other visitors to use the controllers at RD. In effect, turn taking encouraged visitors to turn their attention towards their companions, rather than focusing solely on their own interaction. In addition, these moments presented opportunities and encouraged companions to support each other in their interactions with exhibits.

At exhibits with technological aspects, it is often difficult to direct visitors' attention to their companions during opportunities for interaction. Yet being aware of others is crucial for social interaction. The PhD research observed companions sharing interaction and engaging in role play and teamwork at GD and FF in study 2. Such behaviours presented opportunities for companions to focus on each other and enhanced their social awareness of each other.

As a result of distributed control, companions were frequently observed discussing the merits of different options presented to them and sharing decisions. This was an important and valuable behaviour, as the research aim to understand how to encourage and enable communication and social interaction. Although technology can provide novel ways for visitors to engage intellectually with stories relating to museum collections, we also have a responsibility to consider how technology can support the social agenda of companions visiting the museum together. Moreover, this activity demonstrates that visitors are willing to engage with the available options and thus with the topic or content of the exhibit. It is therefore beneficial for museums that aim to foster learning and intellectual engagement to stimulate such shared decisions. Discussing options and opinions also commonly occurs at non-interactive exhibits, where visitors often pose questions to each other, and discuss options and opinions as they speculate about artefacts. Overall, while technology can, at a basic level, provide novel ways for visitors to engage with museum collections, it is also essential for museum staff and researchers to consider how this technology can support the social context of companions visiting the museum.

Previous research has suggested that it is necessary to both support verbal and non-verbal communication between companions, and create opportunities for visitors to engage socially through organising their actions and interlinking their behaviours (Hindmarsh et al., 2005). Across all case studies, visitors were observed aligning their actions with the actions of their companions using verbal and non-verbal communication. For example, visitors were observed glancing or turning to look at others, which prompted physical actions with the exhibit; mediating others' actions by asking them to "wait", while holding up an arm or hand; and guiding companions interactions based on opinion at RD, or on the privileged information they have at GD.

An important contribution from the PhD is the detail relating to how companions engage in social interaction and share the interaction in different ways.

7.2.4 Distributed control between companions (RQ3)

To address RQ3, this section draws on the insights gained from the three case studies relating to how control was distributed between companions and the role it played in their social and shared interactions. Many of the ways that control was distributed arose from the interplay between multiple controllers. These can be categorised in the following variations:

Firstly, multiple controllers:

- may all control the same thing, creating some form of competition or simply multiplexing control
- may control of something different, manipulating separate things

Second, regardless of whether multiple controllers all manipulate the same or different things, we can determine whether:

- controllers can be used in parallel, or is there some other mechanism of sequencing interaction
- There is one object which acts as a main controller or do different controllers become desirable at different times over the course of the interaction?

As this research has demonstrated, there are variations in how control is distributed in a number of ways which extend beyond the simple physical provision of many controllers. As will be shown in the following, this can be further distinguished into characteristics. While many existing interactive systems have several tangible controllers, at present there has been limited research into the specific qualities of distributed control at such exhibits (Hindmarsh et al., 2005). Thus, it is important that designers and museums curators consider these factors in order to adequately understand their relationship to companions' social and shared interactions between companions. The impact of these variations on how control is distributed is important to understand for future designs which strive to support the social context of groups while using interactive public exhibits. Where some variations directly instigate social and shared interaction, others are supporting factors.

Often, THIMEs which support SSI are multi-user exhibits, with several different controllers which can be used by individually by different members of the group to interact. However, the structure of THIMEs can be varied in order to elicit or support different forms of co-participation (Wakkary et al., 2009), (Ciolfi and Bannon, 2007), (Taylor et al., 2015). In this respect, the PhD research builds upon prior research, such as Hornecker et al. (2007) and Marshall et al. (2008), which discusses the effects of parallel access, simultaneous interaction and enforced turn-taking.

This section responds to RQ3, describing 'the way control was distributed between companions' at the exhibits in the three case studies, highlighting common factors or differences in how control was distributed. The second purpose is to explain what role the ways in which control was distributed played in companions' shared and social interaction. While there is some overlap between these **factors** explained below, they should be recognised independently as considerations and variations of how control can be distributed.

Based on the findings from the three case studies, I argue that control can be distributed by exhibits in three main ways:

1. where controllers are and what they are (physical distribution of control)
2. what the controllers do (functional distribution of control)
3. when to use controllers (temporal distribution of control)

These three ways of distributing control shape the social interactions between companions, and influence how companions share the interaction and are included in the overall activity of interacting with the exhibit. ***Physical distribution*** of controllers is usually immediately visible, and often results in visitors distributing themselves across the controllers. ***Temporal distribution*** of control refers to when controllers are used over the course of the interaction. For example, at FF the wheel to move the ladder is only used at certain moments. The temporal distribution of control can be structured by the exhibit in a predetermined or an open-ended way. Exhibits, such as GD and FF, can constrain visitors to a set controller or the use of specific controllers at a point of time, predetermining the temporal distribution of control between companions. Alternatively, the exhibit can present groups with choices. In such situations, such as those observed at RD, an exhibit may suggest when to interact, but not dictate which controller to use, leaving it open to visitors to make this decision. ***Functional distribution*** of control refers to what controllers do. For example, at GD, control was distributed functionally between companions through controllers which controlled content in different ways.

Functional and temporal distribution of control can modify, enhance and interact with the physical distribution of control. Physical, temporal and functional distribution of control thus work together to distribute control in ways which can encourage, or discourage, social shared interaction, as illustrated below in Figure 7-3. For example, an exhibit may have three physical controllers which manipulate digital content in different ways, yet each of these controllers can only be used at specific moments during the interaction. Thus, control is distributed physically between the controllers, functionally by what the controllers do, and temporally by the moments when it is appropriate to use controllers.

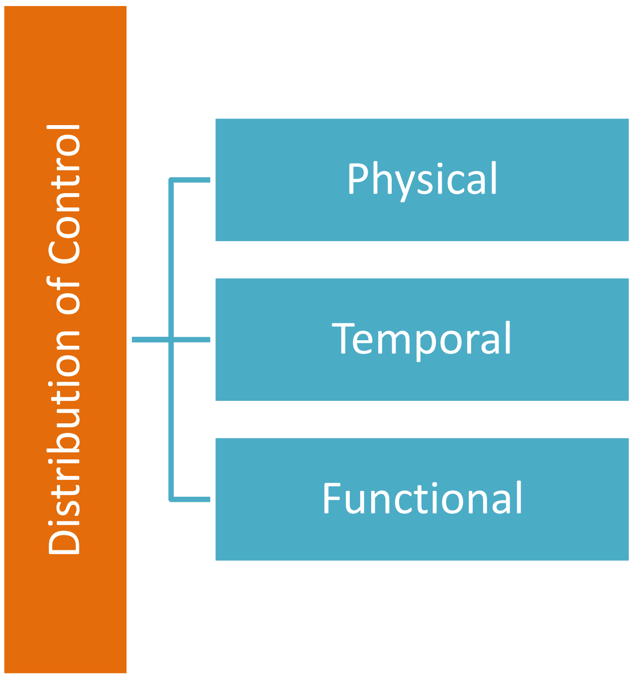


Figure 7-3: Three ways control can be distributed

Each of these three mechanisms can be realised in different ways, and each play a role in companions' SSI. Based on key insights gained from the three case studies, the following variations in how control is distributed considering the commonalities and differences have been identified:

1) Distance and placement of controllers
2) Active and inactive controllers
3) Portable controllers
4) Providing choice over controllers
5) Desirable controllers
6) The function of controllers
7) Supporting factors including a lack of time pressure, the size of controllers, and gestures required to interact and visually embedding digital content directly in controllers

1) Distance & placement of controllers

Separating controllers at a distance from other controllers and from digital content has previously been noted to prompt social activities between companions, and even between multiple parties. This is particularly evident when digital output is displayed at a distance from controllers and as a result is only be visible to people who cannot manipulate the content (Hindmarsh et al., 2005), (Rogers et al., 2004). The distribution of control can also be varied by the distance between controllers and their exact placement. As a result, visitors are placed in particular positions and separated from each other, from other controllers, altering their visibility of companions and of key pieces of the exhibit.

Controllers can be physically separated in order to limit dominating behaviours and to encourage or implicitly force companions to share. In most of the case studies, all of the controllers were attached to the exhibits at fixed locations, and separated at a distance from each other. This meant that one person could not physically assume control of all of the controllers , making it impossible for one person to control the entire exhibit. For example, at GD is was impossible to be at station 1 and 2 at the same time. The distance between and separation of the controllers prevented one person from taking over, thus encouraging collaboration, and requiring companions to share controllers (Benford et al., 2000), (Marshall et al., 2008). However, as observed at GD, too great a distance between controllers can create challenges such as those illustrated by Hindmarsh's (2005) research, in which separating the different elements of the installations made it difficult for visitors to understand their connection. At GD, people were initially unaware of how their own actions related to the actions of others, and often other visitors stood in between visitors who needed to communicate with one another, blocking their line of sight and hindering their coordination. Overall visibility of the digital output is not possible while standing at the controllers at station 1. These issues support the work of McManus (1998), which argues that too much distance between controllers at exhibits can raise issues, and suggests that companions who are positioned more than a metre apart are more likely to work independently, than as part of a group.

The separation of input and output, such as between controllers and informative displays at GD, was also found to have positive effects on social interaction. For example, this separation encouraged people to step back from the interaction in order to gain view the rest of the exhibit, which led to hand overs of control, and prompted companions to engage socially, moving and coordinating with their companions. Stepping back from an activity has been found to support learning (Ackermann, 1990), and similarly can be considered a positive way to encourage learning at exhibits. People who stepped back from interaction were more likely to hand-over control, swap positions with companions and guide companions as to how to use the exhibit. At GD, the separation of resources for the activity, such as the input from the output, also encouraged companions to relay guiding information to each other when they understood the connection or saw the guiding information on the screens.

One drawback to the separation of input and output is that it can create vantage points, which can lead to inequality (Hornecker et al., 2007) and may limit individuals' ability to observe the outcome of their own interactions (Hindmarsh et al., 2005). Nevertheless, in some instances (Hindmarsh et al., 2005), companions have been found to create performances for others even though their view of their output was limited, using this limited visibility in order to entertain and surprise others (Hindmarsh et al., 2005). However, it should be noted that, even in such cases, it appears beneficial for the operator to see the digital response to their own actions.

Having considered the distance and placement of physical controllers, I suggest the following considerations for future work:

- Consider how to encourage visitors to step back from interaction, which may encourage and support companions handing over control.
- Consider the potential advantages and disadvantages of separating viewpoints from action points (Hindmarsh et al., 2005).
- Avoid creating of situations in which people may block the line of sight between companions who need to communicate and coordinate their actions.
- Consider physically separating and distancing controllers from each other, as this limits individuals' ability to dominate the interaction with the exhibit and thus provides opportunities for others members of the group to interact.

2) Active & inactive controllers

The qualities of active and inactive controllers related to distributed control can be divided into three variants. Firstly, there may be a temporal distribution of control when controllers are active or de-activated, creating a pause in interaction. Secondly, controllers may also go offline or inactive when moved outside of the interaction zone, relating to physical and functional distribution of control. Thirdly, inactivity can be related to low pace, or low intensity, of interaction.

Creating moments in which controllers are active or inactive during an activity distributes control temporally, restricting interaction to exact moments. For example, visitors at RD were invited to use the controllers at specific moments, such as when the exhibit presented a challenge or a selection menu. Outside of these moments, the controllers were inactive and using them had no effect on digital content. In effect, this **staggered the interaction temporally** over the course of the activity, creating inactive phases in which people were not prompted to interact, instead people could take time to observe and discuss.

Active and inactive controllers thus have an impact on the intensity of the interaction, and on the frequency with which controllers are used. In contrast to GD and FF, at RD, the intensity of the interaction was relatively low, and had a slow pace. For the majority of the interaction cycle, visitors were not interacting, but instead were watching digital content alongside their companions until the exhibit posed challenges and invited visitors to interact. This low level of interactivity and slow pace appeared to enable companions to take their time to work together, and created situations in which all group members were engaged in the same activity, such as watching the digital content. Previous research has similarly questioned the necessity of intense interaction as a means of supporting social interaction between companions (Warpas, 2014), (Taxén et al., 2004), (Hornecker, 2016). Digital exhibits may require fairly minimal use of controllers, and low-paced, or even passive, activity, but nevertheless support companions to engage with rich digital content, discussing it with each other, pointing out features and referring to artefacts, as well as aligning their actions with others (Hornecker, 2010).

Controllers can also become inactive when moved outside of the interaction space. This can mitigate the risk of companions approaching the exhibit and immediately touching controllers, thereby disrupting the current interactor's activity (Tolmie et al., 2014). Enabling bystanders to access 'offline' controllers can also mitigate this risk. Furthermore, this inactivity can help parents to avoid spending their time managing children's actions in order to avoid conflicts (Heath and vom Lehn, 2003). In study 1, most of the tangible controllers (tokens) were physically accessible to the group at all times, but were inactive or 'offline' unless paired with a sensor area. This allowed bystanders to physically touch and play with controllers without interrupting the person interacting with the exhibit. Providing controllers which were functionally disconnected from the exhibit but physically accessible, allowed companions to engage with the exhibit pre and post interaction, and prompted social interaction between bystanders while they waited for their turn. Furthermore, bystanders were able to plan their future actions and discuss these plans with companions while using the offline controllers to support their planning activities. This supports existing research that suggests that TUIs can support planning activities during which they plan, sort, browse and discuss options with companions (Rogers et al., 2009), (Fernaeus, Tholander and Jonsson, 2008).

Thus, having considered how control is distributed by active and inactive controllers, I make the following recommendations for future work:

- Consider enabling companions who are not part of the direct interaction access to offline controllers in order to support social interaction while they wait to use the exhibit and prepare for their turn.
- Consider how active and inactive controllers can stagger the interaction between people, and create moments in which companions are collectively undertaking the same activity, thus supporting a sense of equality between companions.
- Consider minimizing the intensity of interaction, such as its frequency and speed, in order to provide companions with greater opportunities to engage with each other socially.

3) Portable controllers

Existing research has argued that providing multiple access points between members of a group distributes control between companions, and can support shared interaction (Rogers et al., 2009), (Hornecker et al., 2007), (Wakkary et al., 2009). One of the novel observations of this thesis is that companions' SSI is influenced by the fixed or portable nature of such controllers. In all of the case studies discussed in this thesis, control of the exhibits was distributed physically through several tangible controllers, which were physically distanced from each other. PP4N was the only exhibit at which some controllers were detachable and portable (the tokens), illustrating that portable controllers can be functionally diverse objects. At PP4N the tangible controllers included both wooden tokens, which were portable and 'offline' when taken away from the activation area, and the paint brush, which could be moved on a leash and was thus portable within a range. As a note, a subtype of portable controllers not observed in the case studies are mobile controllers, which are truly portable and remain active regardless of their location.

At PP4N, detached portable tokens that were functionally offline enabled social interaction between companions who were waiting to use the exhibit. While waiting, visitors browsed and held the controllers, re-orientating them to show to other companions, and discussing their planned actions for their own turn at the installation. This activity occupied children waiting for their turn, allowing to take the first step in their interaction by choosing what to paint and planning this together. Offline tangible controllers have been recognised for their social value outside of the museum context, (Rogers et al., 2009), (Fernaeus, Tholander and Jonsson, 2008), (Esteves et al., 2013). However, at present, relatively few museums provide portable offline controllers, as often museums are concerned these will go missing and need to be replaced. Despite this, the Atlantic Wall exhibition at the MUSEON museum in Den Haag had several offline tangible tokens, and far fewer of these than expected went missing (Marshall et al., 2016). However, it should be noted that this exhibit was used by a mostly adult audience, who may have been more conscientious than a younger audience.

The movable paint brush at PP4N being portable but attached with a cable allowed for some flexibility. Visitors were able to move the paintbrush to manage conflicts and negotiate hand overs (explicitly handing it over to the next person or holding it out of range of another person. The semi-portability of the paintbrush enabled companions to use it a tool to help manage conflicts and negotiations.

Having considered how control is distributed by portable controllers, I make the following recommendations for future work:

- Consider how portable controllers, and particularly offline portable controllers can enable visitors to use the controllers as resources to support their social actions with companions, by moving, re-orientating and holding onto controllers.
- Consider how semi-portable controllers, which are moveable within an area but still attached to the exhibit, can help visitors to manage conflicts and negotiate turn taking.

4) Providing Choice over Controllers

Some exhibits which have multiple controllers may not offer visitors a choice over which controller to use. Alternatively, there are exhibits which specifically encourage visitors to choose the use of different controllers throughout the course of their interaction. Exhibits which present groups with a choice can positively influence how control is distributed between companions. At both PP4N and RD, visitors were able to make choices, choosing what to paint in the case of PP4N, or choosing a challenge and then an answer to a question at RD. In both situations, visitors frequently shared these decisions with companions, and as such, selecting the controller of choice was a social action. In contrast, at FF and GD visitors were not provided a choice of controllers at FF and GD, as the exhibits guided visitors as to which controllers to use. Thus, there was a clear difference between the social behaviours observed in study 2 (GD & FF) and study 3 (RD). However, it should be noted that the scope present research allowed for only three case studies, and as such does not allow for hard conclusions.

At RD, visitors considered and discussed possible answer, and then guided their companions to use specific controllers, verbally suggesting and pointing out what to do. Thus interaction with the exhibit was frequently the result of a shared decision. In this way, having **choice** invited people to participate, by giving their opinions or suggesting what to do. Companions at RD were given a choice of controllers to use, all of which had the same functionality. Similarly, at PP4N, a choice of controllers prompted companions to share decisions and engaged in 'what to do' next conversations. I define this activity as 'what to do' conversations during which people shared decisions about what controller to use with companions. These types of conversations contrast with 'how-to' conversations, which concern how to use an exhibit, and often indicate usability issues with the exhibit (Hornecker, 2008). It is important to note that the situations relating to choice involved a number of social actions, such as physically moving controllers in the space, re-orientating controllers, pointing controllers out to companions, paying attention to others' actions, handing over control to others or guiding others actions.

This type of shared decision-making did not occur at FF and GD. When visitors guided companions at GD, it was primarily to relay information in order to guide their successful interaction with the exhibit, and did not involve a shared decision or discussion of the options; instruction, rather than discussion, took place. Both of these situations have advantages and drawbacks. For example, shared decisions can be difficult to make, and at RD, these decisions were not always amicable. As a result of following the instructions at GD and FF, there was less self-agency or group discussions. However, visitors had greater clarity over their roles, and their relationship to each other, which potentially mitigated conflicts and disagreements. Like many situations there are trade-offs to be aware of, in order to make informed decisions about the design of future interactive exhibits.

Additionally, at RD, the <u>**choice**</u> of controllers to gave companions the opportunity to encourage or invite someone else to interact, with companions often handing over control, rather than interacting themselves, despite having access to a controller. Physically and functionally distributing control in this way prompted situations in which visitors guided, invited or directed their companions to interact, stepping back from active control and encouraging the others to become active. The distribution of control was mediated by the group rather than the exhibit, as seen at GD and FF allowing for little spontaneity. Choosing a single controller to use at RD therefore puts companions in a position to decide to give away control, and debate whether to use the nearby controllers.

Nevertheless, explicitly designating roles can be advantageous, in that people in these cases knew better what to do, and there occurred no surprise hand-overs of control to people mid-interaction. The intention here is not to argue for one better than the other, but to understand how different variations in how control is distributed **functionally** and **temporally** can foster different ways of sharing interaction and working together.

Moving conversations from 'how to' ('how do you add water') to 'what to do' ('I think it's the third one. What do you think?') has a parallel in inquiry-based exhibits, such as the Exploratorium in San Francisco. Such exhibits ask people to think as well as act and encourage them have self-agency through decision-making, rather than only through actions. It should be noted that 'what to do' discussions require sufficient usability, so that visitors can progress beyond initial 'how-to' conversations. Providing visitors with the opportunity to make a choice and engage in shared decision making can support visitors engaging intellectually, and foster social interact with their companions in a meaningful way.

Having considered how providing choice of controllers has an effect on the distribution of control, I offer the following recommendations for future work:

- Consider presenting groups a choice or choices, which may prompt companions to share decisions, distribute control between themselves, and discuss 'what to do' together.

5) Desirable controllers

Desirable controllers also impacted the ways in which groups interacted and engaged with companions. A desirable controller can be defined as an object, or input device, which is the most desirable of the available controllers, to users. At exhibits, there may be only one desirable controller, which is always at the same location, and thus obvious to all participants. Or at different times, different controllers may become desirable, thus making it harder for one person to maintain constant control of the desirable controller and dominate the interaction. In the extreme, an exhibit can make it impossible to predict which controller would subsequently become desirable. In addition, in some cases, a controller may be understated and may not appear to be desirable, but may serve a crucial function. In these situations, children, who are often attracted to the most obviously desirable controller, could be supported by parents stationed at the other, essential but less obviously desirable controller, thus ensuring a viable division of labour.

In study 1, the desirability of different controllers sparked discussions and social interactions (in this case, the wooden tokens). In study 2 and 3, the varying desirability of certain controllers at certain moments helped to distribute control between companions. At certain moments, various controllers were either **appropriate or counterproductive** for successful interaction. For example, at FF moving the ladder to a fire was appropriate, but moving the ladder away from a fire, or failing to move it towards it, was counterproductive. Also, while the ladder was moved towards the fire, the person at the hose had to wait, as their action was ineffective. Thus, at certain moments, certain controllers were either desirable or undesirable. At RD, encouraging visitors to think about appropriate or counterproductive controllers helped to slow down the pace of the interaction. I discuss how time and pace can support social interaction between companions in a later section (Point 7: Other supporting factors for distribution of control). At RD, as the use of certain controllers was counterproductive at certain times, companions were **encouraged to give away control** in order to choose the right answer and successfully complete the activity. A useful insight for future designs, as giving up control can be difficult for some children, in particular younger children, as some find it challenging to share with others. Thus the presence of counterproductive controllers could help with the difficulties they face in sharing with others.

Common across both study 2 and study 3, the exhibits all **shifted and moved the desirable controllers** at certain points, thus distributing control and prompting shared interaction. At GD and FF this movement was predictable, as visitors had to use the hose, then the ladder, then hose again, continually repeating this pattern. In contrast, at RD, this movement was unpredictable. Only one controller at any time was desirable, but it was not predictable how this would shift. This introduced a sense of spontaneity to the way control was distributed, leaving the group to determine how control would be distributed. This unpredictability also made it difficult for individuals to dominate the activity, as they could not predict which controllers would need to be used, and thus could not try gain access to it in advance. Thus, contributing to equality of use among group members.

Snibbe and Raffle (2009) argue that interactions should be '*socially balanced*', meaning that interaction should equally emphasise *"a user's awareness of herself, other users, and the media itself"* (Snibbe and Raffle, 2009, p.1449). A structure in which not all controllers are equal but instead there is a **desirable controller** which changes during the course of the activity, requires visitors to sequentially use different controllers. It could be argued that this imposed structure of interaction contravenes the ideal of exhibits as free and open spaces, which possess a lot of experiential value. However, structured turn-taking can enhance awareness of companions. In contrast, when visitors simultaneously use of several controllers in parallel, people do not necessarily focus their attention on others, unless the interaction requires them to do so. When a companion suddenly, and unpredictably, has the desirable controller, often the group will pay attention to this person, and engage in a discussion of what to do next. If no one knows who will be in control next, no one should be ignored. A key difference between the social behaviours observed both GD and FF and RD was the degree to which **visitors guided their companions to use specific controllers**, which happened more at RD. At both GD and FF, and RD the interplay between controllers led visitors to pay attention to their companions during the interaction, rather than focusing solely on the exhibit.

Regarding the desirability of controllers, another aspect to consider is controllers and positions which appeared to be **understated**. In some cases, some controllers appeared to be less important than others. In study 2, at both GD and FF, there were positions that appeared less desirable than others at first sight. For example, at FF it appeared to be more attractive to actively put out the fire, enticing visitors up the ladder to the hose; however, once in this position, visitors would often realize that they depended on another person to steer the ladder. In effect, at FF children were encouraged to go up the ladder initially, which created opportunities for parents, or older siblings, to interact at the understated, but equally powerful controller that moved the ladder. Thus creating opportunities for parents to actively participate in the experience as an interactor, beyond solely engaging in verbal scaffolding or educational facilitation.

Having considered desirable controllers and their influence on the distribution of control, I make the following recommendations for future work:

- Consider having a different desirable controller at different moments in time - shifting the controller that is desirable to use throughout the activity. For instance, making controllers appropriate and counterproductive at various moments in time can help to distribute control.
- Consider making controllers or positions of control appear understated may create opportunities for parents to physically interact
- Consider how a desire to use other controllers can encourage turn taking and provide incentives to give away control, thus encouraging social interaction and sharing interaction during which visitors invite others to interact.
- Consider an interplay back and forth between the use of different controllers to foster turn taking. This interplay can be dictated by the exhibit or by visitors.

6) The function of controllers

The function of controllers and what they do also shapes how control is distributed between companions. For example, do all controllers have the same function such as the tokens at PP4N, or buttons at RD, or do the controllers give access to different dedicated functions such as the paintbrush, token and pots at PP4N, the lever and wheel controllers at both GD and FF. Furthermore, can controllers only function effectively when other controllers are also used in a complementary role, such as the controllers at GD and FF. Thus, distributing control among these. Or do controllers need to be located in an activation area, as in PP4N. Finally, does the function of controllers encourage a sequential interplay between their use?

In study 2, GD and FF had a similar functional arrangement, in which controllers had different functionality, but were interconnected and could not be effectively used without the collaboration of another person at the other controller. This was enforced collaboration as it was near impossible to interact successfully without the assistance of another person. In these cases, control was distributed in a very explicit way, in which roles were explicit. In particular, at FF, there was a distinction between a leading role and a helping role. The exhibit design prescribed these roles and allocated them to different controllers, and thus implicitly assigned them to different people who happened to be at that physical location.

One criticism of such exhibits is that they are not easily scaled down to work for a single participant (vom Lehn and Heath, 2016), (Snibbe and Raffle, 2009). However, as research has shown, people typically visit museums in groups (Kelly et al., 2004), (Heath and vom Lehn, 2003), (Falk et al., 2006). Furthermore, it has been argued that focusing on scaling down in this way can limit the design of exhibits which support more complex forms of collaboration (vom Lehn and Heath, 2016). Thus, there is a trade-off to be made, while some multi-user exhibits cannot be used by an individual alone, these will instead cater for a more complex group experience.

In addition, controllers with different functions and the frequency that they need to be used during the interaction, can create supportive roles, including keeping an overview of the activity for the group. For instance, the hose at FF and station 1 at GD required more frequent use of the controllers. The other controllers were used less frequently and also involved visitors taking on a more supportive role. When it was appropriate to use secondary controllers, control was temporally distributed from one area to another, creating situations in which companions could support each other.

In study 2, physically distributed controllers with different functionality appeared to encourage companions to swap positions and thereby potentially prolonging their time at the exhibit. This varying functionality therefore enabled visitors to take on different roles in the interaction by handling alternative controllers, providing new experiences of the same exhibit, and supporting companions to share each other's perspectives. For example, moving between the hose and wheel at FF or between station 2 and 2 at GD. Crucially for the aims of this research, understanding the perspectives of others is potentially valuable for bonding.

Having considered how the function of controllers relates to the distribution of control, I make the following recommendations for future works:

- Consider whether controllers provide the same function or different functionality.
- Consider whether controllers are interlinked in how they function, and whether they may be used in synchronization together (GD)(FF) or only be used in certain areas (PP4N). For example, consider whether a controller should be ineffective without the use of another.
- Consider whether some controllers should lead the interaction due to them being used more frequently or manipulating the content to a greater extent.
- Consider whether the role of some controllers should be initially downplayed and understated, so that people may firstly approach another controller which appears to be more desirable before realising the influence of the understated controller (GD) (FF). This may create opportunities for adults physical interaction with exhibits.

7) Other supporting factors for distribution of control

A number of less prominent factors also facilitated and supported distribution of control. While less crucial to the distribution of the control in the case studies, these factors nonetheless merit discussion. These include:

1) No time pressure
2) The size of controllers and gesture required to interact. For example, holding controllers with two hands based on the qualities of the controller such as its size or form.
3) Embedding digital content within controllers. Often the display and controllers are separate objects in museums.

<u>No time pressure</u>

At RD, visitors had ample time to use the controllers when faced with a challenge. Without an imposed time limit, companions were able to coordinate their actions, share the decision of what controller to use, and guide others to use the exhibit. In contrast, at GD, time pressure was imposed upon companions, forcing them to interact quickly. This time pressure made it difficult for companions to coordinate their actions and relay guiding information from the display to others before the engine went out or the boiler exploded. Additionally, the time available to react decreased as the interaction continued, making the activity progressively harder. Therefore, eventually visitors were inevitably unable to effectively coordinate their actions and could not take their time to coordinate their interaction at the exhibit. During the co-design process, the museum argued for a timer in the exhibit as a way of increasing excitement. However, it was eventually decided that visitors should have no time limits. Once the exhibit had been installed, museum staff commented on their surprise at people's engagement with the installation.

In support of these findings, previous research has also suggested that time pressure can hamper interaction at interactive museum exhibits (Hornecker, 2016). While time pressure can add excitement, it can also limit companions' ability to share the interaction, and to discuss and reflect on this. At RD, ample time was a supporting factor for the distribution of control among companions. At present, museum exhibit designs are exploring gamification of their interactive exhibits, in which time pressure is often created to add excitement. However, as this research has demonstrated, adding times pressure in order to support a sense of excitement may sacrifice social interactions. Depending on the user experience and interaction intended, it is therefore important to consider how time pressure will impact upon the social context of groups, and not just on excitement levels. Perhaps, this should be considered as a trade-off. Here I presented two extremes, time pressure and no time pressure at all. However, a suggestion for future research is to explore various amount of time pressure and ways in is imposed, questioning the effect on people social interaction, overall experience.

In light of the evidence regarding time limits and distribution of control, I make the following recommendation for future work:

- Consider giving visitors time to think and discuss, as this can support social interactions involving verbal dialogue and shared decision making. Giving visitors ample time in this way can encourage slow considered interaction with the exhibit, allow people time to interact with each other and the ability to turn their attention to their companions.

<u>Size of controllers and gestures required to interact</u>

The gestures required to use controllers and the size of controllers also supported distributed control at the exhibits. For example, at FF, if companions chose to use the hose together, they were easily able to do so. The hose was large enough for two people to hold, and only required a slight movement along a single axis. In contrast, controllers which require rapid movements may make it more difficult for companions to align their movements. For example, the wheel at FF was difficult for two people to turn it together as a result of the rapid movements required. Conversely, effective use of the hose required two manipulations, which may have been difficult for younger children to do alone. In some cases, older children helped younger siblings to use the hose, typically holding the hose in place while the younger child pressed the button. This joint control may support companions to use the same controller, but it does not instigate a distribution of control. Meaning the size, form and gestured required to use the hose controller do not distribute control between companions. These qualities instead support people in distributing control if they chose to do so, therefore they support rather than instigate a distribution of control. The qualities enable rather than enforce a distribution of control, aligning with previous research classifying systems in terms of how they can enable, encourage or enforce collaboration (Benford et al., 2000). Previous research supports the finding that companions are able to share controllers when they are large and require only limited movement, rather than rapid movements (Hornecker, 2010).

Having considered the relationship between the size and gestures required at controllers and the distribution of control, I make the following recommendation for future work:

- Consider having physical controllers that are large enough for two hands, which are attached to exhibits but movable along a single axis, and do not require repeated rapid movements, so that people can easily align and coordinate their movements.

Visually embedding digital content within controllers

In a traditional understanding of TUIs (tangible user interfaces), physical objects both control and represent digital content (Ullmer and Ishii, 2000). Findings from this research suggest that exhibits with TUIs in this traditional sense have social benefits for companions. For example, at RD, controllers had screens embedded in them which displayed changing digital content to follow the narrative over the course of the interaction. Digital content was similarly embedded at PP4N and included a wall projection repeating the content from the interactive tabletop. Embedding content in controller and repeater screens in these instances helped all group members to develop and maintain an awareness of the current ongoing interaction. This embedded content also helped bystanders in the group relate to the ongoing interaction, and in some cases to move into participation by trying to indirectly control the exhibit by making suggestions as to what controller should or could be used. Embedding digital content in controllers appeared to encourage companions to socially interact while making decisions, and to direct or guide their companions to use particular controllers. In the case of RD, at the version of the exhibit with screens embedded in the buttons, there were more social interactions between companions than with at the version of the exhibit without screens embedded in the buttons. Furthermore, visitors rated the setup with the screens embedded in the buttons more highly in terms of being satisfying, entertaining, feeling active rather than passive and feeling they were 'doing it (the activity) together' than the setup without the screens embedded in the buttons.

Having considered the relationship between visually embedding digital content within controller and the distribution of control, I make the following recommendation for future work:

- Consider how controllers which themselves are representations of digital content can support group social and shared interactions. In particular, participation of bystanders in the activity.

7.2.5 Key Themes

Three overarching themes have emerged from this research. Firstly, the theme of reliance and co-dependency, concerning how exhibits foster situations in which companions rely upon each other. Secondly, the theme of equality between companions in terms of their influence over the manipulation of digital content. Finally, the theme of inclusion, concerning how companions are involved and included in each other activities during interaction with an exhibit. The strategies of distributing control outlined in Section 7.2.4 all serve to create some degree of reliance, equality or inclusion between companions. I will now discuss each of these themes in detail.

Reliance upon companions

A common theme across study 2 and study 3 and related to prior research concerning SSI is that of reliance upon companions. According to Benford et al.'s (2000) framework for supporting collaboration, reliance is the strongest way of enforcing collaboration as interaction will fail without collaboration. Encouraging collaboration might be achieved by providing an added benefit when companions coordinate their actions (.ibid). Enabling collaboration allows addition people to join in but it isn't necessary and doesn't add additional benefit (.ibid). These strategies (of distribution) outlined in the sections above, all serve to create some reliance on each other within a group.

Study 2 and study 3 highlighted some of the different ways in which companions rely upon each other. A distribution of control at these exhibits often created dependency between companions by:

1) Creating situations in which group members must relay information to a companion who cannot view relevant content and thus cannot succeed alone (GD).
2) Creating situations in which a visitors cannot use a controller unless another controller is also used, and thus relies on the help of others to use these other controllers (GD) (FF)
3) Creating situations in which there is a lack of control, and thus companions require and rely on others not to interact quickly or with the wrong controller (RD)

At the exhibits, when visitors relied upon companions, they frequently engaged in social and shared interaction. For example, at RD, in order to successfully complete the activity, companions relied upon each other not to interact quickly with potentially the wrong controller. As such, visitors were encouraged to turn attention to and coordinate with companions, thereby engaging in social and share interaction. Furthermore, in all of the exhibits studied in this research, reliance appeared to stem from the relationship between controllers and how control was distributed.

In a museum context, encouraging reliance and co-dependency could potentially prevent situations in which several individuals engage in rapid interaction simultaneously, which can make it hard to keep track of who's doing what and can cause interference (Hinrichs, 2013) and cause conflict (Allen and Gutwill, 2004). This PhD research has demonstrated that situations in which companions rely upon each other, turn taking behaviours are likely. Turn taking has been shown to prolong visitors time at exhibits, foster on topic discussion, and help companions to engage socially at an exhibit (Block et al., 2015). Debenedetti (2003) argues that is important to support both visitors' individual, introspective and social experiences in order to support visitors' agenda to strengthen and consolidate bonds with their companions. Exhibits which create a sense of reliance between companions can offer visitors the opportunity to do activities together and thus support bonding with their companions. Moreover, allowing children to support each other and to support parents could be facilitate an innovative reconsideration of typical parent-child roles in museums. Thus, reliance may create new opportunities for children and families to support each other while interacting and foster an awareness of each other during interaction. Overall, in order to support social activities between companions in a museum context, future design should consider various ways exhibits can encourage or enable companions to support each other, such as fostering a sense of co-dependency. For example, qualities which enable the dual use of one controller so that older kids can support younger siblings interaction or situations in which guiding information is visible for a companion but not for the visitors at the controllers.

Equality

Equality was also a commonly identified theme in all of the case studies. In this sense, equality concerns in how exhibits support more than one person to contribute to and influence the interaction with an exhibit. Equality is directly related to the central motivation of this research, which is to investigate how to support the inclusion and involvement of companions in each others interaction with a THIME. Equality is not simply an equal division of parts of the exhibit, but rather equal opportunities to contribute to and influence the interaction.

This research is primarily concerned with equality in terms of:

- The physical, or what people can do.
- The temporal, or when people can and cannot, or should and should not interact.
- The functional, or why and how people do or do not interact in certain ways with controllers, or engage in verbal indirect control.

A range of prior research has focused on supporting equality between companions by providing several equal functioning controllers or by giving companions equal access to controllers (Hornecker et al., 2007), (Marshall et al., 2008), (Snibbe and Raffle, 2009), (Ciolfi and Bannon, 2007), (Hindmarsh et al., 2005), (Benford et al., 2000). This body of research is inconclusive regarding the benefits of equality in terms of collaborative behaviours and social interactions. For example, Snibbe and Raffle (2009) found that people spent most of their time concentrating on their own personal interactions rather than collaborating. Marshall et al (2008) found that providing equal access to controllers resulted in more equal shares in active participation, resulting in quieter people being able to participate non-verbally.

The exhibits studied in this PhD research supported equality in various ways. Supporting equality does not only mean providing multiple controllers, it relates more generally to constituting equality regarding the chance to influence the activity. Most commonly, the exhibits encouraged non-manipulative actions, such as guiding other visitors' interactions. At RD in particular, influence over the activity requires the companions to consideration of others' opinions and how they relate to interaction. Equality can also be considered as the level influence each group member has over digital content. For example, group members may be given equal access to controllers which manipulate digital content in different ways but how **frequently** different controllers are used during the activity contributes to equality between group members. This is an open question for future research and design to consider if the interaction should or shouldn't be equal and how equality can be supported at interactive exhibits.

Equality between groups members can consists of involvement in physical interaction and involvement in the activity in non-physical ways. In order to establish a sense of equality between companions it is therefore important explore the following aspects:

- Consider providing controllers which function in the same way between companions, such as controllers with equal functionality (RD)(PP4N).
- Consider physically distributing controllers (GD)(FF)(RD).
- Consider companions having an equal lack of control over the interaction (RD) (PP4N). An equal **lack of control** can guide the group to focus on the one thing, limiting parallel independent activities, prompt visitors to coordinate with companions.

- Consider removing a single control point or vantage point, as this could limit dominating behaviours. This could be achieved by moving the single desirable controller between people during the task (RD) (GD) (FF). A suggestion for future research is to focus on situations where passing over controllers is initiated by the exhibit or by visitors.
- Consider having a desirable controller which moves unpredictably. The unpredictable movement supports equality in that visitors can't easily dominate.
- Consider how people's opinions can contribute to the interaction (RD) This can support equality in that everyone has an opinion it is not based on possessing a controller or being in a position of power.

Equality is an essential component of a visitor's museum experience if that experience is to be social. When only one person is able to interact with an exhibit, any other members of the group are limited to watching their companion interact, and there are limited opportunities for socially engagement (Heath and Vom Lehn, 2010), (Heath and Vom Lehn, 2008), (Hindmarsh et al., 2005). In such situations, one person often easily to dominates the interaction, while others passively wait for a turn. Having recognised this issue, some installations support multiple companions by giving companions equal access to controllers, such as multitouch interactive surfaces or individual competition-based screens (Snibbe and Raffle, 2009), (Hornecker, 2016). While this provision leads to a sense of equality for all to interact, it does not necessarily foster social interaction between companions. Often, this provision results in companions interacting independently alongside one another, rather than collectively. A careful examination of the value of equality, and the ways which it can be supported are key areas for further and possibly fruitful exploration in the field of museum design. For example, creating privileged vantage points to view or interact with content in some cases helps group social interactions, turn taking and sharing interaction with the exhibit (GD).

This research has illustrated that there are several ways in which museum exhibits can support equality beyond the provision of multiple controllers. Furthermore, it has also evidenced that there are situations in which carefully designed inequality, such as privileged vantage points, may trigger shared social interactions, by encouraging visitors to share information and help each other.

Supporting Inclusion in the overarching activity

The final theme is inclusion, which concerns supporting companions' 'inclusion', co-participation and involvement in each other's interactions and activities. Previous research has highlighted that supporting multiple visitors' interaction while at the same time engendering social interaction between companions can be challenging (Hindmarsh et al., 2005), (Ludvigsen, 2005), (Benford et al., 2000). As such, some researchers have advocated for a shift in focus from interaction with the exhibit to visitors engaging in face to face activities during interaction, 'co-participation (Heath and Vom Lehn, 2010) and collective action (Ludvigsen, 2005). Often, at exhibits where only one person can interact, visitors may co-participate by engaging in discussions around the content, providing advice, suggestions of what to do or explaining to others (Patel et al., 2016).

In all of the studies considered in this thesis, visitors influenced their companions' interaction with the exhibit by guiding others to interact with controllers, or making comments and suggestions. In effect, these behaviours are ways that companions engaged socially and sought to include themselves in the activity at these exhibits. Inclusion in this way was more common at some exhibits than at others. As such, it is evident that distributed control at exhibits can be structure in ways which increase the likelihood of companions influencing the interaction with the exhibit without directly using controllers. I call this **indirect control**.

In the case of GD, information on when to use the controllers was separated from the relevant controllers. Consequently, visitors relayed this information to their companions and guided their interaction with the relevant controllers, thus indirectly controlling the exhibit. Similarly, at RD, visitors instructed their companions to use or not use certain controllers. In response, their companions listened to and acted upon these suggestions. Future exhibits could explore this space by investigating situations where companions can indirectly control exhibits through social interaction between companions.

As museums continue to explore possibilities with new technologies, there is a need to question how to support the social dimension of companions visiting museums. The research demonstrates that to take part in activities at interactive exhibits, visitors do not necessarily have to engage in hands-on interaction. As argued in this section, co-participation and inclusion refers to the overall activity and includes indirect means of control. Moreover, these indirect actions are important to consider as they often effectively elicit social interaction. As such, it is crucial we consider how to support such activities. This aligns with Ludvigsen's model where people don't directly interact but may engage with others who are interacting with the exhibit (Ludvigsen, 2005). Future designs could explore this approach further, through structures which required or encourage companions to exert indirect control over the activity, through verbal communication. For example, to encourage indirect action of this kind, designs could stagger stages of interaction, and encourage visitors to transition between different ways of participating in an activity. Rather than thinking only about multi-user interaction, we should furthermore consider how to support indirect control, such as situations where companions engage in 'what to do' discussions. This includes making choices together, influencing each other's interaction, guiding each other's interaction, turning attention to others interaction. Overall, in order to adequately evaluate and bolster SSI at exhibits, it is essential to consider how to support indirect control as well as multi-user interaction.

7.3 Research Limitations

The present research had a number of limitations. Firstly, study 1 utilised a slightly different methodology to study 2 and study 3, as it did not involve the general public in the wild, and instead invited people into a curtained off area. While this methodological distinction was unavoidable, owing the centre's child protection policies, subsequent studies could not be accurately compared to study 1. Secondly, the research was based on only a small number of installations owing to a limited available time frame the scope of the research. As such the results provided should be considered a starting point for larger scale investigations into similar subject matter, based on a wider range of exhibit configurations. Finally, the research focused specifically on tangible hybrid interactive museum exhibits and the social dimension of museum visitors' experience, again owing to the scope of the research. As such, the findings have not been compared to existing research regarding other museum technologies and social contexts. Such a comparison would greatly illuminate the role of THIMEs in supporting social and shared interaction.

7.4 Future Work

This research has raised a number of questions and highlighted a range of directions for future research. Firstly, three identified strategies for distributing control – physical distribution, functional distribution and temporal distribution – could be explored and challenged in future research concerned with shared social interaction between companions, both in the fields of HCI and museum studies. My work has provided some examples of how these three strategies work to distribute control between people, but it would be beneficial to develop research which generates further examples, possibly from different exhibit structures and configurations. Such research would further aid the design of future exhibits. Other areas which warrant further research include individuals' transitions between active and non-active participation, and the development of design considerations for social interaction in the museum context which explores specific types of social interaction and roles individuals assume in group interaction with such exhibits.

In the context of museums, I argue it is important to reconceptualise groups' interaction with exhibits as a holistic interaction, which also involves a range of human-to-human interactions, rather only human-to-exhibit interaction. As such, focusing on designing for an interplay of visitors interaction with their companions and with the exhibit, rather than focusing on individuals in a group interacting with the exhibit. As demonstrated in the analysis of GD and RD, exhibits can support situations in which companions influence other people's interactions with the exhibit, thereby fostering social engagement between companions. While HCI usually focuses on users' direct manipulative interaction with digital content, in the context of the museum experience, we are concerned with the ongoing activities and experiences with these technologies, and how these relate more widely to visitors' behaviours and social experiences. The present research aimed to address this gap in knowledge. In this way, the present research offers a similar perspective to research on large-scale public interfaces, which has focused on the spectator experience observing others interacting (Reeves et al. 2007, Williamson et al. 2014) rather than the experience of individuals interacting with the exhibits.

Conducting the research of this thesis has raised a number of further and new questions that could not be addressed within the scope of the PhD. For example, while I personally developed some of the installations, the development process was not the focus of this thesis and as such was not discussed in any great detail. Similarly, the thesis did not extensively examine the collaborative processes which I engaged in with the museums for which these exhibits were developed. By working together with several institutions, much was learned about the requirements of heritage institutions, how to collaborate with them, about the constraints that guide the design of exhibits; but these issues were not the focus of this thesis. One avenue for future research which I marked based on this PhD research is to explore: What trade-offs cultural heritage professionals are faced with when considering different technologies and design strategies for interactive exhibits to support various visitor experiences at interactives exhibits?

In addition, this research has touched upon a number of points outside of the scope of the research, highlighting potential opportunities for future research such as:

- What other configurations of installations might be useful to investigate?
- Are there other dimensions apart from the distribution of control to consider?
- What is the relationship between the intensity of interaction and social interactions?
- How a range of structured to unstructured (open) interactive exhibits relate to companions shared social interactions?
- What is the role time pressure plays in certain situations, contexts or experiences?

7.5 Conclusions

The research addresses a question that over the past decade or decades various researchers have been dealing with: how to design exhibits that facilitate or engender interaction? This PhD research has responded to the question by developing a number of design considerations relating to how control is distributed between groups at interactive installations, which has been discussed throughout the thesis.

This research has focused specifically on 1) how control of digital content is distributed between companions at THIMEs with several physical objects acting as controllers; and, 2) the various ways which people share interaction with the exhibit and socially interact with companions while using THIMEs. The research has been motivated by a desire to aid designs which support interaction with tangible user interfaces and foster visitors' social interaction with companions.

Control over an exhibit can be distributed in ways that enable multiple companions to participate in the interaction. One of the primary contributions of this research is a reconceptualisation of the relationship between TUIs and social interaction, through a specific consideration of how control is distributed across groups. The physical distribution of control and the various ways this is achieved has been widely considered in existing literature (Hornecker et al., 2007), and therefore can be viewed as a baseline for work undertaken in this thesis. The present research has built upon this work, and outlined a range of other mechanisms for distributing control. Overall, through an examination of three case studies, three main strategies for distribution of control using controllers were identified: the physical, or where controllers are located; the temporal, or when controllers are used; and the functional, or what controllers do. The research also discussed a range of strategies or mechanisms for distribution of control in relation to physical tangible controllers which encourage social and shared interaction between companions. This research has started to unpack how control is distributed as a result of three overarching mechanisms (temporal, functional and physical distribution) and provides a number of case studies. This is a relatively under-explored way of thinking about how exhibits may encourage and support companions shared and social interactions.

This research contributes to two different areas for consideration in investigating social and shared behaviours at THIMES. Firstly, the qualities of the exhibits themselves, and secondly, the behaviours which these qualities supported or were likely to support. The research has also identified the three main strategies for distributing control – physical, temporal and functional – as an area which should be explored in future research.

The nature of this research is interdisciplinary and as such contributes to various fields which include: adding to the limited research focusing on companions social shared interaction in public spaces, unpacking the distribution of control which questions previous limitations in how control for groups and companions might be viewed and establishing a range of design considerations for future products and installation designers and researchers to consider when concerned with supporting the social context of companions interaction. These contributions add to the fields of Human-computer interaction, museum and visitors' studies and product and interaction design.

In summary, this research demonstrates how control is distributed physically, how control is distributed temporally and how control is distributed functionally. It identified how these three strategies can be used and combined to enable, encourage or enforce SSI. The factors and behaviours detailed in the thesis suggest that certain designs can support and even elicit companions to engage socially and to share their interaction with interactive exhibits.

7.6 Final Personal Statement

The purpose of this research was not to identify the perfect exhibit which entirely satisfies both museum curators and visitors. While conducting this research, I have learned that such exhibits rarely exist and exercising empathy for others goals often comes into account. Instead, this research conducted a detailed investigation of a range of installations in order to understand how different features support and hinder our social interactions with each other as museum visitors. In doing so, I hope I have developed a framework to aid in the development of future exhibits which support museum visitors to focus on others and productively share their experiences while using interactive museum exhibits.

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Appendices

Appendix A

A.1 Participation Information sheet from Study 1

Photography/Video Consent Form

University of Strathclyde

I hereby declare that I am willing to take part in a study that supports the research for Loraine Clarke's PhD in Computer and Information Science Department at the University of Strathclyde. The nature of this study is as follows:

Title: Painting Patterns for Nature Exhibition Piece at the Ark Cultural Centre for Children

Purpose: The study is to being carried out to reflect on the experience children and parents have while interacting with the 'Painting Patterns for Nature' exhibition piece as part of Loraine Clarke's PhD research. The study will focus on the positive and negative experience people may have with the installation.

Participation in the study will involve the group interacting with the exhibition piece as they would naturally while being video and audio recorded. The study is looking to video a completely natural interaction with the piece so the children (and you) will be free to leave the piece naturally, in their/your own time. I would like you to explore the piece as you would with any of the pieces in the Ark. More than likely if the children get bored or spot something else of interest in the exhibition they will leave the piece. In general though, most children normally spend around 20 to 30 minutes at the piece depending on how interested they are in it.

I have been fully briefed on the nature of this study and my role in it and was given the opportunity to ask questions before agreeing to participate.

Full confidentiality in terms of the details of my participation and my personal details is guaranteed. Some or all of the data (verbal and behavioural) may be used (quoted) in the report on the evaluation for illustrative purposes.

There is no obligation on me or the children to participate in this study. Our participation in this study <u>may</u> be recorded by video or audio means and I agree to this. However, should any party feel uncomfortable with being recorded at any time, we can request that all recording equipment be switched off. I am entitled to copies of all recordings made during the session if I wish to have them.

Thank you for taking part in this study.

Please sign below to confirm that you agree to photograph/video footage of you or your child being used in any PhD related research publications.

Name of child if applicable ....Date of Birth....................
(please print)

Your Name (please print)...Date............................

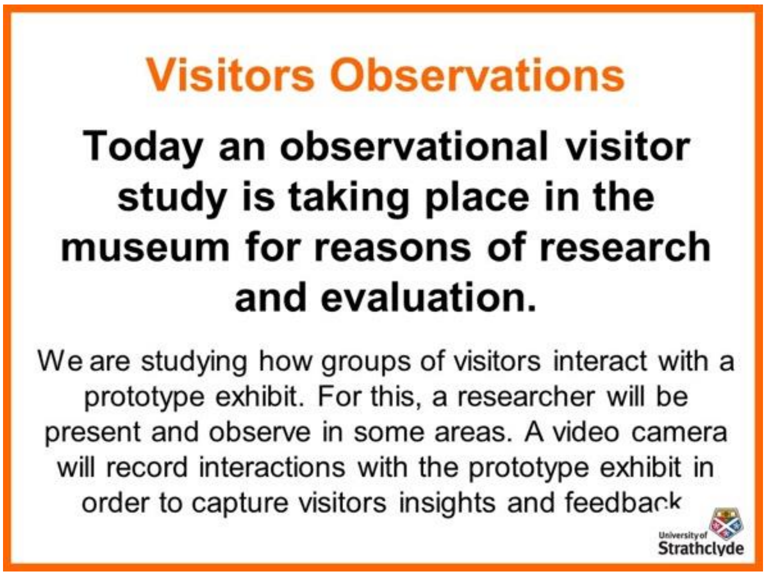
Address...Postcode..........................

Telephone number or email address...

Your signature*..Child/Young Person signature*..

Appendix B

B.1 Video Based Research Signage from Study 2 and Study 3



Appendix C

C.1 Co-Design workshop with Museum Visitors for Study 3. Consent Form

University of Strathclyde Science

DEPARTMENT OF COMPUTER & INFORMATION SCIENCES

Participant Information Sheet for Co-Design Workshop

Name of department: Computer and Information Sciences
Title of the study: Co-Design Workshop, Help Design a New Interactive Exhibit

Introduction
Loraine Clarke is a PhD student from the Computer and Information Science Department at the University of Strathclyde. Loraine is running a co-design workshop today to involve visitors in the design of new interactive exhibits for the 'Razzle Dazzle ships' story. The workshop involves visitors (mainly teenagers) giving feedback on ideas we have for a new interactive exhibit and designing new interactive exhibits together.

Loraine's research focuses on interactive exhibits in museums. The research questions what visitors like, dislike and find interesting about aspects of interactive exhibits. In particular, Loraine is studying how the exhibits help groups to share experiences and socialise together.

What is the purpose of this investigation?
The purpose of the co-design workshop is to involve visitors in helping to design a new interactive exhibits for the story of Razzle Dazzle ships. We'd like to involve visitors in the design to include what they like, dislike or find interesting in the design of the exhibit.

Do you have to take part?
Taking part in the workshop is on a voluntary basis. There is no obligation to participate in this study and you are free to withdraw your participation at any time without having to explain or give a reason.

What the workshop involves?
The workshop puts you in the role of a designer, where you can change parts of the exhibit to explore ideas, suit what you like or dislike. Your role in this study is that of a co-designer, helping to design the exhibit is and the experience during it's usage. The workshop involves visitors giving feedback and re-designing ideas we have about the story of Razzle Dazzle ships in World War 1.

The workshop should take 20 to 30 minutes. The structure of the workshop is:

1) Introduction to the Story of Razzle Dazzle Ships during World War 1
2) Highlight point of interest in the Razzle Dazzle Story
3) Introduction to the Interactive exhibit idea
4) Play & Re-design interactive exhibit model
5) Visitors are invited to discuss their ideas and fill out a feedback from

At certain stages of the workshop you will be required to perform the 'thinking aloud' method where you verbalise what you are thinking as you are exploring the exhibit or designing. A demonstration of this will be given to you by the facilitator.

Your participation in this workshop <u>may</u> be recorded by notes, photographs or audio recording by the researcher. However, should you feel uncomfortable with being recorded at any time, you can request that all recording equipment be switched off. You are entitled to copies of all recordings made during the session if you wish to have them.

The place of useful learning

THE | UK Entrepreneurial University of the Year 2013/14
UK University of the Year 2012/13

University of Strathclyde Science

DEPARTMENT OF COMPUTER & INFORMATION SCIENCES

Why have you been invited to take part?
We are inviting teenagers or groups from the general public to participate in the workshop so we can involve the viewpoint of everyday visitors in the design of the exhibits, rather than only museum professionals or museum enthusiast. We are looking for teenagers in particular as the ideas we've developed are aimed at the target audience teenagers but are suitable for all ages and groups.

What happens to the information in the project?
The information will be used for research, design, educational and publications relating to Loraine Clarke's PhD research.

All photographs will be edited so faces are covered. An example of this is shown below:

Example anonymised image

No personal, private or confidential information is required from you. Full confidentiality in terms of the details of your participation and your personal details are guaranteed. Some or all of the data (verbal and behavioural) may be used (quoted) in a report, presentation or publication for illustrative purposes, but you shall not be identifiable from this data.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

What happens next?
If you are happy to be involved in the workshop, please sign the consent form to confirm this.

If you would not like to be involved in the workshop, thank you for your time and attention.

Researcher contact details:
Name of Researcher: Loraine Clarke
Email: loraine.clarke@strath.ac.uk

University of Strathclyde Science

DEPARTMENT OF COMPUTER & INFORMATION SCIENCES

Declaration of Consent Form for Co-Design Workshop

Name of department: **Computer and Information Sciences**
Title of the study: **Co-Design Workshop, Help Design a New Interactive Exhibit**

I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction. Yes [________] No [_______]

I understand that my participation is voluntary and that I am free to withdraw from the project at any time, without having to give a reason and without any consequences. Yes [________] No [_______]

I understand that I can withdraw my data from the study at any time. Yes [________] No [_______]

I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available. Yes [________] No [_______]

I consent to being a participant in the project Yes [________] No [_______]

I consent to being audio recorded as part of the project Yes [________] No [_______]

I consent to being photographed as part of the project Yes [________] No [_______]

I consent to the information gathered during the workshop being used for research, design, educational and publications relating to Loraine Clarke's PhD research. Yes [________] No [_______]

Thank you for taking part in the workshop. We hope you enjoy it.

Name of child if applicable ....Date of Birth..................

(please print)

Your Name (please print)..Date..........................

Email address (if you'd like to be contacted for future workshops or studies) ....

....

Your signature*...Child/Young Person signature*....................................

*If the child is under 16 years of age, the parent/guardian must sign
If 12 years or over, but under 16, both the child and his/her parent/guardian must sign
If 16 years or over, only the individual must sign

N.B: the contact details you provide will only be used in the event of a query regarding research. Your details will not be used for any other purpose and will not be disclosed to anyone outside of Culture & Sport Glasgow or the University of Strathclyde.

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C.2 Co-Design Worksheet for workshop with Museum Staff for Study 3

DEPARTMENT OF COMPUTER & INFORMATION SCIENCES

University of Strathclyde Science

Co-Design & Feedback Workshop Participant Information Sheet on a New Interactive Exhibit for Razzle Dazzle Ships

Name of department: Computer and Information Sciences
Title of the study: Co-Design and Feedback Workshop

Introduction
Imagine this is an idea for a new interactive exhibit presented to you by a company. We'd like to get your feedback on the idea including suggestions on what you'd like to change or re-design before the exhibit gets fully implemented. We've outlined some questions for discussion with the group or to fill in on the sheets, as you wish.

Idea being discussed: Painting Exhibit [________] Box Wall Exhibit [________]

Questions:

What is your first impression of the exhibit?

What problems can you see with this exhibit?

What do you like about the exhibit?

What do you find interesting?

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Do you have any concerns about the daily running of this exhibit?

What do you dislike about the exhibit?

What you think of this idea?

Are there things you would like to change about the exhibit before it is implemented? Any ideas for re-design or changes?

DEPARTMENT OF COMPUTER & INFORMATION SCIENCES

University of Strathclyde Science

What behaviours do you imagine happening at this exhibit?

What do you think about the content presented on the exhibit?

Would you like to give any other comments or feedback?

Thank you for your time and feedback

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C.3 Post Interaction questionnaire with semantic differentials for Study 3

University of Strathclyde Glasgow

Razzle Dazzle Prototype Museum Exhibit Feedback

1) What is your age?

□ under 8	□ 8-10	□ 11-13	□ 14-16	□ 17-19
□ 20-24	□ 25-34	□ 35-44	□ 45-64	□ 65+

2) Gender

□ Female □ Male

3) I generally visit museums

□ 4 or more times a year
□ 2 to 3 times a year
□ once a year
□ rarely or less than once a year

4) The exhibit was ....

difficult to use O—O—O—O—O—O—O simple to use

hard to know what to do O—O—O—O—O—O—O easy to know what to do

confusing O—O—O—O—O—O—O clear

boring O—O—O—O—O—O—O entertaining

passive O—O—O—O—O—O—O active

5) When I was using the exhibit I felt.........

uninterested O—O—O—O—O—O—O interested

calm O—O—O—O—O—O—O excited

unsociable O—O—O—O—O—O—O sociable

unhappy O—O—O—O—O—O—O happy

frustrated O—O—O—O—O—O—O satisfied

disappointed O—O—O—O—O—O—O delighted

Date: Time: Post it colour:

6) The content (ie. Words, pictures, story etc) was...............................

uninteresting ○—○—○—○—○—○—○ interesting

trivial ○—○—○—○—○—○—○ serious

useless ○—○—○—○—○—○—○ informative

confusing ○—○—○—○—○—○—○ easy to understand

7) When I was using the exhibit I worked with others ....

not at all ○—○—○—○—○—○—○ all the time

half of the time

Date: Time: Post it colour: