# How Did That Interactive Make You Feel?

Towards a framework

for evaluating the emotional and sensory experience of

next generation in-gallery technology.

Thesis submitted for the degree of

Doctor of Philosophy

at the University of Leicester

by

Jingyu Peng

School of Museum Studies

University of Leicester

November 2019

How Did That Interactive Make You Feel?

Towards a framework for evaluating the emotional and sensory experience of next generation in-gallery technology

by Jingyu Peng

## Abstract

This thesis explores a different way of researching and analysing in-gallery digital media. It attempts to understand how visitors feel sensorily and emotionally during the experience of interacting with in-gallery digital media, and to provide the basis of a workable framework to measure these experiences. The work is inspired by both the 'sensory turn' in museum studies (that has aimed to uncover a comprehensive understanding of these feelings and sensory engagement), and the arrival of new emerging formats of in-gallery digital technology (that are more likely to involve multi-sensory, highly immersive and shared experience). The thesis investigates how to measure visitors' experience with in-gallery technologies from a brand-new perspective, beyond the traditional models of usability and learning – and into, instead, emotion and sensation.

The research was conducted at the National Space Centre, Leicester (UK), testing the effectiveness of traditional tools in visitor studies and exploring the appropriateness of new evaluative methods. A series of methods were tested in three evaluative design cycles, each including a combination of interviews, questionnaires, 'think-aloud' methods and physiological measurement. Based on the results of measuring sensation and emotion within three different settings within the case study museum (each representing a different format of digital technology), the thesis not only offers a practical guide to museums, but proposes six core principles on approaching this new framework for evaluative design: *differentiate*; *expand*; *combine*; *extend*; *contextualise*; and *scale*.

The findings of the research are intended to highlight the importance of adopting a time-based, non-verbal and non-filtered understanding and measurement of experience. Ultimately, however, the thesis identifies not only the importance of understanding in sensory and emotional terms the impact of digitally created environments on visitor experience, but also the value of using a new set of theoretical informants and theoretical foundations for digital heritage and museum studies research.

# Acknowledgements

This thesis was made possible through the support and guidance of many people, and I am very grateful to each of them.

First of all, I would like to extend my heartfelt thanks to my supervisor, Professor Ross Parry for his insightful guidance and tremendous encouragement at every stage of the journey. I would also like to thank my second supervisor, Dr Giasemi Vavoula for her helpful advice and suggestions.

The research would not have been possible without the support and help of the National Space Centre in Leicester. I am extremely appreciative of the support from Kevin Yates, Gareth Dennis, Gareth Howell, Dan Kendall and the Space Crew. I would also like to thank all visitors who participated in this study, and offered their time and shared their thoughts about their museum visit.

I would especially like to thank Professor Effie Law at the Department of Informatics for her key insights and suggestions for further reading, which greatly enhanced my understanding of user experience methodology.

I also wish to thank my colleagues and staff members at the School of Museum Studies, especially Dr Sheila Watson and Dr Ceri Jones for sharing their expertise; Yahao Wang, Amornchat Sermcheep, Dr Yon Jai Kim and Sumi Kim for their encouragement, and special thanks to Christine Cheesman and Bob Ahluwalia for their help. Without them, this research would not have been possible.

Additionally, I would like to thank Dr Amy Hetherington for proofreading the whole thesis; Minjie Gao, Cesare Cuzzola and Jenni Hunt for their comments; and Zhongnan Qian, Dr Zhiyong Li and Dr Fulong Li for their valuable advice.

Finally, I would like to thank my dearest parents, Renjie and Yan, for their love and care throughout the completion of this journey, and unfailingly support both in the good and bad times. This thesis is dedicated to you.

# Table of Contents

# List of Figures

## List of Tables

# Chapter 1  Introduction

On a Thursday afternoon in the Palace Museum, Beijing, a family make their way into the Duan Men Digital Gallery. As they pass by the digital treasury on the multi-touch interactive wall that displays 3D models of a hundred pieces of imperial treasure, the girl grips her father's hand and points to the screen wall, saying, 'Oh wow, that vase looks amazing.' Then, they stop in front of the screen wall, the father selects and zooms in on the 3D model displayed on the screen and shows the girl how to view different angles of the precious ceramic vase from Qin dynasty. This may look like an ordinary scene in museums, however, the experiences they really had were special and unique. It is about physically being inside a six hundred year old historical palace, facing a massive multi-touch screen, interacting with the screen wall by touching and swiping and having a shared experience with their family.

How does the museum know the mixed feelings visitors might have while interacting with in-gallery digital media like this, an experience that mixes pleasure and excitement, and combines visual enjoyment and the sense of touch. How does the museum know different people's experience with the technology, if they feel the same or there is a lot of variation? How does the museum know the change of feeling from the first walk inside the room to the moment when visitors are attracted by interactives? The technology they use is immersive, social and multi-sensory, and this poses problems for the evaluation tools that we currently use which, up to now, have tended to focus much more on measuring learning impact and usability. And yet today, museums are increasingly more interested in the actual experience visitors have, in particular, the sensory and emotional experience.

It is these challenges of understanding multi-sensory, immersive and social experiences with new technology, these contradictions of traditional tools built around the classic evaluation perspective and new tasks of measuring emotions and sensations of interacting with digital technology that this thesis confronts.

## 1.1 Research Question

Informed by the sensory turn in museum studies, this thesis is an intellectual exercise in exploring a different way of researching and analysing in-gallery digital media. This thesis attempts to understand how visitors feel sensorily and emotionally during the experience of interacting with in-gallery digital media and to provide the basis of a workable framework to measure these experiences. To identify a new set of assumptions, terms and elements that might together be the start of new evaluative framework for understanding visitors' in-gallery experiences (particularly their senses and emotions) of digital interactives.

The research aims to form the basis of a new framework to evaluate the application of digital technology through the impact created by emerging technology and digital environments on human senses and feelings. The hypothesis allows us to shift the emphasis of our conversations away from learning and the usability of technology, instead towards much more open discussion considering sensations and emotions. The thesis endeavours to meet this aim by posing (and centring) the following questions:

1. What are the sensory and emotional experiences of visitors in their interactive experience with digital technology in museums?
2. How can museums access and measure the experiences visitors have?
3. What are the elements needed for a framework to evaluate this experience?

The thesis will answer these questions (about a more sensory approach to the discussion of, and evaluation of digital interactives) through a series of enquires: understanding the senses and emotions in a museum context, identifying the characteristics of new in-gallery technology, and reviewing the classic perspective and methods of evaluating technology in museums. Based on the key museological, technological and evaluative contexts of current practice, this research conducted evaluative interventions in the National Space Centre, UK, to test the effectiveness of evaluation methods. Three digital installations in the institution have been chosen as examples of the immersive, multi-sensory and multi-user nature of the new wave of in-gallery technologies emerging in museums today.

In short, this thesis attempts to develop discussions from the traditional discourses around 'learning' and 'usability' (that have tended to frame approaches to evaluation of technology), towards new considerations around 'sensation' and 'emotion'. It tries to provide new museological lenses to form the basis of new framework to evaluate the impact of emerging digital media on sensations and emotions in exhibition settings.

The findings demonstrate that we need to think about combining, expending, differentiating, extending, contextualising and scaling our methods in ways that allow us to accommodate not just different types of new in-gallery digital experiences, but also allow for different institutional and resource settings. In addition to testing the effectiveness of using traditional evaluation methods, and to explore the usefulness of new methods for measuring sensory and emotional experience with in-gallery technology, this research intended to highlight the importance of adopting a time-based, non-verbal and non-filtered understanding and measurement of experience. Ultimately, the thesis identifies not only the importance of understanding in sensory and emotional terms the impact of digitally created environments on visitor experience, but also the value of using a new set of theoretical informants and theoretical foundations for digital heritage and museum studies research.

## 1.2 Research Context

This thesis is informed by (and contributes to) a number of areas of museum studies and museum practice. This research is built on the combination of three areas: museum technology, evaluation methods, and sensations and emotions. These three areas and the overlapping parts shown in the Venn diagram (Figure 1.1) formed the theoretical framework of this research.

It acknowledges (and hopes to extend) visitor studies research into the realm of exploring the sensations and emotions of museum visits. It is squarely located in continuing museological interest in the 'sensory turn' and 'emotional turn'. In particular, it aims to expand the discourse that we currently have around digital technology by understanding the impacts of digital technology from the sensory and emotional perspective. Equally, it attempts to make an important, substantive contribution to the evolving and maturing of digital heritage. It aims to identify the key trends and characteristics in technological development and to understand the influence of these for museums and their visitors. And yet, it is also a practical exercise of evaluative design which focuses on evaluating in-gallery technology and measuring sensations and emotions from a multi-disciplinary perspective.

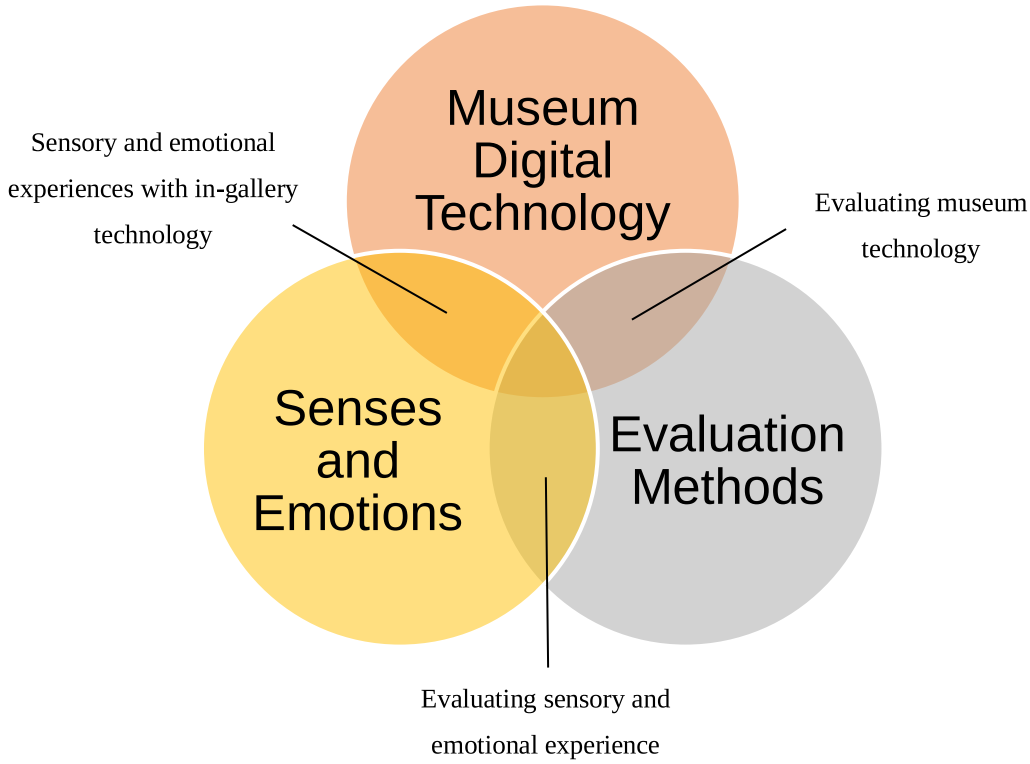



*Figure 1.1 Theoretical framework of the research.*

Firstly, the research is inspired by the trend of the 'sensory turn' in academic study (which has aimed to recover a comprehensive understanding of the body and senses), and the 'emotional turn' (which values the role of emotions in interpretation and narratives). These now offer us a brand-new perspective of understanding museum visiting experience. The definition of senses varies from discipline to discipline, including the common understanding of the five senses that can date back to 200 BCE (Sorabji, 1971), and the exteroceptive senses and interoceptive senses which come from the neuroscience perspective. Similarly, the definition of emotions varies a lot from scholar to scholar. The common way of defining emotions includes the basic and discrete view and the dimensional view of emotions (Panksepp and Biven, 2012), as well as the shared and universal view of emotions and the constructivist approach that values cultural influences (Tarlow, 2012). Acknowledging these differences, the thesis discusses what does the sensory and emotional experience mean in this research in Chapter 2.

Influenced by the trend of re-thinking and re-analysing the human body and senses, and the development of sensory studies, scholars in museum studies are starting to address issues of sensory engagement. For the visual sense, based on the research of visual perception; Casile and Ticini (2014) bring up implications for museums special design and Zeki (1999) points out the connection of art and the human visual system. For the sense of touch, we see scholars such as Pye (2008), Black (2005), Chatterjee (2008), Levent and McRainey (2014) and Candlin (2010) discussing the power of touch through object handling and how this assists learning in museums. Additionally, we also start to see scholars in museum studies investigating the senses of sound, smell and taste (Drobnick, 2005 & 2014; Stevenson, 2009; Voegelin, 2014; Cluett, 2014).

Beyond physical sensations, visitors' emotions and feelings during their visit have also been explored in recent studies. In museum studies, Tyson (2008) examined the possibility of using emotions as a tool to assist interpretation; Modlin et al. (2011) viewed museum experience as an emotive journey; Rodehn (2018) examined emotions in museum guided tours and its value for pedagogy strategies; Witcomb's (2013) research viewed emotions in the context of learning and interpretation; and Watson (2016) looked at the emotions in museum storytelling.

Poignantly, just as museum studies writing has been affected by this turn to emotion and to the senses, we have also seen the arrival of emerging formats of in-gallery digital technology. Situated in this normative and 'postdigital' era, for museum visitors, digital media in museums is not something 'new' and 'unfamiliar', but is becoming increasingly normalized and more importantly, is a part of what they expect (Parry, 2013). In recent years, new technologies such as VR, AR, 3D printing, and multi-touch technology have been coming into museums. And more recently, the Palace Museum in Beijing and the National Palace Museum in Taipei have started to explore the possibility of integrating 5G technology in the museum visiting experience.

These technological developments offer various possibilities that allow museums to create more diverse experiences. Instead of simply pressing a button or clicking a mouse, visitors' experiences with in-gallery digital media have become more immersive, multi-sensory and in some cases, may create a shared, social and interactive experience for visitors. The thesis reviews technology watch reports, including the CFM's annual forecasting report the TrendsWatch and the New Media Consortium

Horizon Reports Museum Edition; as well as museum websites, journal articles, insiders' blogs and industry publications, to identify and summarize key overarching trends and patterns in the adoption of new digital media in museums (see Chapter 3).

This is media that is more likely to involve multi-sensory experiences, enable manipulation by multiple users, and create highly immersive viewing experiences – all of which questions the appropriateness of our classic set of existing evaluation tools. We are left questioning whether our classic visitor studies toolset is effective enough for measuring user experiences of the new wave of in-gallery technology; especially measuring experiences from the new perspective of sensations and emotions.

In order to seek responses to these questions, the thesis reviews the evaluation of technology in museums. Important frameworks built for museum technology including the M3 model (Vavoula and Sharples, 2009), a three-level framework that evaluates learning with mobile devices; the Digital Engagement Framework (Visser and Richardson, 2013) a model for evaluating online audience engagement; the MUSEUMTECH Model (Damala et al., 2019), which is a comprehensive framework for museum technology in three dimensions: museum professionals, the institution and the visitor; and the 'One by One' project and its aim to develop a 'Framework of Museum Digital Literacy' to support museums' needs of digital transformation and build digital confidence. [1]

There are two main groups of evaluation studies of museum technology. One group focuses on evaluating learning and the education value of the technology, including the evaluation of the Myartspace which examined the effectiveness of connecting learning in the classroom and museum (Vavoula et al., 2009); research in the Deutsches Museum which used a designed-based approach to investigate how digital media supports museum learning (Hauser et al., 2009); Economou and Pujol Tost (2007) discuss the educational value of VR in cultural heritage settings. The other group of studies evaluate the usability and utility of the technology, such as the evaluation of the Augmented Representation of Cultural Objects which investigated whether the system meet the needs of museum curators (Sylaiou et al., 2008); Stoica et al. (2005) conduced

[1] One by One. Available at: https://one-by-one.uk/2018/03/16/phase-5-summary/ (Accessed: 06 November 2019)

a usability evaluation of using handheld devices; Cunliffe et al. (2007) measured whether museum web sites meet the needs of their users; Kidd et al., (2011) discussed the interactivity and usability of multi-touch interfaces in museums.

However, until very recently, there has been a limited amount of research that has focused on understanding the emotional and sensory aspect of experience with museum digital technology. We see the study of Damala et al. (2016) which investigated the multi-sensory, tangible and embodied experiences in museum visits and the EMOTIVE project (Economou et al., 2018) that aims to investigate emotional engagement and digital storytelling in cultural heritage settings. Yet, the sensory and emotional aspects of digital technology need to be further explored and be understood more deeply and holistically.

## 1.3 Theoretical Approach

This research builds theoretically on and is inspired by previous research in museum studies. To begin with, this research follows the increasing interest in visitor research in museum studies in the past few decades. Besides, the research also aims to find out how emerging technologies engage different human senses, and users' multi-sensory experiences with it. Therefore, it is fair to say that the research follows the sensory turn, which has brought many discussions in museum studies in recent years. Apart from the sensory turn, the research also builds on Kevin Robin's understanding of digital media and research from various academic areas.

The idea of 'dis-illusioning' the virtual, proposed by Kevin Robins (1996a), a researcher in sociology, social theory and communication and media studies, is a key premise of my research. There is a common view of taking the virtual environment as an alternative of reality and actual space. There can be tendency for the virtual environment and virtual worlds to be described in somewhat exaggerated terms (such as 'utopian' and 'illusion'), emphasising how a user might experience these as having been transported to another world. However, Robins (1996b) has pointed out that the virtual world is not separate from (or an alternative of) the real world, but instead is a part of it. Consequently, our experience in the virtual environment should also be part of our reality and part of the present (Robins, 1996a).

Indeed, nowadays, technology is able to create a detailed and vivid virtual environment that delivers a multi-sensory and immersive experience. When it comes to the question of whether the high quality of virtual experience could be seen as an alternative to reality, however, the answer is probably no. This research is inspired by the idea of 'dis-illusioning' the virtual, and takes it as a part of our reality. Although the high level of immersion offered by technology could make users feel that they are in 'another world', this is only a part of their experience. They can still feel that they are standing on the ground or sitting on a chair, their skin can feel the temperature, or they can sense their body and movement, they can hear their own voice when they are talking, they can communicate with others. Thus, it is inaccurate to view the virtual as isolated from the reality. Despite that, the virtual experience has become increasingly open to experiences of de-realisation and de-localisation, in order to have a clear understanding of reality, personal and collective lives, we should dis-illusion and de-mythologise the virtual culture (Robins, 1996b). For the research presented in this thesis, museums should value and research the sensory experience and senses, partially because of the sensory turn in museum studies and the multi-sensory characterises of new technology, but also because of the link between virtual environment and reality. The digitally-created environment in museums is a form of virtual environment; visitors' experiences with it are not only about the immersion, but also about the sense of physically being inside that space. It is about what we see, what we hear, what we touch and how our body feels.

This thesis relates to a number of scholarly areas. Within museum studies, my research is related to three areas in particular. Firstly, it relates to current research on embodiment, sensory experience and the growing literature around emotion. Secondly, the project relates to visitor studies, in particular the effective development of tools and methods. The third area is digital heritage, in particular the design and influence of digital interactives in exhibitions.

Outside of museum studies, the research attempts to forge new theoretical alignments between different subjects. The work intentionally brings together ideas and theories from various disciplines. Media studies formed the premises of the study, including the idea of 'dis-illusioning' the virtual and the theory of social shaping of technology. Philosophy provided fundamental supports for understanding the human body and the basic senses. From marketing studies, the study learned the evaluation methods that combine verbal and non-verbal instruments. Psychology research provided inspiration with the idea of 'two selves' (Kahneman, 2010), the different dimensions of emotion, and measurement scales such as the Semantic Differentiate Scale (Mehrabian and Russell, 1974), and the Self-Assessment Manikin (Bradley and Lang, 1994). Tourism studies showed the elicitation framework of evaluating sensory experience. Neuroscience and psychophysiological research, provided theoretical insights for measuring emotions through physiological responses and a practical guide for conducting physiological measurements. These scholarly areas provided a multi-disciplinary perspective for this research and played a significant role in the process of improving the evaluative design that is at the heart of it.

## 1.4 Methodological Approach

The research works towards a new evaluation framework for emerging in-gallery digital media in museums and aims to measure the impact of technology on visitors' feelings and experiences. Drawing from literature in museum studies, cultural studies, media studies and digital media theory, the research mixed qualitative and quantitative research techniques, using a single case study approach.

This research is an exercise in evaluative design. After the initial design and prototype of the evaluative methods, the methods were tested and improved through iterative cycles. Therefore, the fieldwork consists of a pilot study and three design cycles. The main purpose of the pilot study is to familiarise myself with the environment and to practice data collection techniques. After the pilot, the main fieldwork is divided into three cycles; in each design cycle, different methods are tested. Cycle one was conducted in 2017, cycle two was tested in early 2018 and the last cycle was finished at the end of 2018.

A combination of qualitative and quantitative methods were used for data collection, including questionnaires, interviews, observation, 'think-aloud' methods and physiological measurements. Questionnaire participants were randomly-selected adult visitors who had interacted or would interact with selected digital installations. To generate an overall understanding of the visitors' experience of in-gallery digital technology and their feelings, the researcher recruited participants from different genders and age groups, using qualitative data collection methods.

This research is evidence-based practice. Unlike many projects (and theses) of this kind, the research methodology (and tools) are actually the point of study – the thesis is attempting to research ‘research methods’. Therefore, rather than selecting a theoretical framework or hypothesis, the improvements in each cycle rely on the evidence of findings and limitations found through the evaluative design process. In the first cycle of the evaluative design, the research began by testing traditional methods: interview, questionnaire and observations. These three methods are considered the most frequently used methods in various evaluation studies in the museum setting (Foster, 2008; Nelson and Cohn, 2015). Then, the second and third design cycles were refined based on practical evidence collected and analysed from the first round and inspired by theoretical concepts. To be more specific, reflection on the limitations of each method, the evolution from Cycle 1 to Cycle 2, is inspired by Kahneman’s (2011) idea of ‘two selves’ and considers the temporal dimension of evaluation tools. The transformation from Cycle 2 to Cycle 3 is enlightened by the three types of emotional output systems pointed out by Bradley and Lang (2002) and explores the possibility of measuring affective experience through physiometric methods. These theories and concepts that illuminated the evaluative design are not pre-selected, but guided by the requirements of con-current and non-filtered measurements of affective and sensory experience identified in the design process.

The field research was conducted in collaboration with the National Space Centre (NSC), Leicester, UK. NSC is a museum and the UK’s largest attraction in space science and astronomy. This institution was particularly suitable as a case study for a number of reasons. First, it has various formats of in-gallery interactives, meaning it provides an ideal environment for testing different types of technology in museums. Secondly, the in-house studio (NSC Creative) specialises in designing immersive projects for theme parks and museums, which means that the institution has strong support to make sure their digital content and design is up-to-date. Thirdly, the NSC is an institution that is keen to examine its interactivity, and which therefore, allowed this research to explore various possibilities of evaluation methods.

The Sir Patrick Moore Planetarium, Venus Simulator and Interactive Table were selected as examples of this new generation of in-gallery technologies, as they represent the highly immersive, multi-sensory and multi-user nature of new digital interactives respectively. The Sir Patrick Moore Planetarium is a 360-degree full-dome planetarium, the largest planetarium in the UK. The planetarium show chosen to conduct the research is called 'We Are Stars!' and it tells the story of the Universe from its birth to today. This 25-minute immersive cinema experience is suitable for both children and adults who want to explore the secret of cosmic chemistry. The second example is the simulator in the Immersive Venus Exhibit. With wrap-around projections on a curved wall and a surround sound system, visitors in the Venus Simulator pretend to be in an airship with destination Venus. It takes visitors on a journey through the Venusian atmosphere and includes a vibrating floor developed by the in-house design team which adds the final touch to this multi-sensory experience and creates the physical feeling of landing. The Space Oddities gallery exhibits unusual objects and tells interesting but lesser-known parts of space history. The interactive table in this gallery allows up to six individuals or small groups to find out about the stories of objects, space oddities and astronauts and related information at the same time, it is a place for exploring, communication and sharing. A more detailed description of the NSC and the three selected digital exhibits is presented in Chapter 5.

The research is compliant with the University's Code of Ethics on Research Conduct and ethical approval letters were received to pursue the fieldwork. An information sheet of the research project was provided during the process, and participants of interviews, 'think-aloud' sessions and physiological measurements have read and signed the informed consent form. At the NSC, Kevin Yates (Head of Exhibition and Design) gave formal consent to the researcher to collect data in the exhibition space and use the data for academic purposes.

To protect participants' privacy, all data collected in this research has been stored in computers with passwords, and information such as participant's full name and address was not collected (Singleton and Straits, 1999). This research has followed a strict ethics code and handled participants' information with caution. The research has involved testing of different types of methods in the process of evaluative design. As the different methods were applied in the three design cycles, the study made three separate ethics applications with careful consideration of data collection methods in each cycle. In addition, the researcher updated the information sheet and consent forms with reference to the new data protection regulations (GDPR) in June 2018. More detailed information on research ethics can be found in Chapters 5 and 7.

## 1.5 Thesis Structure

The thesis is divided into a further eight chapters and organised into three main parts: three contextualising chapters which review the academic turn to senses and emotions, new technological trends and characteristics of new in-gallery digital interactives, and evaluation perspectives and methods; three analytical chapters, which explain the design, process and findings in the three cycles of evaluative design; and then finally two synthesising and concluding chapters that map the progress of the three cycles, synthesise core principles and practical guidelines and summarize the thesis.

Our discussion begins, therefore, with the three context chapters, Chapter 2 to Chapter 4, which set out to review literature in the three areas: the sensory turn and emotional turn, museum technology, and evaluation methods. These chapters map the academic interest in re-thinking the role of senses and emotions in museums and heritage; the trend of the new and emerging forms of museum technology; and the discussion of methods used in evaluations of museum interactives, respectively.

To be more specific, Chapter 2 consists of two sections: the first section examines the trend to re-think the human body and senses in social sciences and humanities in the past few decades, and how this sensory turn influences museum studies. Then, the second section discusses research in museum studies that address issues around emotions and emotional experience in museums and heritage sites. This chapter sets out the research interests of senses and emotions in museum studies, which are pre-conditions and inspirations of this doctoral research.

Then, starting with a discussion of the relationship between museums and technology, Chapter 3 provides an overview of new and emerging technologies that have been adopted in museums and other cultural institutions in recent years. Additionally, by viewing examples of digital exhibits in museums worldwide, this chapter identifies three key characteristics of new in-gallery technology: multi-sensory, immersive and multi-user. These new characteristics are so different from the traditional formats of interactives, therefore, it poses challenges of our understanding of visitors' experience and the traditional tools evaluating them.

Following these new questions and challenges explored in Chapter 3, Chapter 4 focuses on reviewing evaluation studies of technology in museums, particularly of in-gallery digital interactives. This chapter points out the two classic and three common perspectives of tools used in evaluating in-gallery technology. Consequently, it raises questions of whether our tools and frameworks that have been built to measure usability and learning outcomes of technology are still effective for measuring sensations and emotions.

Therefore, to test the effectiveness of traditional tools and develop new tools for measuring sensory and emotional experiences with digital interactives, the three following chapters describe the iterative process of evaluative design in the NSC. Chapter 5 introduces the case study site and the three digital installations that have been selected as examples of the new generation of in-gallery technology. The first cycle of evaluative design starts with the triptych of common tools: questionnaire, interview and observation. The results of Cycle 1 suggest improvements needed to capture sensory feedback and reveals that using the classic tools may not be enough to reflect the change of feelings over time.

With the aim of collecting time-based feedback and reflecting the temporal dimension in the interacting experience, Chapter 6 starts with introducing Kahneman's idea of the 'two selves', with the differences between 'remembering self' and 'experiencing self' leading to improvement; from measuring memory-based experience alone in Cycle 1 to collecting both memory-based and momentary-based feedback in Cycle 2. Chapter 7 shows the results of using a second version of the questionnaire, that enabled the researcher to collect more detailed sensory responses and capture emotions in three stages of the activity; the 'think-aloud' method that allows participants to report their feelings in real-time; and the improved observational coding methods of video recording. The main changes in Cycle 2 include the improvement of visualization, data analysis and data collection techniques.

However, in both Cycle 1 and Cycle 2, the methods only measures visitor's feelings via language and behaviour output systems, as a result, the feedback collected are either 'filtered' by participants or by the observer. Therefore, Chapter 7 explores the possibility of measuring emotions through physiological responses. Physiological measurement is rarely used in visitor studies and in museum settings. The chapter starts with a review of various types of physiological measurements and analyses the requirements for conducing physiological measurements in museums. This chapter shares findings from using a GSR device measuring electrodermal activities (an indicator of arousal) with the three formats of in-gallery technology.

Following the three analytical chapters, Chapter 7 maps the process of evaluative design, summarizes methods applied in each cycle and points out characteristics and requirements (for participant, research and organization) of each method. Significantly, based on the findings from the three cycles, Chapter 7 identifies strengthens and limitations of the tested methods and proposes six core principles for a framework of measuring sensory and emotional experiences with in-gallery technology. Chapter 8 discusses the original contribution of this thesis from practical, conceptual and methodological approaches. The thesis ends with a discussion reflecting on how sensations and emotions with digital technology should be evaluated in the future, to enable a holistic understanding of the museum visiting experience.

# Chapter 2 Sensations and Emotions in Museums

## 2.1 Introduction

Today, rather than simply being places that collect, store, conserve and exhibit artefacts, museums are playing a more important role for both society and individuals by offering visitors the opportunity to learn, discover, communicate and be entertained. Although collecting remains a crucial part of museums' focus, museums have begun to pay more attention to their visitors.

Following the trend of researching visitor experiences, this chapter aims to address issues related to visitors' sensory and emotional experience during their visits. This chapter specifically focuses on two topics: sensations and emotions.

The chapter starts with the sensory turn, a turn that aims to form a comprehensive understanding in humanities and social sensory studies, and how this turn towards sensory influences museums studies. As well as a brief summary of the developments and changes of understanding about human senses and sensory experience, it introduces ideas from Connor (2005), Howes (1991, 2005) and Classen (2005a, 2005b). Following the discussion around the definition of human senses, this section is further divided into sub-sessions, addressing questions around the senses of sight and touch and the less-explored senses of sound, smell and taste in museums, by drawing upon descriptions of the sensory system, sensory reception and applying features of the senses with practices in the museum field. Next, the embodiment and embodied museum experience are discussed in order to answer questions of what is embodiment and how to generate an embodied museum experience.

Secondly, the chapter goes beyond physical sensations and explores visitors' emotions and feelings during their visit. This section shares debates in different academic areas of the definition of emotion and shares examples of how emotion is employed in museums to assist interpretation of 'dark' history and design educational activities. In the end, a brief summary about multi-sensory and emotional museum experience is addressed, based on the previous discussion.

## 2.2 The Senses and Sensory Turn

In the social science and humanities, there has been a distinctive trend during the last thirty years, which aims to establish a comprehensive understanding of the human body and its senses (Uchida and Peng, 2019). In the field of sensory studies, two important scholars should be noted: anthropologist David Howes and historian Constance Classen, as many works in this area are published or inspired by them. Their influential books, such as *Varieties of Sensory Experience* (Howes, 1991), *Empire of the Senses* (Howes, 2005) and *The Book of Touch* (Classen, 2005b) provide a new perspective to the understanding of senses and sensorium. Some of the literature is directly related to museum studies. For instance, in a chapter of Classen's (2005b) book, it describes that in the late seventeenth and eighteenth centuries, some visitors would touch, smell or even taste exhibited artefacts.

Driven by the prosperity of sensory studies, museum professionals started to consider the role of senses in the museum setting. The most salient trend in this re-understanding senses is the re-introduction of the importance of touch and object handling. Museums' policy of touch has changed greatly when looking back to the history of museums. Classen and Howes (2006) documented the early museums in the seventeenth and eighteenth century, where museums were sites for hands-on experiences that encouraged object handling. This tactile engagement opened to curators and visitors was mainly because of four reasons: touch was viewed as a means of learning; to enhance aesthetic appreciation and enjoyment of art objects, as it provided access to appreciate the beauty of artefacts different from visual experience; to feel a sensation of intimacy with the creator of the touched or handled objects; and fourthly, to increase the sense of wellbeing (Howes, 2014).

However, in the nineteenth century, when museums were starting to open access for the general public, object handling experience in museums became more and more rare. It was not only because of the possibility of damaging objects but, more importantly, because of the change of view on the aesthetic apparition and the therapeutic value that was understood as no long believable. During this time, rather than 'feel' the objects through touch, it was encouraged for visitors to view museum objects from a distance and with new ways of looking, walking and feeling (Rees Leah, 2012).

Museum visitors were purely spectators until the late twentieth century, when museums started to create more interactive and engaging experiences. From then on, we start to re-think the meaning of touch in the museum environment. The handling of objects in museums witnessed an expansion of its impact and has become an effective way to increase participation and accessibility (Pye, 2008). Notably, in this re-introduction of touch, Chatterjee and her colleagues research on the therapeutic value of museum object handling are one of the major developments. In addition to this rehabilitation of touch, it also contributed to the introduction of other bodily senses, as well as the less explored senses of smell and taste.

While museum practitioners and scholars started to re-think the sensory experience of touch and other sensations, the development of technology, especially media technology, has also made museums more sensory-engaging and interactive spaces (the evidence of this is discussed in Chapter 3).

Sensation is an essential part of our experience and reality (Bull et al., 2006). The way visitors experience museums is through a combination of sensory, aesthetic, intellectual, and social factors. The predictions that the human brain makes, and the nature of experience inherently involve sensory stimuli from multiple channels (Pascual-Leone and Hamilton, 2001). In this context, museums should take the opportunity to consider shaping and creating a multi-sensory visiting experience that combines visual, auditory, olfactory, tactile interactions and other senses (Pascual-Leone et al., 2005). The numerous publications addressing visitors' sensory engagement in museums and cultural institutions not only encourages museums to go beyond the visual and create a more accessible experience for all, but also provides us with a new lens to understand and evaluate the museum experience.  Understanding the sensory experience in museums is crucial for a better understanding of the overall visiting experience.

From a common and traditional perspective, there are five physical senses of human beings, which are: sight, smell, taste, touch, and hearing. This way of distinguishing and defining senses dates back to 200 BCE, when the ancient Greek philosopher Aristotle identified these five senses in his book *De Anima* (Sorabji, 1971). In this book, Aristotle set separate chapters for each of these senses and defined them according to their objects (Sorabji, 1971). Although this is a generally accepted way to divide physical senses, there are also other ways of classification. In the book *Les cinq sens*, Serres demonstrated his understanding of five senses and named them ‘Voiles’, ‘Boîtes’, ‘Tables’, ‘Visite’ and ‘Joie’ (Connor, 2005). Here, voiles stood for the sense with skin and touch; boîtes meant hearing; tables described the conjoined sense of taste and smell; visite and joie represented vision and bodily joy respectively (Connor, 2005). From the neuroscience perspective, sensation could be generated by stimuli arising from both internal and external environment (Purves, et al., 2012). Human senses include not only the basic five senses of haptic, visual, auditive, olfactory and gustatory perception, but also proprioception (perception of the body and its parts), visceroception (perception of the viscera) and nociception (perception of pain), as well as the perception of body movements, temperature, communicated affective expression and signals etc. (Mausfeld, 2013).

Based upon different views on the classification of human senses, this thesis mainly follows the traditional understanding of senses. Additional to the five senses, it combines the types of experiences that might evolve in a museum visit and the neuroscience perspective of sensations (such as the sense of movement and temperature), as well as the embodiment. The following sections discuss senses in six categories: touch, hearing, smell, taste, sight and embodiment, and try to understand these senses within the trend of sensory turn and analyse how museums engage sensory experience by using examples of museum practice.

### 2.2.1 Sight

When modern museums emerged in the nineteenth century, they were viewed by some as a ‘museum of sight’ (Classen and Howes, 2006). Most of our museum experiences are largely relying on sight. The leading position of sight among other senses has been established for a long time. Every day, thousands of people travel a long distance to visit museums and art galleries in order to view their collections, exhibitions and sometimes their architectures all over the world. In this type of visiting experience, our visual sense plays a crucial role. Although individuals’ experience, cultural background and their understanding of artefacts or exhibits might differ and the value of every piece of art work might vary, individuals’ visual perception of artefacts and their neuronal and cognitive processes of aesthetics are similar to each other.

Figuring out the process of how human visual systems work is considered to be one of the most important achievements of the field of modern neuroscience, as reviewed by Chalupa and Werner (2003), and there are many scholars contributing to this great achievement. The explanation that compares the process of the visual perception system to the process of how a camera recreates a picture of the scene in front of you is probably the most popular comparison. However, after several decades of neuroscience research in this area, this way of explaining it has been proven to be a false analogy (Casile and Ticini, 2014). This is mainly because of the fact that our goal of a visual system is only to interpret and identify certain features and essential components of what we see instead of 'taking a picture' that captures every detail in a second (Casile and Ticini, 2014).

There are also studies that have proven that the unique characteristics of visual systems influences our experience with art. The connection between the way the human brain processes visual information and artworks was first explored by Margaret Livingstone (1988), who proposed that artists seemed to realise the principle of how our brain processes visual information. Pointillism is a good example that supports Livingstone's suggestion. As in our visual system, colour information is elaborated at lower spatial resolution compared to shape information. This phenomenon also exists in pointillist painting (Livingstone, 1988). When we observe a pointillist painting at a close distance, we can see every single dot, but if we stand from a comparatively far distance, what we see is an overall picture instead of individual dots. Besides this, Semir Zeki, who coined the term 'neuroaesthetics', also pointed out the connection of art and the visual system. Zeki (1999) points out that all visual art, which is perceived throughout a visual system, must obey the rules of the visual system. He suggests that features like colour, motion and shape should be in the leading role of visual arts, as those features have primacy in our visual perception (Zeki, 1999). Additionally, visual perception of artistic work is not merely about seeing, as the artistic content that contains emotions is also able to evoke the response of our body (Freedberg and Gallese, 2007).

Based on the understanding of the visual perception and the connection between the visual system and works of art, Casile and Ticini (2014) bring up three potential implications for museums and art exhibitions. The first potential implication for exhibitions is spatial layout. The spatial arrangement of artefacts will influence visitors' perception and degree of embodiment (Casile and Ticini, 2014). To be more specific, when objects are close to a viewer's body, the visual representations together with action representations will produce a higher degree of embodiment than objects displayed far away. The second suggestion to museum and art exhibitions is about perspective. Related neuroscience studies show that observing actions from first-person perspective generates strong activation of sensory-motion cortex (Maeda, et al., 2002). Thirdly, the individual preference of art will influence the process of aesthetic appraisal (Casile and Ticini, 2014).

The visual sense of the visitor is the dominant sense when they visit a museum and view its collections. However, our visual experience in museums is not only about viewing artefacts or artworks, it also covers reading labels, leaflets, panels and maps, supporting and enabling visitors to engage with interactives and taking part in various activities. Yet, our museum experience nowadays is something more than seeing, it is also about touch, hearing, smell, taste, and even feel, by our whole body.

### 2.2.2 Touch

One of the most remarkable elements of the sensory turn in museum studies is the revival of the sense of touch (Howes, 2014). Drawing from results obtained in four workshops ('Touch and the Value of Object Handling') funded by the Arts and Humanities Research Council, Chatterjee's (2008) edited volume addresses issues related to different aspects of touch in museums (particularly in history and art museums) and other cultural institutions. Through discussions about the history of touch in museums, neuroscience perspectives on touch, touch and emotions, new digital technologies for enhancing tactile experiences, and the social and therapeutic value of touch, the book examines the importance of touch in museums from a wide range of perspectives. Similarly, as expressed in the academic conference 'Magic Touch' (held at the Institute of Archaeology, University of London), Pye (2008) also approaches the power of touch from different angles, including history, science, technology and visitors' experience. Other scholars have approached the subject from specific perspectives, such as Black (2005), who reintroduced touch as a means to enhance visitors' engagement through object handling, and Candlin (2010) who discussed the museological interpretations of touch in art history and historical museum practice.

Recent research proved that the sensory inputs of the human brain are not separate, and haptic inputs and visual inputs are interactive (Lacey and Sathian, 2014). In fact, from a neuroscience perspective, touch and sight are similar in several ways. Firstly, both of them are view-dependent (Peissig and Tarr, 2007; Lacey and Sathian, 2011). Both touch and sight can acquire information of the object and even provide ‘views’ from different angles (Peissig and Tarr, 2007). Additionally, vision and touch share a common method of object identification (Lacey and Sathian, 2014). Generally speaking, individuals have their own preferences and display two types of visual imagery: object imagery and spatial imagery (Kozhevnikov et al., 2002). This is same with haptic representation (Lacey et al., 2011). In both vision and touch, object imagers tend to generate an image with the actual appearance of an object, such as shape and texture, and spatial images tend to focus more on objects’ spatial relations (Lacey et al., 2011). Moreover, haptic and visual shape processing involves the same cortical area called the later occipital complex (LOC) (Lacey et al., 2011). Initially, LOC was considered as the visual object-selective region (Malach et al., 1995), but later studies found that part of LOC is responsible for both visual and haptic shape perception (Amedi et al., 2001).

These exciting findings in neuroscience studies may enlighten museum practice and help to increasing accessibility, enhance visitor’s engagement and improve the overall visiting experience. By touching, people can receive information about shape, texture and spatial relations of objects. The ability of human brains to form haptic images makes it possible for blind people and people with low vision to engage with art works and historical artefacts. The Art inSight programme at MoMA is an example of helping visitors with visual impairments using tactile experience. This programme launched in 2005 and is open to the general public (McGee and Rosenberg, 2014). It includes activities like touching sculptures, creating objects with white paper clay, and sometimes, when the first two activities are unavailable, MoMA provided objects related to the art-making process for participants to touch and handle (McGee and Rosenberg, 2014). Through this programme, participants get the chance to ‘see’ objects without visual involvement and develop a greater understanding of art and the art-making processes.

Besides this, touch in museums promotes deeper understanding and increases participation. The Material Lab at MoMA is a case that successfully employs tactile experience to increase visitor's engagement, especially for family visitors. In the Material Lab, the museum has designed many activities. In 'Discovery Boxes', visitors are invited to discover various materials like velvet, rubber and paint though touching and handling (McGee and Rosenberg, 2014). In the art-making station, participants get hands-on experience of the art-making process, including sculpture, assemblage, drawing and many others. After running the programme for eighteen months, survey results indicated that about 96 per cent of visitors thought the Lab had a positive influence on their museum experience. 84 per cent of them felt that through touch they were given a chance to explore materials and to understand the art works in MoMA better (McGee and Rosenberg, 2014). One adult participant commented that, 'Art is no longer just a spectator sport but something that all can participate in' (McGee and Rosenberg, 2014: 52).

Moreover, touch is also a method for museums to improve satisfaction and pleasure in the visiting experience. The exhibition 'Touch and the Enjoyment of Sculpture: Exploring the Appeal of Renaissance Statuettes' in the Walters Art Museum is an example of an exhibition designed for improving visitors' satisfaction through touching. In this exhibit, visitors were offered replicas of small bronze statuettes that are displayed in the exhibition and allowed to touch and handle them, and in the end, they were asked to provide feedback on this tactile experience (Levent and McRainey, 2014). The results show how the tactile experience with statuettes rewarded them with pleasure, and as a result, encouraged the Walters Art Museum to try and design more exhibitions with touchable objects.

### 2.2.3 Less-explored Senses

Compared to the notion of touch, other non-visual senses are less explored in the field of museum studies, with fewer scholars addressing issues of sound, smell, taste and embodiment. A critical resource for understanding sensory stimulation in museums (especially in terms of the less-explored senses) is the edited volume by Levent and Pascual-Leone (2014). In this book, Cluett (2014) examines the role of sound in experiencing artworks and the history and development of sound as a curatorial theme from 1966 to contemporary exhibitions. Voegelin (2014) offers practical guidance and examples on visiting museums and galleries through sound-walking. For 'the forgotten sense' (Stevenson, 2014) of smell, Drobnick (2014) presents curatorial examples of exhibiting scent-based artworks and points out challenges for curating olfactory artworks. From the neuroscience perspective, Stevenson (2014) analyses the use of smell in exhibitions and how it could enhance the museum experience thanks to the unusual physiological characteristics of smell. In regard to the sense of taste, a sense that is rarely researched in the museum context, Mihalache (2014) highlights its connection to culture and education and its potential for creating a more participatory and multisensory museum experience.

#### 2.2.3.1 Sound

Sound is everywhere. The invisible materiality of sound exists throughout our museum experience. The museum is a visual place that displays artefacts and artworks, but at the same time it is also an audio environment, as it is full of various sounds: footsteps, visitors' whispers, children's laugher, tour guides' speaking, audio guides, background music, noise of an air conditioner and many others.

Our understanding of sound perception and the auditory system mainly begins in the previous century, especially in the later couple of decades. In brief, the function of our auditory system begins with receiving sound input into the ear canal and then the cochlea (Arnott and Alain, 2014). Next, the sound will go up through various subcortical nuclei and, in the end, travel to the right and left auditory cortices in the temporal lobes of our brain (Arnott and Alain, 2014). The sound perception, in a nutshell, is the registration of sound vibration in the brain generated by surrounding air pressure (Plomp, 2013). The knowledge of the human auditory system is implicated in modern museum practice, for example, in the design of activities targeted to special groups of audiences by taking into consideration the frequency of sound. Keeping sound information for general visitors below 8,000 Hz, while exhibition or activities specially designed for young people could accept higher frequencies between 15,000 to 20,000 Hz (Arnott and Alain, 2014).

Sound plays different roles in museums to shape visitors' auditory experience. The initial acknowledgement of sound in the curatorial theme begins around 1965/1966 (Cluett, 2014). During that time, composers and choreographers began to be aware of the visual potential of their works. After that, around 1980, a growing number of curators began to choose to express their theme with sound. In this stage, sound started to become a curatorial focus (Cluett, 2014). However, for the last stage of the development of sound as a curatorial theme, a specific time that marks the beginning is hard to define. Generally speaking, it is the time when curators and practitioners became more aware of the idea of ‘sound art’ (Cluett, 2014).

Despite being from a curatorial theme, sounds such as background music, also serves as a key component for exhibitions. This is largely because of the connection between sound and emotions. As pointed out by Arnott and Alain (2014), the auditory input that is received by our brain has direct effect on our emotions. Music is an ideal example to explain the connection between sound input and emotions. Music with fast tempo and major chords is more likely to be associated with ‘happy’, while slow tempo and minor chords is considered more related to ‘sad’ (Pallesen et al., 2005).

#### 2.2.3.2 Smell

A multi-sensory museum experience might be linked with visual experiences of viewing paintings and photographs, tactile experiences of touching and feeling the shape of sculptures and texture of materials, auditory experiences of hearing music and various other sounds. However, our olfactory experience in museums is more likely to be ignored. Around 1980, institutions such as living historical sites, heritage centres, museums and other tourist attractions began to make their exhibitions more diversified by engaging with a variety of smells (Drobnick, 2005).

Scent could be employed in various ways. Sometimes, it is used in activities that directly engage our nose (Stevenson, 2014). For example, the Museum of Perfume in Paris and the International Museum of Perfume in Paris are fully focused on displaying smells; visitors have the opportunity to smell many types of perfumes from past to present. Sometimes, it involves our nose in a less obvious way, such as museums that are devoted to food and drink. This is because when we eat or drink, a certain part of our flavour reception comes from the retronasal olfaction (Rozin, 1982). Therefore, in the food museums, such as National Mustard Museum, the European Bread Museum and Musee du Vin, while visitors enjoy food or drink, the experience also involve the sense of smell.

The sense of smell is not only restricted in the museums of perfume, food or drink, as there are also other examples of special exhibitions designed with a focus on olfactory sensorium. For example, in the display called 'Tate Sensorium' at Tate Britain, visitors can 'see' art with bespoke fragrances created by a selection of perfumers.[2] Additionally, with the increasing notice of the sense of smell in museums, in some cases, smell is used as a final touch to recreate special atmospheres and employed as part of a wider multimodal exhibition (Stevenson, 2014). For instance, Jorvik Viking Centre[3] in York utilizes Viking-age smells in its exhibition and Madame Tussaud's Wax Museum in London uses special effects to recreate the smells of London life.

Our olfactory system is unique, and some features of it may have implications for museum researchers and professionals. The first feature we should noticed is, when we notice a smell, we will adapt to the new smell rapidly (Stevenson, 2014). For example, when we first enter a room, the smell of the space is noticeable, however, after we stay in that room for a while, we will adapt to that smell, which means the smell will no longer be as perceivable. Therefore, when museums design exhibitions that employ smell, one challenge is how to manage the subtle change of smell and keep the smell noticeable for visitors as they move through the space.

The second feature would be connection between smell and our memory. When a new combination of individual chemicals is detected by our olfactory system, our brain will compare these incoming chemicals that are stored in the nervous system with previously stored patterns (Stevenson, 2009). Hawkes and Doty (2009) also point out that the olfactory system has close links with the brain system, which is in charge of personal memory. Thus, for museums, smell can be a tool that brings visitors back to a previous or childhood memory, or evokes memories that are associated with a specific period of time.

In addition, a certain amount of olfactory processing happens in the orbitofrontal cortex of our brain, which happens to be the part that is responsible for emotion and

---

[2] Tate. Available at: https://www.tate.org.uk/whats-on/tate-britain/display/ik-prize-2015-tate-sensorium (Accessed: 07 November 2019)
[3] Jorvik Viking Centre. Available at: https://www.jorvikvikingcentre.co.uk/press/norse-ty-niffs-historic-aroma-packages-trialled-bring-vikings-smells-home/#T2XR2Xfu9ubFV4rC.97 (Accessed: 07 November 2019)

motivation (Hawkes and Doty, 2009). This feature enables smells to evoke emotions, especially strong emotions like disgust and fear. Thus, smell could also offer the opportunity for museums to improve the emotional pungency of an exhibition (Stevenson, 2009).

2.2.3.3 Taste

Taste is considered to be the most subjective sense compared to other senses. According to Gallegos and McHoul (2006), our sense of taste is largely associated with private feelings and the judgment of good taste and bad taste is relying on our personal preference. On the other hand, taste is also a social sense (Ackerman, 1991). As pointed out by Haden (2011), taste is a tool of social differentiation that can distinguish different culture, community, group and class. This social and cultural characteristic of flavour and food, suggested the sense of taste might have pedagogical value for museums as a unique method to understanding culture and history (Mihalache, 2014).

Food and taste are always analysed under the perspective of art and aesthetics (Mihalache, 2014). The representation of taste and food in visual form is common in museums. As food has already existed in the history of art for a long time, with many paintings and other forms of artwork depicting food as a means to express pleasant, enticing and attractive feelings, as well as a tool to convey danger and terror (Mihalache, 2014). But the translation from the image of food to taste can only exist in viewers' imaginations. Presenting food in this way can inspire further thought and imagination of the flavour and taste of food as described by Korsmeyer (1999).

### 2.2.4 Embodiment

In addition to the five senses, the embodiment experience has also received increasing attention. For instance, using a historical approach, Rees Leahy (2012) analyses visitors' embodied encounter with museums by discussing theories, politics and practices of the visitor embodied experience from the eighteenth century to the present. Also, Dudley's (2009) work deals with the sensory and emotional sphere with an emphasis on the engagement with objects. Some chapters specifically mention the need for embodied sensory engagement with physical things in museums and galleries, to avoid being limited by the visual.

Before discussing the idea of embodiment in museums, one question should be answered in advance. What do we mean by embodiment? Generally speaking, embodiment is about the feeling when we are physically located in a place. Embodiment includes our visual, auditory, haptic and other senses. Apart from the five senses, embodiment should involve the feeling of the body, such as the feeling of temperature, balance and movement; as well as our emotions and feelings of the surrounding atmosphere, such as the feelings of excitement, calm and peace.

Most of our museum experiences rely on sight. The leading position of sight among other senses has been established since ancient Greek times. As argued by Heraclitus, vision is more reliable than hearing (Kleinberg-Levin, 1993). Indeed, in the traditional understanding, vision is always linked with truth and knowledge. However, our museum experience is not simply about the visual. Maurice Merleau-Ponty proposes that people come to a museum or exhibition not only to see works of art, but more importantly, they want to see the world according to those works (McGilchrist, 2009). Every masterpiece of art is an expression of the entire world by itself, and it shares multisensory links with the world. Our experience with art is multisensory, and is not restricted to visual appearance; it might also contain the sensing of sounds, texture, temperature and smells (Montagu, 1986).

Atmosphere is an important aspect in museums, and it is hard to define (Ambrose and Crispin, 2012). Why do you prefer one museum over others? Why does a particular gallery make you feel comfortable? This might be a result of its collections and displays, but it also relates to the overall atmosphere in that museum or gallery. Many elements can be used to create an atmosphere that the curator desires. For example, as mentioned in previous sections, sound and music is an important element of atmosphere, because its tempo and chords could be easily linked with individual's emotion, such as happiness and sadness. Besides this, spatial feeling, colour, layout, lighting and many other elements may influence the atmosphere of an exhibition space as well. For instance, large and empty spaces make people feel lonely, while small spaces are more likely to make someone feel cosy; exhibition spaces decorated with red tends to generate feelings of passion, while blue is always linked with calmness.

In terms of how to define and manage the relationship of our body with that of the museum, many scholars have given their suggestions. Mauss (1973) uses the term ‘bodily techniques’ to describe the rules and regulations about how to look, walk, talk, read and other behaviours in museums. Similarly, Rees Leahy (2012: 3) views the museum ‘as a site of social and corporeal practice’, and considers embodiment in museums as ‘body-space relations’ (2009: 165) and ‘triangular relationship between body-art-space’ (2009: 166). Pallasmaa (2014) points out that a museum space should appropriately manage the psychological and perceptual factors between the visitor and the object. In addition, a museum or exhibition design should try to involve the specific characteristic of the exhibits and create an embodied sense to visitors by activating multiple sensory channels (Pallasmaa, 2014).

The body in museums is a complex and elusive quest, as the feelings of our bodies come from so many different sensory channels and it might be influenced by any detail in our surroundings. As Classen (2007: 895) says:

> ‘One of the most difficult subjects for an historian to investigate is that of the corporeal practices of earlier eras. Ways of walking, eating, smelling and touching, while laden with social significance, are often so taken for granted that they are little commented on by their practitioners. It takes a very thorough observer to record the ordinary bodily motions of daily life.’

Although there are many factors and uncertainties that could affect the feeling of our bodies, one thing for sure is that the creation of embodiment of the visiting experience is something that is worth considering by museums and curators. As suggested by Pallasmaa (2014), a memorable and impressive visiting experience in museums should not solely be about learning or receiving new knowledge, it should be a journey that include body movement, sensory engagement through multiple channels, associations, imaginations and emotional engagement.

## 2.3 Emotions in Museum Experience

Museums and heritage sites could easily be filled with emotions because of their expression to identities, wellbeing and sense of place, however, as stated by Smith and Campbell (2016), emotions and similar affects in heritage and museums have often been dismissed. The ‘flat’ and ‘neutralized’ expert interpretations of the past have led to the loss of consideration of affective qualities in museological scholarship and practice.

Until the twenty-first century, the acknowledgements of emotions and affects in museum and heritage studies have begun to emerge (Wetherell et al., 2018).

Similar to the 'sensory turn', there is also an 'emotional turn' (Tarlow, 2012:170) in museum studies and many other disciplines, which has shown a specific focus on investigating and challenging the ideas around the impact of museums and heritage sites on visitors and their visiting experience through their strategies of interpretation, narrative, activities and so on (Munro, 2014). One debate in this emotional turn is around the definition of emotions. Scholars from different areas understand emotion from their own perspectives, one of the main debates is how it is connected to the cognitive ability of our brain (Watson, 2015). From this perspective, Stearns and Stearns (1985:813) explain, emotion is generated by a

> 'complex set of interactions among subjective and objective factors, mediated through neural and/or hormonal systems, which gives rise to feelings (affective experiences of pleasure or displeasure) and also general cognitive progresses toward appraising the experience'.

In short, emotions are felt, and could be defined as a brief duration response to external stimuli (de Rojas and Camarero, 2008; Logan and Reeves, 2008).

The approaches towards emotion vary from discipline to discipline, and from scholar to scholar. Generally, basic emotions and constructivism are two main approaches. As defined by Tarlow (2012:170), basic or key emotions are 'emotions that are biological in origin, shared across culture, and recognizable by universally shared facial expressions.' This approach understands emotions from the neurological and biological origin in the brain and believes all human beings have universal emotions, regardless of their cultural backgrounds. It is the view that is commonly held by psychologists and neuroscientists. For instance, the seven emotional systems identified by Panksepp and Biven (2012): SEEKING (expectancy), FEAR (anxiety), RAGE (anger), LUST (sexual excitement), CARE (nurturance), PANIC/GRIEF (sadness) and PLAY (social joy) that are controlled by subcortical regions of our brains. Also, the six core emotions which include: fear, anger, disgust, sadness, happiness and surprise, published by Ekman (1994a). Both of these systems fall into universal and basic approaches to understanding emotions. In addition, scholars who think emotions are universal might even have different views of emotional life, namely 'basic' emotions and 'dimensional' emotional life (Panksepp and Biven, 2012). The 'basic' emotions refer to specific emotions, while the dimensional view visualizes the foundation of our emotional nature using a unitary bivalent, one valence from positive to negative and a second valence from high arousal to low arousal (Panksepp and Biven, 2012).

On the other hand, the constructivist approach in emotion studies holds the belief that 'emotions are culturally constructed and constituted and that even the bodily perturbations associated with emotion are experienced in culturally determined ways' (Tarlow, 2012: 170). Therefore, unlike the psychological approach of emotions, which think emotions are shared cross-culturally, the constructivist, also called 'cultural or contextual approach' (Tarlow, 2012:171) of emotions, argues that the emotions are shaped and influenced by the cultural and social context. These two approaches are fundamentally different, as described by Tarlow (2012) they could be viewed as two poles of the spectrum of understanding emotions: one end is the psychological view point with more focus on whose emotions are expressed, while on the other end, the constructivist point of view values how emotions are being shaped. For most researchers, they develop their attitude somewhere between these two poles (Bowen, 2014).

For scholars in museum and heritage studies, as pointed out by Wetherell et al. (2018), there are three formulations for research emotions and affects. The first common standpoint of researching emotions is built upon twentieth century Western psychological theories, which is the 'basic', 'shared' and 'universal' understanding of the emotions discussed above. However, instead of purely following the psychological point of view, these theories have been further developed within the context of museum and heritage studies. To be more specific, the emotions and affects triggered by – or associated with – a heritage site or a museum object are not a fixed feeling that is shared by different audiences, but an ongoing and flexible construction of sensations, individual experiences, meanings and consequences (Wetherell et al., 2018).

The second formulation is to take a phenomenological approach. This approach focuses on the change of individuals' emotions and affects as well as the arise of these feelings (Wetherell et al., 2018). In other words, it asks questions of what these emotions are, rather than how these emotions are assembled: what triggered these emotions and what these mean for the heritage site or museum? Consequently, the main concern of this approach is the difficulty of generating deeper and insightful reckoning of the conditions and consequences that arise from emotions (Bourdieu, 1990).

The third standpoint of research in this turn to emotions and affects is thinking of it as a form of ‘unmediated intensity or excess’ (Wetherell et al., 2018). From this view, emotions and affects are a form of excess that exist in places and spaces, and these communal affects could be automatically passed or transferred to the person who passed through the space (Anderson, 2009). Therefore, walking in a heritage site or visiting a museum could then be thought of as an experience of being surrounded and unavoidably hailed by affects in that space. The three assumptions are ways that emphasise the sense making of emotions and the connections between emotions and space. These new emphasis and new questions around emotions and affects inspire us to reconsider its attachment to history, objects, identity, places and institutions.

As pointed out by Munro (2014), one of the major problems that scholars are facing when examining the affective contents in museums is the difficulty in distinguishing the theories of emotion from theories of affect. According to Watson (2018), the meaning of the term ‘affect’ might vary from discipline to discipline, and from writer to writer too. This research focus on the emotional journey with in-gallery digital media as a whole, therefore, according to Munro (2014), this suggests emotion and affect should be interchangeable in this circumstance.

Previous studies have highlighted the complexity of the emotional responses of visitors to museums and heritage sites (Crang and Tolia-Kelly, 2010; Tolia-Kelly, 2010). Crang and Tolia-Kelly (2010) point out that visitors’ feelings of museums and heritage sites are always ignored. This section tries to examine the body of literature which discusses the emotional responses in museum and heritage site visits.

Resulting from the recent attention on the affective nature of the museum visiting experience, museums are changing their traditional and didactic ways of display to new models with more possibilities and uncertainties (Gregory and Witcomb, 2007; Modlin et al., 2011). Additionally, the ‘emotional turn’ in museum studies has also led to literature that has emphasised the emotional nature of visitor interactions with museums (Schorch, 2014). In this body of literature, museums seek to bring out emotional responses in visitors.

### 2.3.1 Emotions in Museums

Emotion plays a critical role in human evolution, learning, thinking and behaviour. In addition, it is closely link to the development of our memories (Turner, 2006). Museums are places where we learn, think and feel. Although for a long time, the importance of emotion in museums and heritage sites might have been overlooked, recent studies suggest emotional experience should be noticed for the purposes of engagement and leaning. Existing studies are likely to analyse from two perspectives when investigating emotions in museums. The first perspective is to associate emotion with history, especially, the 'dark' history such as colonialism, race and war. The second one is from the perspective of emotion as a supporting element of museum education and fostering learning in museums. In this part, studies that deal with emotional issues with slavery and examples of engaging emotions to improve learning will be discussed.

Tyson's (2008) research is an example of using emotion as a tool to assist in interpretation. The study was conducted in two living history museums: Historic Fort Snelling in St. Paul, Minnesota and Conner Prairie, in Fishers, Indiana, and it demonstrates how museums deal with visitors' emotional comfort with the 'unpleasant' history of slavery. While Historic Fort Snelling's programme tried to erase the slavery history at the site, Conner Prairie created a special event called 'Follow the North Star' to fore-ground the trauma of visitors after viewing the exhibition. In this event, visitors could participate in a ninety minute role-play set in the mid-nineteenth century as fugitive slaves on Indiana's Underground Railroad. Both of the two sites, through their own ways of interpretation, achieved the goal of keeping visitors satisfied and emotionally comfortable with the history of slavery. In order to understand how these two museums delivered their interpretation strategy in more detail, the study's author conducted archival research, interviews and participant observation at the Historic Fort Snelling (Tyson, 2008). She worked in this museum for seven tourist seasons (in 1999 and 2001-2006) and in this way, she had the opportunity to experience the feeling of interpreting this part of history by herself and to gain responses from other co-workers of how these emotions were experienced. In addition, she conducted in-depth interviews with 23 employees who worked as interpreters in the museum. The interview questions were about programming, management and work conditions etc. and interviewees were asked to refer to their own experiences.

Similar to Tyson's (2008) in-depth research, Modlin, Alderman and Gentry's (2011) study of plantation house museums also involves the observation of interpreters. The research defines a tour of a plantation house museum as an 'emotive journey' (Modlin et al., 2011) and focuses on tour guides' capacity for producing empathy. The research team conducted non-intrusive participation observation. In the observation process, the team took part in the guided tour like normal visitors, and in this way, first-hand experiences of how visitors felt about the guided tour at the site could be experienced and recorded by the researchers themselves.

There are also various studies which discuss how emotions help museum education. For instance, Rodéhn (2018) proves how emotions and feelings could be used as pedagogy strategies and tools by examining what emotions do in museum guided tours. Watson (2016) chooses examples drawn from museums in the UK, Germany and Turkey and takes the history relating to slavery to explore how history museums express emotion and produce effective responses. The study aims to find out how emotion, especially notions of empathy, could assist as a tool for learning history and cultural identity. Additionally, research carried out by Witcomb (2013) is about affect, feeling and museum learning as well. The goal of this research is to find out how exhibitions apply affect in their interpretation strategy and how this experience could translate into critical forms of thinking.

In addition to the notion of emotions as tools to assist interpretation and pedagogical strategies, the role of emotions has been concerned within the body of literation around health and wellbeing. As Jermyn (2001) noted, the engagement with museums has positive impacts on individual's wellbeing; for instance, individual's self-confidence and self-esteem (Newman et al. 2005). These discussions have particularly focused on how museums could be beneficial to individuals who could be considered vulnerable or marginalized (Munro, 2013), including Chatterjee's explorations of the healing power of object handling (Chatterjee and Noble, 2009; Chatterjee et al., 2009) and Morse's investigation of the social inclusion and community participation in museum practice (Morse, 2019 & 2020).

The existing research on emotions in museum studies, at least as represented in the examples shown here, has tended to link with topics around museum interpretation education and wellbeing. For the topic of this research, however, user's emotional responses of interacting with in-gallery digital installations still remains unexplored.

## 2.4 Summary

This chapter discussed the 'sensory turn' and the 'emotional turn' which happen in the humanities and social science, and the impact for museums studies and museum practice.

The re-thinking of sensory engagement and senses improves the understanding of sensory experience in museum. Based on the findings from neuroscience, we are able to identify how the sensory system works and characteristics of each individual sense. The unique feature of senses, such as the link between smell and memory, sound and emotion, as well as touch and shape perception enable us to design more multi-sensory exhibitions and activities for diverse museum visitors. Also, the debate around what are senses, offers theoretical support and guides us to think about what is the sense and sensory experience from the perspective of museum studies. 'Sense' in this research largely follows the traditional understanding of the 'five senses' and adds the extra dimension of embodiment, which in consideration of the nature of museum visits, not only involves, sight, sound, touch, smell and taste, but equally the bodily sensations of the atmosphere, temperature and sense of balance, etc.

The investigation of ideas around emotions in heritage sites and museums began the conversation of emotional experience and emotional comfort. Visitors' emotional response to interacting with in-gallery media is an area that remains unexplored. Therefore, this research aims to form a basic understanding of the emotions and feelings that visitors might have during the experience with new media technology. Rather than focusing on the construction of emotions and affects, this research draws from psychology theories and models and asks a set of questions to map the various of emotions that might appear in these interactions with in-gallery technology.

Both the theoretical debate of various definitions in different academic disciplines and the examples of considering emotions in museums practice has brought in a new aspect of designing and understanding museum visitor experiences. This research does not focus on distinguishing the difference between affection and emotion. As for the two understandings of universally specific emotions and the dimensional view of emotional life, both of them are recognized approaches for understanding emotions, therefore, this research employs both of these two approaches, depending on the design and prototype of the evaluation tools.

Re-thinking the role of senses and emotions and the re-introduction of the importance of sensory and emotional engagement in museum and heritage studies has left questions, such as what if these sensory and emotional turns do appear in museum technology? Possible consequences could be we start to notice the senses, emotions and affects that users could have while interacting with in-gallery technology and begin to research and design tools that could be used to capture, measure and understand visitors' sensory and emotional experiences.

# Chapter 3 Characteristics of a New Generation of Museum Interactives

## 3.1 Introduction

Since the first adoption of computers in the museum sector in the 1960s, scholars and writers began to imagine and envision how digital could change and shape museums and the heritage sector, and to what extend this technology could improve the experience of future visitors (Parry, 2013). After six decades of the adoption of computers in museums, the relationship between museum and technology, the views of technology and this medium in museums has profoundly changed.

At the end of the last century, museologist Sola (1997) warned that museums should avoid applying technology for its own sake and allowing themselves to be guided by technology; this is what he termed the 'technology trap'. Instead of being guiding by technology, he argued that what was more crucial was to view technology critically and analytically. Over decades, technology has changed and reshaped museums in various aspects, from the incompatibility of technology and museum practice, to the museum nowadays, where technology plays an irreplaceable and critical role. Parry (2007) described the history of technology in museums as a history of incompatibility and compatibility. This incompatibility could be traced to the first encounters with technology in museums, which could also be seen as 'the resistance to change' and 'the shock of the new' (Parry 2007: 137) experienced by museum practitioners in 1960s. Moreover, the incompatibility also exists in many aspects, it could be found:

> 'between numerical, automated, modular, variable, and transcoded computers and a modern museum that instead (and in contrast) privileged the material world; that carried the traditions of the 'creative cabinet' and the idea of the museum as a framed experience; that emphasised fixity and stability and the authorship and authority of the curator; and that held on to institutional structures that resisted being re-shaped by a modish technology.'
>
> (Parry, 2007: 138)

While noting the incompatibility between modern museums, museum practitioners and technology in the earlier period, Parry (2007) also described the history of museum technology as a story of compatibility. This narrative is from the institutions willing to embrace the challenge. Today's museums are becoming more accommodating of computers and various digital technologies, instead of the resistance to change. This compatibility could be noticed when we examine how today's museums have been re-shaped and are continuing to be re-shaped by technology, from database to institutional structure, from research to interpretation, from collection management to audience engagement. Although technology poses challenges for museums, it has become an essential part that has 'transformative impact' (Parry 2007: 4) for the museums and heritage sectors. This relationship between museums and technology is, as described by Parry (2007: 140), 'constructively disruptive'.

Early discussions and debates around museum technology were mainly focused on the practical issues, for example, the technological aspects of operation. The subject of 'museum computing' was less exposed to the rest of museum studies, as the discussion was mainly about how to use the technology. Although there was some literature related to museum technology in the 1970s to 1990s, including the integration of communication and media theory in museum studies, Hooper-Greenhill's work on the postmuseum, and Hein's work of museum histories and futures from a philosophic perspective. However, these were not specifically focused on the area of museum computing (Parry, 2005). Until the late 1990s, new studies and research of new technology started to emerge. From this time, museum researchers and practitioners began to explore the ways of talking and thinking about museum technology (Anderson, 1997; Parry, 2007 & 2013), to understand the impact of media technology, for instance, the educational value (Teather and Wilhelm, 1999), to assist exhibition interpretation (Thomas and Mintz, 1998), and the increase in accessibility (Dierking and Falk, 1998). Since then, the body of research that constitutes museum computing has been recast as 'digital heritage', with the rise of theories and the expanding range of research topics. Especially in recent years, there are various key publications of digital heritage. Including Parry's (2013) work on the new concept of the postdigital museum, the multidisciplinary understanding of media and media-related practice in museums by Drotner et al. (2020), and Winesmith and Anderson's (2020) work that examines how technology impacts on all museum work and provides a possible vision for the museum sector through a non-traditional approach to conversations.

Unlike the 'problematic' technology for museums in the 1960s, the discourse around new technology is no longer about a choice between 'digital' and 'nondigital'. Instead, it is becoming a part of visitors' expectations and an irreplaceable and normative part of museum institutions (Parry, 2013). The concept of digital normativity in museums, according to Parry (2013: 27) describes:

> The presence of digital media in these museums to evoke the philosophical connotations that the digital s not only typical and standard, but indeed perceived to be how things ought to be, while also recognizing that these arrangements might also be situated (local) and constructed (a value judgement).

Situated in this normative and 'postdigital' (Parry, 2013: 24) phase, the relationship of museums and digital media has been reshaped. For the heritage sector and museums, digital is becoming an essential part that should be taken into consideration for policy making and embedded into organizational strategies (Parry, 2013). For scholarship, the concept of 'postdigital' takes forward the discussion and understanding of the relationship between museums and digital, the boundary between 'digital' and 'non-digital' becomes less distinct, and 'digital' has become integrated, blended and mixed into all aspects of museums. The relationship between museums and their visitors has been reset too, as digital media has enabled museums to communicate in a more responsive manner and be connected with visitors on-site and off-site. For museum visitors, digital media in museums is no longer something 'new' and 'unfamiliar', but normalized and expected (Parry, 2013).

Acknowledging this digital transformation in museums, this chapter specifically focuses on the application of in-gallery technology. This chapter reviews new and emerging formats of interactives applied in museums worldwide. The first section examines five significant technologies that have been adopted in museums in recent years or are predicted to be adopted in the near future. Secondly, by reviewing museum websites, journal articles, reports, insiders' blogs and other industry publications, the chapter also identifies and summarises key overarching trends and patterns of the adoption of new digital media in museums.

## 3.2 New Technology in Museums

This section describes five major technologies leveraged by museums in order to improve visiting experience and enhance interactivity. These technologies are: indoor positioning systems, natural user interfaces, 3D printing and scanning, augmented reality and wearable technology.

### 3.2.1 Indoor Positioning Systems

Many people are already familiar with digital mapping, such as Google Maps both online and on their smartphones. With the help of GPS (global positioning systems), people can easily find the way to shopping malls, train stations and other destinations with ease. Moreover, using location-aware applications, information of nearby restaurants, theme parks or tourist attractions can be identified immediately. Those navigation and location positioning systems that are already used outside are displaying a trend of moving into indoor areas.

Indoor positioning technology is attracting wide interest. Industry giants, including Google and Apple, are moving into this domain (Tarr, 2015). One early example of indoor maps is by Google, which launched indoor maps of buildings in the United States and Japan for Android devices starting in 2011[4]. Now, Google provides thousands of indoor maps for buildings all over the world. In the UK, Google provides indoor maps in airports, convention centres, libraries, retail and major museums, such as the British Museum, Natural History Museum, National Sea Life Centre Birmingham and Victoria and Albert Museum.

Indoor positioning technology that can provide location-based service (LBS) is particularly promising for museums. For visitors, IPS helps to solve traditional predicaments of wayfinding by sharing information with patrons (CFM, 2013). For instance, the 'Smithsonian Tours app' is an IPS app implemented by the Smithsonian Institution which provides turn-by-turn walking directions to its visitors. It is used in several of its museums. Its functions include pointing out location of artefacts inside

[4] Diep, F. (2012) *Indoor GPS' Coming to Mobile Devices in 2013*. Available at: http://www.nbcnews.com/id/46698199/ns/technology_and_science-innovation/t/indoor-gps-coming-mobile-devices/#.XdAuFlf7SUl (Accessed: 1 November 2019)

galleries and providing information of nearby metro stations.[5] Additionally, IPS also assists in creating interactive museum experiences. In the Rijksmuseum Amsterdam App, for example, visitors can create personalized visiting routes by selecting their favourite artworks in the collection first, then they can follow the guide of the navigation system's directions and view selected artworks from room to room around an interactive floor plan.[6] On the other hand, for museum themselves, location based technologies also allow museums to gather various data, such as how long visitors spend in an area and which is the most popular interactives or collections in the museum (Johnson et al., 2015).

### 3.2.2 Natural User Interface

Compard to traditional user interfaces (e.g. keyboard, mouse), Natural User Interface (NUI) refers to a user interface that is designed to use existing skills, such as speech, touch, facial and body interaction, for interacting directly with digital content (Loureiro and Rodrigues, 2011). Although the concept dates back to 1980s, when Steve Mann conducted researches on human-machine interactions, the wide adoption of NUI is only about a decade old (Johnson et al., 2013). In recent years, with the enhanced accuracy of understanding gestures, facial expressions and recognising voices (Johnson et al., 2015), users are able to control and interact with digital content using NUI more efficiently.

NUI has transformed the way museums display their artefacts and exhibits and how visitors interact with them (Johnson et al., 2015). The most common way for museums to apply NUI is through touch screen kiosks or multi-touch tables. The interactive multimedia table in a new gallery of the Ulster Museum, Belfast is an example (Figure 3.1). This table is made up of six touchscreen, which display a mixture of content including images, text, video and audio files so as to provide visitors with more detail and encourage them to explore its collections.[7] Moreover, several motion-sensing technologies have been installed in museums as well. 'Fly like a Pterosaur' in the

---

[5] The Smithsonian Institution. Available at: http://www.smithsonianmag.com/app/smithsonian-visitors-guide-app/ (Accessed: 06 November 2019)
[6] The Rijksmuseum. Available at: https://www.rijksmuseum.nl/en/discover-the-rijksmuseum-through-the-app (Accessed: 06 November 2019)
[7] Centre Screen. Available at: http://www.centrescreen.co.uk/news-post/interactive-multimedia-table-at-ulster-museum/ (Accessed: 06 November 2019)

American Museum of Natural History (Figure 3.2) is a representative example that employs motion-tracking technology. This whole-body interactive allows visitors to control the movement of a pterosaur on the screen in front of them by their body movements and to overlook the mysterious prehistory landscape from the pterosaur's perspective.[8]

*Figure 3.1 A multimedia table in a new gallery of the Ulster Museum. Source: Centre Screen.[9]*

[8] American Museum of Natural History. Available at: http://www.amnh.org/global-business-development/exhibition-intellectual-property/view-all-ip-offerings/fly-like-a-pterosaur-interactive (Accessed: 06 November 2019)

[9] Available at: http://www.centrescreen.co.uk/project-post/ulster-museum/ (Accessed: 06 November 2019)

*Figure 3.2 The 'Fly like a Pterosaur' interactive in American Museum of Natural History. Source: American Museum of Natural History.*[10]

### 3.2.3 3D Printing and Scanning

3D printing is a profoundly disruptive technology, as it is capable of mass customisation and just-in-time manufacturing, producing personalised products with a comparatively low price and changing the manufacturing process (CHIN, 2015). Traditionally, computer-controlled machines manufacture objects by removing extra parts from solid blocks of materials (CFM, 2013). However, 3D printing is an example of 'additive manufacturing' which uses a contrastive way, building an object by adding raw materials (CFM, 2013). In industry fields, 3D printers are already capable of producing various types of products, including models, jewellery, musical instruments and even food. With a high degree of precision, it is able to manufacture objects with movable parts (CHIN, 2015). The 3D medial 'bio printers' can even produce human body parts, such as organs, bones and skin given specific printing materials (CHIN, 2015). In recent years, the invention of a tabletop printer makes 3D printing technology more affordable and demonstrates a rising popularity in museums (CHIN, 2014a).

[10] Available at: http://www.amnh.org/global-business-development/exhibition-intellectual-property/view-all-ip-offerings/fly-like-a-pterosaur-interactive (Accessed: 06 November 2019)

Indeed, 3D printing technology is not only beneficial for the industry, but also applicable in museums as it can assist exhibition planning, conservation activities and provide broader access for scholars and the general public (Neely and Rozner, 2015). To be more specific, 3D-printed replicas offer alternative opportunities for museums to research or display rare or delicate objects. One example is the 3D printed replica of Thomas Hart Benton's clay maquette (Figure 3.3) used by the Peabody Essex Museum in the United States.[11] It is a coloured clay model with complicated details created by Benton before he drew a painting, which was considered too fragile for a national tour exhibit.[12] With the 3D printed maquette, visitors are able to see exactly what the original object looked like, get the chance to touch and feel the shape of it, while maintaining the condition of the original artefact. Besides this, 3D printing also contributes to enhancing visitor engagement. The 'Hands On!' tours held by the Art Institute of Chicago is a successful case of engaging adults with physical and mental challenges. The tour has thirty participants with Alzheimer's disease or other forms of dementia, as well as visitors with low vision (Neely and Rozner, 2015). By touching and holding the 3D printed objects, those visitors are able to 'see' those objects (Figure 3.4). Moreover, 3D printing technology also improves the efficiency of the restoration process dramatically, such as producing replacement parts or even recreating damaged objects (CHIN, 2015). Harvard's Semitic Museum used 3D printing successfully and recreated a two foot long ceramic lion statue which was damaged about 3300 years ago (Figure 3.5).[13]

[11] 3D printer and 3D printing news. Available at: http://www.3ders.org/articles/20150714-museum-uses-3d-printing-to-take-fragile-maquette-by-thomas-hart-benton-on-tour.html (Accessed: 06 November 2019)
[12] ibid
[13] The Harvard Gazette. Available at: http://news.harvard.edu/gazette/story/2012/12/an-ancient-statue-re-created/ (Accessed: 06 November 2019)

*Figure 3.3 The 3D printed replica of Thomas Hart Benton's clay maquette (left) and the original maquette (right). Source: 3D printer and 3D printing news.*[14]

*Figure 3.4 A visitor with sight impairment touching a 3D printed replica. (Neely and Rozner, 2015)*

*Figure 3.5 A 3D-printed component from the face of one of the ceramic lions. Source: The Harvard Gazette.*[15]

---

[14] Available at: http://www.3ders.org/articles/20150714-museum-uses-3d-printing-to-take-fragile-maquette-by-thomas-hart-benton-on-tour.html (Accessed: 06 November)

[15] Available at: http://news.harvard.edu/gazette/story/2012/12/an-ancient-statue-re-created/ (Accessed: 06 November)

However, 3D is not only for printing (CHIN, 2015). Museums nowadays have begun to discover other possibilities offered by 3D technology: 3D scanning, information sharing and some educational activities. The Art Institution of Chicago has applied an interactive activity with 3D scanning in their fifth annual Diwali Family Festival. In this programme, visitors can pose like their favourite sculpture from the Alsdorf Galleries of Southeast Asian Art, and an artist would then scan their posture into 3D printable files.[16] During this programme, visitors can watch the magic process of 3D scanning while getting a better understanding of museum collections. In addition to this, museums such as the Smithsonian and Rijksmuseum in Amsterdam have provided 3D printable templates of its collections online. As CHIN reported (2014b), the Smithsonian has digitised a large amount of artefacts online. In fact, this institution aims to digitalise approximately ten percent of its collections and share it with the public.[17]

Although there are controversial issues, such as challenges to intellectual property rights, health care and public security (CFM, 2013), the impact of 3D technology for museums, as Neely and Langer (2013) put it, is time to 'feel the museum'.

### 3.2.4 Augmented Reality

Different from virtual reality (VR) that creates a virtual world to replace the real space and real objects around the user, augmented reality (AR) supplements and enriches the real space or real objects with a virtual experience (Angeli and O'Neil, 2015). In fact, AR is not a new concept; the hype for the idea of AR began in the 1930s (Barbas et al., 2015). Until 1990, Professor Tom Caudell who worked in Boeing was the first one to coin the term 'augmented reality' to describe 'a digital display used by aircraft electricians that blended virtual graphics onto a physical reality' (Barbas et al., 2015). According to CFM (2012: 20), AR, sometimes called 'blended reality' refers to 'a set of technologies that can layer digital elements— sound, video, graphics, even touch sensations— over real world experiences via mobile device'. In the 1990s, AR was adopted by various major companies and, nowadays, it is capable of delivering an

[16] Museum3D. Available at: https://archive.artic.edu/museum3d/museum3d.artic.edu/2014/09/15/the-diwali-festival/index.html (Accessed: 06 November)
[17] Smithsonian 3D Lab. Available at: http://3d.si.edu/about (Accessed: 06 November)

augmented reality experience to the general public via their personal computers and smartphones (Johnson et al., 2011).

Generally speaking, AR technology can be divided into two types: computer vision AR and sensor AR (Boyer and Marcus, 2011). Computer vision AR refers to a computer's capability to transform a marker into a 3D object. The functionality of computer vision AR can be achieved by visiting a pre-designed webpage and scanning the marker with the computer's webcam (Boyer and Marcus, 2011). Another category of AR applications, sensor-based AR, is designed specifically for mobile devices using a positioning system. The Roman Leicester app for iPad developed by De Montfort University is an example of using sensor AR. This location-based app uses the technology to enable users to view a selection of 3D Roman buildings and artefacts, virtually reconstructing the city of Roman Leicester circa 210CE and bringing history back to life.[18]

In 2011, the NMC Horizon Report predicted that AR would become the mainstream technology in museums within two to three years (Johnson et al., 2011). After several years of development, many museums have equipped their exhibits with AR. The new Attenborough Studio lecture theatre at the Natural History Museum is an example of an in-gallery interactive exhibit with extensive use of AR (Figure 3.6). In this exhibition, the museum offers an innovative experience using interactive film. Each participant is given a tablet provided by the museum and the webcam on the tablet displays animated 3D model of extinct creatures combined with live video of their surroundings, giving users the opportunity to feel like they are walking and playing with those extinct creatures.[19] However, the application of AR is not restricted to galleries, it is used outside museums as well. Taking the 'Street Museum' app created by Museum of London as an example, which is considered to be one of the first successful cases of AR application (Figure 3.7). The application encourages viewers to discover an older London by presenting historic photographs and introductory information of buildings

---

[18] De Montfort University. Available at: http://www.romanleicester.dmu.ac.uk/app.html (Accessed: 07 November)

[19] Thomas G. (2010) *BBC Research and Development Blog.* Available at: http://www.bbc.co.uk/blogs/researchanddevelopment/2010/12/augmented-reality-film-launche.shtml (Accessed: 07 November)

and streetscapes.[20] When users hold their mobile phone up in London, the app is able to provide the view of the historical city based on the current location of the users, and give a unique perspective of the history of London.[21]

*Figure 3.6 A visitor is using a device provided by the Natural History Museum at the Attenborough Studio lecture theatre. Source: BBC Research and Development Blog.*[22]


[20] Museum of London Available at: https://www.museumoflondon.org.uk/Resources/app/Dickens_webpage/home.html (Accessed: 07 November)

[21] Ibid.

[22] Thomas G. (2010) *BBC Research and Development Blog.* Available at: http://www.bbc.co.uk/blogs/researchanddevelopment/2010/12/augmented-reality-film-launche.shtml (Accessed: 07 November)

*Figure 3.7 An example of using the 'Street Museum' app. Source: Mail Online.*[23]

### 3.2.5 Wearable Technology

The year 2014 was named the 'year of the wearable technology boom', as existing functions in PC, tablet and smartphones moved to objects that we could wear on or even in our bodies (CFM, 2015). The terms 'wearable technology', 'wearable devices', and 'wearables' all refer to electronic technologies or computers that are incorporated into items of clothing and accessories which can comfortably be worn on the body (Ching and Singh, 2016). Currently, wearable devices are widely adopted in gathering medical data and other information to do biometric analysis with. However, to understand this phase in a broader level, wearable technology can be considered as any technology that is capable of working on or in our bodies (CFM, 2015).

Since the last century, a number of ideas for wearable devices were developed and inventions were carried out. For instance, as early as 1968, Ivan Sutherland mentioned head-wear devices that can provide the user a combination of virtual and real world with the help of a half-silvered mirror display (Sutherland, 1968). About a decade later, a shoe-based computer was invented by a well-known group of physics researchers who are also known as Eudaemons (Mann, 1997). In the 1980s, wearable headsets, such as wearable glasses and cameras, received special attention and underwent many experiments and research; these experiments made wearables less obtrusive (Mann, 1997). Nowadays, this technology has been applied to different types of wearables, such as headsets, bracelets, wearable cameras and so on.

Wearable technology has great potential in museum. Digital enthusiast Stimler and artist Andrew have shared their experiences about using Google Glass in museums. They tested Google Glass at the Metropolitan Museum of Art in 2014. For them, Google Glass not only recorded museum collections' colours, forms and techniques; the whole experience of wearing a Google Glass also served as a good artistic inspiration (Stmiler and Andrew, 2014). On the other hand, museums like Bard Graduate Center

---

[23] Mail Online. Available at: https://www.dailymail.co.uk/sciencetech/article-2567739/Streetmuseum-app-creates-hybrid-images-London.html (Accessed: 07 November)

Gallery and The de Young Museum are experimenting with other possibilities using Google Glasses in their exhibitions in order to enrich the visiting experience.

## 3.3 Trends of In-Gallery Interactives

There has been significant change in the development of technology as it appears in museums and galleries, especially in recent years. We find museums more and more value visitors' experiences, not only their learning and aesthetic experience, but also their individual experiences with digital media.

A museum experience is no longer just about what happens on-site, it has transferred into a continuous experience that happens both inside the museum space and outside it. This kind of 'persistency' of visit is mainly achieved by linking on-site experiences with pre- and post-visit experiences online. In general, visitors' continuous experience in museums is most likely to be achieved through mobile devices and personalised tags. The Natural History Museum of Utah uses a unique smartphone guide which allows visitors to enrich and continue their experience by linking that experience to their personal portal on the museum's webpage (Menlove, 2013). Also, continuous experiences have even became part of museum strategy, like the three-pronged strategy in the Metropolitan Museum of Art, which includes an online experience, on-site visiting experience and post-visit leaning and activities online (Johnson et al., 2015). As much as we see this continuous experience, another trend of museum technology is to create personalized experiences. Based on an analysis of visitors' personal information, museums can provide personalized tours. For example, the Rijksmuseum Amsterdam, who worked cooperatively with Technical University Eindhoven and Telematics Institute to conduct the CHIP (Cultural Heritage Information Presentation) project to provide personalized virtual tours and physical tours by using Tour Wizard and Mobile Museum Guide (Roes et al., 2009). These personalised tours fitted individuals' needs and preferences together to help visitors explore the museums and learn from them in a suitable way.

Aside from the trend of continuous experience and personalized experiences which we can see in museum technology, there are also some special characteristics of the new generation of museum interactives. This section identifies some particular characteristics and patterns that emerged when museums adopted new and emerging technologies. By viewing examples in exhibitions and museums, there are three distinctive characteristics of emerging formats of digital installations: multi-sensory, high immersiveness and multi-user.

### 3.3.1 Multi-sensory Experience

As discussed in Chapter 2, the trend of sensory turn in social science and humanities has had significant impact on museum studies, in the aspect of establishing a comprehensive understanding of the senses and sensory experience in museums. Also, the nature of the museum experience is a mixture of aesthetic, intellectual, social factors and sensory stimuli through multiple channels. As a result of the impact of sensory turn and the nature of museum experience, how to enrich sensory engagement has become a critical part in the design of museum interactives. By viewing the application of newly installed museum interactives, it is clear that providing multi-sensory experiences is a key characteristic of emerging in-gallery technology. The new generation of museum interactives is no longer limited to pressing a button, clicking a mouse, tapping a keyboard or passively watching a video which mainly involves stimulation through one sensory channel; instead they have become more interactive, engaging and multi-sensory.

Different from museums' conventional way of targeting one sense at a time, technologies now enable museums to capture and combine visitors' multiple senses. The most common sense in the museum experience is visual, but museums nowadays focus on developing interactions that can channel other senses, such as smell, hearing and touch (CFM, 2014). This trend drives museums to develop more immersive exhibits and develop multi-sensory interactives.

The most common type of combining multiple senses in museum interactives, is the combination of visual and audio experience. The Virtual Orchestra, an interactive digital exhibit powered by the Philharmonia Orchestra is a good example of mixture of sight and hearing (Figure 3.8). This ten-room installation showcases, in each room, screens playing videos of different performers from different angles and broadcasts surround sound throughout. Walking through the exhibition, viewers can go 'inside' each room to experience a symphony orchestra. By using large screens, unconventional projecting surfaces, touch screens, and 360-degree projections, the exhibition created a high-definition and multi-sensory experience and allowed visitors to feel like a musician, conductor or composer in the orchestra. Additionally, there is a special part of the exhibit where visitors have the opportunity to further their virtual orchestra experience by wearing a VR headset. Here, 3D audio and video allow them to go inside a concert hall virtually and experience the orchestra up-close. Viewers are also able to focus on a particular performer simply by turning their head.

*Figure 3.8 A visitor interacting with the Virtual Orchestra exhibition. Source: Photograph by the author.*

Other than the combination of visual and audio experiences, to include the sense of touch is another common way of developing a multi-sensory experience. For instance, the Cooper Hewitt explores the possibility of touch. As a design museum, Cooper Hewitt encourages visitors to design their own wallpapers on an interactive touchscreen table, the design pattern (Figure 3.9). Based on its marvellous wall-covering collections, the museum developed the ‘making’ app, which is used on large interactive touch screen tables (Chan and Cope, 2015). Visitors are invited to draw their own wallpaper on the touchscreen first, then the pattern can be projected on the surrounding walls.

*Figure 3.9 A visitor is using the 'Making app' to design a wallpaper pattern. Source: Cooper Hewitt.*[24]

From another point of view, engaging the sense of touch contributes to creating a multi-sensory experience, more importantly, it is a tool to increase accessibility. It is a possibility for museums to engage more visitors in another way, which allows them not only to see objects, but offers the opportunity to feel them. More specifically, some emerging technologies, especially 3D printing and scanning, enable museums to engage visitors with physical challenges. The Hands On! Tours at the Art Institute of Chicago (as discussed in section '3D printing and scanning') is an example that allows people with dementia and disability to explore the museum in a new light. Moreover, Brooklyn Museum's verbal description and touch tours also create a unique experience for individuals with visual disabilities. Through feeling those 3D printed objects and engaging in multi-sensory experiences in a series of tours, individuals who are blind or partially sighted are now able to experience art beyond sight.[25]

Unlike the widely applied examples of combining sight with hearing and touch, the application of engaging the sense of taste and smell is comparatively uncommon. The permanent exhibition 'Borderless' created by teamLab in the MORI Building DIGITAL

---

[24] Copper Hewitt. Available at: http://www.cooperhewitt.org/2015/02/02/announcing-the-immersion-room-instagram-contest/ (Accessed: 07 November 2019)
[25] Brooklyn Museum. Available at: https://www.brooklynmuseum.org/education/access. (Accessed: 07 September 2019)

ART MUSEUM opens a window of using the sense of taste. In the En Tea House, visitors could enjoy a mixture of visual, auditory and taste. This exhibition use projections of seasonal flowers on tables and even blooms in tea cups, but what is more special is that these projections are not pre-recorded but rendered in real-time by a computer program.[26] This artwork starts when there is tea in a cup for the visitor to drink, then the projection changes based on the amount of water in the cup in real time, when the tea is finished flowers disappear in the empty cup.

Additional to the examples of museum digital installations that specifically engage the traditional understanding of basic five senses – sight, touch, sound, taste or smell (see Chapter 2), there are also examples of engaging sense of movement and vestibular sense (sense of balance). The Earthquake Simulator in the Volcanoes and Earthquakes Exhibition at the Natural History Museum London is a typical example of this kind of multi-sensory engagement. The simulator shows what it is feels like to experience the Great Hanshin earthquake, which occurred in 1995, from the inside of a Japanese supermarket in Kobe.[27] The footage plays on TV screens, lights flicker off and on, and strong shakes come from the ground underneath, so that this earthquake simulation fully recreates the experience of what happened during the Kobe earthquake. Also, the exhibition AI: More than Human which opened at the Barbican Centre London in May 2019, is another example of not only considering the traditional five senses, but also interacting with our whole body. The interactive installation called 'Future You' created by Universal Everything, allows users a unique reflection of themselves. The reflection mimics and learns from the users and creates a new visual interactive response to each motion for each user based on their body movements.[28]

### 3.3.2 Multi-user

Compared to the traditional kiosks that might only be used by one visitor, modern museums are more willing to employ interactives that could be manipulated by multiple

[26] teamLab. Available at: https://www.teamlab.art/ew/flowersbloom/ (Accessed: 07 November 2019)
[27] Natural History Museum. Available at: https://www.nhm.ac.uk/natureplus/blogs/whats-new/2014/01/31/volcanoes-and-earthquakes-is.html (Accessed: 07 November 2019)
[28] Wonderland. Available at: https://www.wonderlandmagazine.com/2019/03/26/ai-more-than-human-barbican-exhibition/ (Accessed: 07 November 2019)

users instead of using kiosks meant for only one user. The second key word of new and emerging in-gallery technology is, therefore, multi-user.

As explained by Chan (2014), museums are moving away from designing programmes for single-visitors to focusing on activities that can apply to multi-user large screens. Multi-user interactives in museums and galleries are computer systems that allow several users to operate and interact together with digital representations of museum artefacts or related and background information from its collections (Yee-King et. al, 2013). Compared to interactives that can only be manipulated by a single user, multi-user interactives are a form that allows both interaction between human and machines and among users. It is a shared environment, where people could communicate with and learn from each other. In terms of the formats of interactives, multi-user experiences are more likely to be screen based. Generally speaking, multi-user screen interactives in museums and galleries can be divided into two main types: multi-user touch-screen tables and multi-user interactive walls.

Touchscreens are not uncommon in museums nowadays; they are a tool to assist display, interaction and even education. The Cooper Hewitt Smithsonian Design Museum is an example of using large touchscreen tables as a way to communicate and engage visitors. These 84-, 55-, 32-inch ultra-high definition screens installed throughout all floors enable multiple users to browse museum collections, view details of objects, create their own work and share their design with others.[29] Another well-known representative of using multi-touch interactive tables is in the Churchill War Rooms, at the Imperial War Museum in London (Figure 3.10). A 17-meter-long touch screen table is installed in the central area of the museum displaying the timeline of former British Prime Minister, Sir Winston Churchill. This long interactive table displaces a time span of the war years across the biggest exhibition room in the museum. While visitors walk through the room, they can explore a great deal of information on this touch table, including texts, images, film clips and documents about the great man and his life.

[29] Cooper Hewitt. Available at: http://www.cooperhewitt.org/new-experience/ (Accessed 07 November 2019)

*Figure 3.10 Visitors are using the touch screen table in the Churchill War Rooms. Source: IWM.* [30]

Cooper Hewitt and Churchill War Rooms demonstrate how to use multi-user tables to provide additional information and encourage interaction, while the two examples described below show how they could support education. The first one is a multi-touch interactive table-top game 'Frog Pond' in the Computer History Museum in California (Figure 3.11).[31] This innovative game introduces computer programming processes to visitors while they are playing, which makes it possible for young children to understand the complex process of programming in a fun and cooperative way. The Collect and Connect Multi-user Interactive Table at the Auckland War Memorial Museum is a much-documented example of a multi-user touch table. The Collect and Connect game is a physical interactive experience designed for young audiences from 9 to 12 years old. It allows multiple users to explore the museum's collections, and tasks visitors to become a 'curator' and collect objects related to a specific topic by using their own 3D printed game token.[32] This cutting-edge digital experience is a unique and playful way of understanding how museums collect and curate.

---

[30] IWM. Available at: https://www.iwm.org.uk/events/churchill-museum (Accessed: 07 November 2019)
[31] Northwestern University. Available at: http://www.sesp.northwestern.edu/news-center/news/2014/10/mike-horn-frog-pond-museum-exhibit.html (Accessed: 07 November 2019)
[32] Auckland War Memorial Museums. Available at: https://mw2016.museumsandtheweb.com/glami/collect-connect-interactive-table/ (Accessed : 07 November 2019)

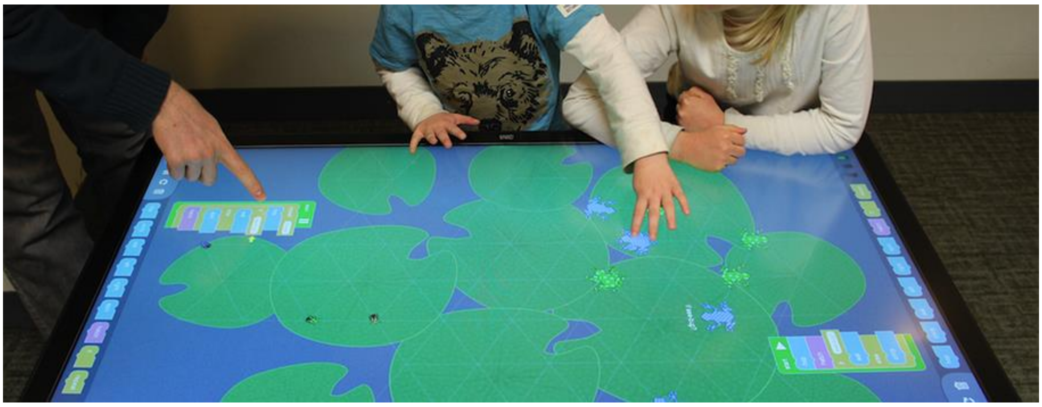


*Figure 3.11 Users interacting with the multi-touch tabletop game. Source: TIDAL Lab.*[33]

Beyond tables, we can also see museums designing experiences for multiple users by using other parts of their architecture, for instance, interactive walls (Uchida and Peng, 2019). One of the most well-known examples would be the ArtLens Wall in Gallery One at the Cleveland Museum of Art (Figure 3.12). This 40 foot by 5 foot interactive, multi-touch and MicroTile wall displays real-time works of art from the museum's permanent collection, giving an innovative way of accessing the museum collection especially for the light-sensitive artworks that are not suitable for permanent display.[34] The multi-touch systems make it possible for multiple viewers to interact with the wall, and it can even simultaneously be divided into 20 separate interfaces across the screen. Additionally, with RFID the Collection Wall can be connected to mobile devices and seamlessly store images of artworks. This giant interactive wall presents how museums could blend artworks, communicative media and interpretation.[35]

[33] Tangible Interactive Design and Learning Laboratory. Available at: http://tidal.northwestern.edu/ (Accessed : 07 November 2019)
[34] The Cleveland Museum of Art. Available at: http://www.clevelandart.org/artlens-gallery/artlens-wall (Accessed : 07 November 2019)
[35] The Cleveland Museum of Art. Available at: https://mw2014.museumsandtheweb.com/bow/collection-wall/ (Accessed : 07 November 2019)

*Figure 3.12 The huge multi-touch Collection Wall in Gallery One. Source: The Cleveland Museum of Art.*[36]

### 3.3.3 Immersive

Immersive experience is the third key characteristic of new technological experiences in museum. In fact, they are considered to be inherently multi-sensory (CFM, 2014). This is because to create an immersive museum experience where visitors can be free from external disruptions and more focused on the content in front of them in a more mindful and profound way, always involves multi-sensory engagement. The fact that multisensory immersive experiences can enhance engagement and heighten emotional experience has been recognised for decades. The series research conducted by Falk and his colleagues (Falk and Dierking, 2008; Falk et al., 2004) found evidence that an immersion experience is not only a sensory experience, it is connected to emotional engagement, and has further impact on memory, decision-making and learning.

In the digital age, media technology has the great potential for museums to create immersive storytelling for exhibition, increase immersive sensory engagement and forging deeper understanding and memories of visits. This section gives example from immersive experiences in museums and exhibitions worldwide, and discusses the power of immersion from the aspect of creating virtual space, combining architecture and recreating archaeological and historical sites.

[36] Ibid.

Supported by AR, VR and 3D project technology, virtual immersion is an effective form of expression when considering the creation of digital virtual space in exhibitions. We see various examples of using VR, AR or mixed reality (MR) in museums, including the VR experience in 'Yorkshire's Jurassic World' in Yorkshire Museum, the AR interactive film shown at the Natural History Museum, and the MR project (to launch in 2020) in the Science Museum and the Natural History Museums.[37] Also, there are other types of virtual space in exhibitions that are purely sensory. For instance, the Rain Room is an example of sensory experiential immersion, where visitors enjoying multi-sensory immersive journey under 'rain'. Rain Room is a sound and light installation that allows people to walk in the rain without getting wet (Figure 3.13). By using 3D tracking cameras, the sensors detect real time movement of visitors. It is a creative combination of nature, art and technology where visitors are able to see the water drops, hear the sound of rain and feel the atmosphere of rainy days.[38] This iconic exhibition has travelled to the Barbican in London, MoMA in New York, Yuz Museum in Shanghai, LACMA in Los Angeles and became a permanent installation at the Sharjah Art Foundation in the United Arab Emirates. Other similar installations can be seen in many projects designed by the teamLab; for instance, 'Story of the forest' at the National Museum of Singapore, 'Universe of Water Particles in the Tank' at the Thank Shanghai, and 'Flutter of Butterflies Beyond Borders' in Saatchi Gallery, London. These incredibly immersive exhibitions create breath-taking virtual immersive environments and allow visitors to enjoying the audio-visual feast.

[37] Science Museum Group. Available at: https://group.sciencemuseum.org.uk/project/audiences-of-the-future-robots-mixed-reality-experience/ (Accessed : 07 November 2019)
[38] Random International. Available at: https://www.random-international.com/rain-room-2012 (Accessed : 07 November 2019)

*Figure 3.13 Artists are dancing in the 'Rain Room'. Source: Photograph by Charles Roussel.*[39]

We have seen the combination of museums using some parts of its architecture with multi-touch screens in the former section, but here we also identify various representatives of using museum architecture to generate immersive experience. For instance, Van Gogh Alive is a great illustration of immersion, as it is a revolutionary way of using museum architecture while engaging with art works. It is a multiscreen environment with a lot of high-definition projections on walls, columns and the floor surrounding visitors. Integrating lighting, colours and sound, visitors can 'dive into' Van Gogh's world and appreciate his masterpieces in this immersive way. This case shows how immersive exhibitions could be beneficial by using museum architecture, and actually, the relationship between technology and museums building is not unidirectional but one of reciprocity. Examples such as the Geo-Gosmo at the National Museum of Emerging Science and Innovation in Japan and the touring artwork 'Museum of the Moon' currently displayed at the Natural History Museum in London show how immersive digital installations could guide visitors to view and feel the atmosphere and the entire space as a whole. As the nature of spherical displays provides an unobstructed 360-degree field for all visitors (Benko et. al, 2008), it invites viewers

[39] Roussel C. (2013) Available at: http://www.domusweb.it/en/art/2013/07/8/random_internationalrainroom.html *(Accessed: 07 November 2019)*

to walk around and explore the installation from different angles, encouraging them to view the installation while feeling the space.

Immersive environments would also be something worth considering in the re-creation of historic sites in the archaeological field. The projection show 'Dream of Eternity' (Figure 3.14) at the Human Provincial Museum, China, is one example of re-constructing an archaeological site with digital media. This projection show was a highlight when the museum reopened in 2017. It is a real-sized recreation of a Han Dynasty tomb (19.5m long, 17.8m wide and 17m deep) using projected animation. Working with traditional music, the show uses typical Han Dynasty drawing patterns from the collection to tell the story of the owner of the tomb, Madam Xinzhui, and her dream of eternal life. It was the first time for visitors to have the chance to see and feel how the tomb looked, aside from images and documentaries.

*Figure 3.14 'Dream of Eternity' in Human Provincial Museum, China. Source: Photography by the author.*

## 3.4 Summary

To conclude, this chapter discussed key new and emerging technologies that appear in museums and key characteristics of emerging formats of in-gallery interactives. New technology includes indoor positioning systems, natural user interface, 3D printing and scanning, augmented reality and wearable technology that was introduced in this chapter and which has brought new possibilities for museum. It has enhanced the connectivity between museums and their visitors, empowered museums to deliver digital content to broader audiences, and enriched visiting experiences by increasing accessibility and interactivity.

Aside from these new and emerging types of technology that appear in museums and other related institutions, there is also a trend of new formats of in-gallery interactives. To create digital experiences that could communicate with visitors through multiple sensory channels; to immerse visitors by generating special environments, atmosphere and the sense of space; and to encourage interaction among visitors by using technology that can engage multiple users.

These key characteristics of this new generation of in-gallery technology has outstanding opportunities compared to traditional interactives. It creates new visiting experiences that could be multi-sensory, highly immersive and shared with multiple users. The examples of digital installations found in museums, art galleries and visitor centres mentioned in this chapter are more likely to have one or two characterises of the new trend of technology, instead of all three features. Therefore, to understand the impacts and consequences of the new and emerging formats of technology on the visiting experience, we should select multiple examples as case studies to reflect all three characteristics (more details of the choice of examples is demonstrated in Chapter 5). Meanwhile, these characteristics of new technology are different from the traditional formats of interactives; consequently, they propose new challenges for our understanding, as well as the current toolset to evaluate them. Have the ways visitors interact with in-gallery changed too? Do we understand the new experience that visitors have with these new interactives? Are our existing evaluative tools in visitor studies effective enough to reflect these key characteristics of interactives and to measure visitors' experiences with it? It is the new requirements of understanding the new in-gallery technology and the potential new tools and models to capture and evaluate the experience that will be investigated in this research.

# Chapter 4 Evaluating Museum Technology and Evaluation Methods

## 4.1 Introduction

The study of education and learning in museums has a very long history, going back even as far as there have been public museums in existence (Hein, 1998). This focus of the educational value of museums can be traced back to 1884, when Higgins first published research to examine the educational value of a museum visit. There was a consensus that museums were important educational institutions, and in the twentieth century (Hein, 1998), this trend led to the increasing attention about the importance of learning in museums. For example, Gilman's observation of visitor experience is one of the earliest research moments in visitor studies, and provided many recommendations for museums and their exhibitions, while also proposing the idea of 'museum fatigue' (Gilman, 1916). Another famous early study of visitors is Melton's study in the Buffalo Museum of Science, where children's learning was examined through tests consisting of objective questions (Melton, 1988). The research pointed out that it was difficult to draw a conclusion of learning outcomes in any simple way, as it was not only based upon the knowledge obtained during the visit but also the prior knowledge that visitors brought to the museum. These early studies of visitors and museum learning generated new concepts and methods for later research.

Different from this early period, where there are only a few publications about visitor studies, the study of visitors has gained wide attention in the past few decades. Many studies have been published covering a wide range of topics in the area of visitor research, including Loomis (1987), Miles et al. (1988), Falk and Dierking (1992), Screven (1993), Hooper-Greenhill (1994), Hein (1998), and Bitgood (2011). These studies offer different perspectives of visitor studies. Besides this, special research groups, which focus on studying visitors, have been established, such as Audience Research and Evaluation and the Visitor Studies Association. The establishment of research groups and institutions largely promote the development of visitor studies and provide a large number of documents for future researchers.

As various types of technology have been introduced to museums and their visitors, in-gallery technology as became an essential part of the museum experience and raised increasing interest for museum curators, practitioners and researchers. This chapter particularly focuses on the research that measures the impact of technologies in museums and galleries. This chapter aims to present a brief review of research that has attempted to evaluate the applications of digital technology in museums. Specifically, in section two, the chapter focuses on reviewing evaluation studies of museum technology from two traditional perspectives: learning and usability. Then, current evaluation works, particularly around in-gallery digital technology are reviewed and typical methods and tools that have been used in those evaluation programmes are identified. Lastly, the chapter discusses the implications of this thesis' three context chapters (Chapters 2 to 4) and the needs to learn from other disciplines when evaluating sensations and emotions.

## 4.2 Perspectives of Evaluating Museum Technology

Before starting the conversation of evaluation methods for in-gallery technology, two questions need to be address in advance: what is evaluation, and what are the common methods of evaluation? For museums, evaluation is an evidence-based argument to prove a robust statement by reporting its social, environmental, economic and cultural impacts and benefits (Ambrose and Paine, 2012). As defined by Damala et al. (2019: 3), evaluation is to find out 'using a variety of approaches, tools, and methodologies – what works, as well as identifying what needs to be improved.' Other than for demonstrating to funding agencies and shareholders the impacts of the organization, evaluations are beneficial for museums in many aspects: it measures whether the exhibition, project or activity met its pre-set aims, objectives and outcomes; improves museums' understanding of visitors and their needs; and identifies strengths and weaknesses for improvements (Foster, 2008).

Many evaluations of museum digital interactives have been conducted by museums and academics, especially since the beginning of the 21st century. The nature of museum digital interactives led to the fact that the evaluative research of them could be carried out by individual or institutions from various academic disciplines, therefore we might see scholars from education, visitor studies, Human-Computer Interaction (HCI) and many others work towards the same question. The most frequently asked questions in the evaluation of digital interactives are: who used them? How visitors used them? And what visitors have learned from them? Despite of these similarities, research from different fields might address the question from their own perspectives. For instance, in the field of visitor studies, a tendency to identify the patterns of visitor behaviour is apparent (Scott et al., 2013), while museum educators might be interested in the learning aspect of technology and HCI researchers are more interested in finding out users' response to using digital interactives (Heath and vom Lehn, 2004).

The goals of evaluating museum technology can be various too, as described by Demala et al. these include:

> 'selecting the appropriate technology; adapting it to fit the goals; creating, updating, and reusing content; personalising, monitoring, and tweaking in order to guarantee robustness and flawless performance; understanding the impact on the workflow processes for the museum personnel; proceeding to a cost-benefit analysis; inferring whether staff training is required; investigating energy and maintenance issues; guaranteeing security and safety; managing and guaranteeing accessibility for all visitors; and managing personal data storage and usage.' (2019:4)

Indeed, there are various aspects which could be investigated relating to museum technology. This section focuses on reviewing evaluation studies measuring visitors' experience with different types of technology.

Economou and Pujol Tost (2007) reviewed the studies of ICT applications in both formal and informal learning environments. The study reviewed various evaluation studies of ICT, especially VR, and pointed out the shift of focus in museum evaluation from learning outcomes and construction of meaning in exhibits in the 1990s, to an increasing focus on the whole experience with ICT (Economou and Pujol Tost, 2007). The study showed the profile of technology users was changing, from the higher interest of young users and female users in earlier studies to becoming more attractive for both young and adult users alike, and female and male users in more recent research (Economou and Pujol Tost, 2007). Significantly, the study raised the needs of researching and evaluating ICT applications in the cultural sector and in informal settings.

During the same period, the adoption of the web in museum has been discussed with an increasing notice of the importance of virtual visitors and their experiences (Cunliffe et al., 2007; Haapalainen, 1999). The usability evaluation conducted by Cunliffe et al. (2007) highlighted the need for designing museum websites to meet with a visitor-centred approach. Unlike major museums that are able to develop their website with experienced web development companies, small museums may have limited recourse, and in many cases are non-professional in-house development. Therefore, especially for non-profession developers, this study strongly suggested following a principled process and user-centred methods to develop usable products (Cunliffe et al., 2007). Similarly, the evaluation study of the Augmented Representation of Cultural Objectives, a system of museums to develop virtual museum exhibitions online, has also confirmed the importance of a visitor-centred approach in the early design process to provide an attractive, useful, comprehensive and customized virtual museum system for users (Sylaiou et al., 2008)

Hauser et al. (2009) developed a new approach – a design-based research approach, to evaluate how digital media can support learning in museum environments. In this study, three digital installations in the Deutsches Museum were examined as examples, to demonstrate the educational potential of media exhibits in museums (Hauser et al., 2009).

Although various types of in-gallery digital media are evaluated in many studies, the focus of these studies could be concluded into two aspects: educational value and usability. The evaluation studies of Cunliffe et al. (2007) and Sylaiou et al. (2008) looked at the usability issue of museum technology. Examples of evaluating museum technology from the usability perspective could also be found in Stoica et al. (2005) who discussed the design and the architecture of the development of a museum mobile system. Hornecker and Stifter (2006) investigated issues of using and interacting with the smartcard (a ‘digital backpack’ where visitors store collected or self-created data) in the Austrian Technical Museum in Vienna. The research of Economou and Pujol Tost (2007) and Hauser et al. (2009), on the other hand, examined the technology from the learning perspective. Evaluation conducted around learning can be seen in many studies. For instance, Pujol Tost and Economou (2009) investigated the effectiveness of immersive VR technology to assist learning in cultural heritage settings, and pointed out VR is suitable for learning in these environments, but also have limitations by its computational interface and communicational language. Valvula et al. (2009) evaluated the Myartspace, a service on mobile phones, and its effectiveness for supporting learning between museums and classrooms.

## 4.3 Evaluation Methods

The following discussion mainly examines museum technology onsite and installed in the gallery space, which include museum interactives or interactive exhibits such as computers and other multimedia components (Falk et al., 2004). Although the aims and questions asked in the evaluations might vary, the research methods they used have many similarities. Most researchers chose to combine both qualitative and quantitative methods. And the commonly used methods of data collection are represented, including observations, in-depth interviews and focus groups for qualitative information, and individual questionnaires to collect more qualitative data (Economou and Pujol, 2007). The East of England Museum Hub (Foster, 2008) also draws similar conclusions, and pointed out that common types of data collection methods include questionnaires, interviews, focus groups, verbal comments, and observations. This statement has been further explained by the results found by the National Science Foundation funded project Building Informal Science Education. This project analysed 319 evaluation reports of science centres, natural science museums, art museums and history museums published online. After all the data had been coded, the project team found interviews to be the most commonly used data collection method (79% of 319 reported applied this method), 60% and 55% of them used observation and survey respectively; while 15% used focus groups, 13% relied on artefact review and 8% chose other methods (Nelson and Cohn, 2015).

Interviews are the frequently used method for exhibition evaluations. The evaluation of Atlantic Wall: War in the City of Peace at Museon used semi-structured post-visit interviews. Forty-nine visitors were interviewed in Museon with the purpose to ask participants the research questions directly and to further explore the reason for their recorded behaviours in earlier observations (Damala, et al., 2016). Post-interviews are also applied to evaluating two digital installations in an exhibition called ‘Feint: Illusion in Ancient Greek Art’ an, exhibition at the Allard Pierson Museum. In this case, interviews were conducted to retrieve in-depth information of visitors' motivations and interpretation of textual information (Damala, et al., 2016). Similar with the interview in the Atlantic Wall exhibition, each interview lasted for about twenty minutes and was carried out in a quiet area close to the museum café. Both single visitors and members of visiting groups (who were at least eighteen years old) were asked to participate, however, only seven interviews were completed in the end. The low participation rate was partly explained by the long length of each interview (Damala, et al., 2016).

The study carried out by Schorch (2014) took semi-structured and in-depth narrative interviews with foreign visitors to Te Papa (four visitors from Australia, Canada and America respectively, 12 interviewees in total). After six months, the researcher conducted follow up interviews via phone call. Combined with the applied 'zoom model' (Pamphilon, 1999) of data analysis, the research fundamentally examined individual stories gathered from interviewees that exposed content that was relevant to sense, feelings and embodiment. The results of this study provided evidence to support the hypothesis of feelings as interpretations.

Unlike the examples above, which conducted interviews after the activity, Scott's (2013) study employed walk-around interviews in the Fabrica and the V&A. In this study, visitors who agreed to take part in the interviews visited the exhibition within the company of a researcher, allowing the researcher to receive visitors' comments of their experience as they happened.

Except for interviewing visitors, some evaluation studies of in-gallery technology also interviewed museum staff, such as digital curators and educators. For instance, in the evaluation of Myartspace, museum educators and teachers were interviewed before the student learning experience in the classroom or museum (Vavoula et al., 2009). These interviews provided the evaluator information on the teachers' and museum educators' plan for the student learning experience and gathered feedback of students' previous museum visiting experience (Vavoula et al., 2009). Economou's (1998) evaluation in the Ashmolean Museum involved interviews with museum staff as well. This helped the evaluator to gain an overview of the interactive computer program and the museum's expectation. Interviews with museum staff are a frequently used method for evaluating the learning outcomes of using digital interactives. For a museum, whether visitors' learning outcomes meet its expectation or not is an important feature to measure its effectiveness of delivering the educational agenda.

Questionnaires are also a common technique in evaluation studies of in-gallery technology. Questionnaires can be conducted at different stages of museum visits, and sometimes post-visit questionnaires after several months of their museum visits are also carried out by post or email. Normally, post-visit questionnaires are often seen in studies that aim to measure learning impact of exhibitions, as it is a very efficient tool that helps to reveal the most memorable parts of the exhibition and to test the successfulness of delivering an educational agenda. For instance, the research on the interactive installation in the Powerhouse Museum carried out by Falk et al. (2004) measured the long-term learning impacts of visitors' experiences with interactives and compared it with short-term learning outcomes. Similarly, the summative evaluation of Euesperides used postal questionnaires. The results from this mail survey showed that most visitors were able to recall certain details of the exhibition and the program as well, though their answers strongly suggested that the interactive computer program was highly memorable with long lasting impact (Economou, 1998).

In Damala's et al. (2016)'s research of evaluating tangible and multisensory museum visiting experiences, different types of questionnaires have been conducted, including a visitor experience questionnaire (VEQ) and a visitor profile questionnaire (VPQ). In the evaluation for the Atlantic Wall exhibition, VEQ was designed and used to gather various information from visitors, which included demographics, expectations of their visit, time spent, experience of using replicas, learning and emotional impact. Eighty-eight questionnaires were filled in, and they helped to gain a better understanding of visitors around their expectations, preferences and visiting experiences. VPQ consisted of two pages of A4 paper, and was developed to create a profile of visitors about their levels of interest in exhibited content, visiting habits, demographic information. The team collected 101 VPQs (Damala, et al. 2016). The VEQ was developed to gain quantifiable data of the user experience as a whole. The first four sections remained the same with the VPQ, so in total the questionnaires consisted of four A4 pages. The study summarized lessons learned from this evaluation and the key challenges identified within questionnaires were that the visitor needed to spend a long time answering all the questions and a number of open-ended questions turned out to be problematic for visitors to offer answers (Damala, et. al., 2016).

The third traditional method is typically observation, and it allows the researcher to observe visitors' behaviour and record related information at the same time (Borun and Korn, 1999). In the evaluation of museum technologies, observation is also a method that is applied by many studies.

For instance, in a study of multi-touch interfaces in museums, observation plays a major role. Kidd's research aimed to glean data and report findings about the interfaces of the newer generation of multi-touch interactives based on observations at nine museums in England (Kidd, et al., 2011). Unlike the traditional kiosk-based computer exhibits, which raised concerns on limiting users' social experience in the museum environment (Falk and Dierking, 2008), new technologies allow multiple visitors to use interactives at the same time. In order to know how people engage with computer interfaces and do multiple 'tasks' at one time, the study observed more than 100 screen-based interactives, including 30 multi-touch interactives (Kidd, et al., 2011). Although observation alone in this study cannot answer all questions from such encounters, it revealed certain phenomenon when visitors engaged with interfaces and raised questions for future research.

In the research of interactive art and visitor shyness (Scott, et al., 2013), observations played a key role in recording certain behaviours of visitors that were considered as expressions of shyness, such as blushing, gaze aversion and bodily gesture (Scott, et al., 2013). The study of interactive multimedia in the National Museum of Korea Contemporary Art is also an example that mainly relied on observation (Suh et al., 2014). The study observed 200 visitors via video recordings, recoded the time spent and coded visitors' movement and interactions with the interactive exhibits in order to understand the relationship between visitors and the multimedia exhibit (Suh et al., 2014). Similarly, the meSch project used observation to help identify visiting patterns and trajectories in the exhibition area (Damala, et al., 2016). This study pointed out one of the biggest challenges is the difficulty for the observer to remain unnoticed in the exhibition space, especially where fewer visitors are presented (Damala, et al., 2016).

Although this section discussed questionnaires, observation, interviews separately, almost all studies mentioned in the previous discussion applied mix methods. Examples of using mixed methods of data collection can be found in various studies. For instance, the evaluation of ICT applications in New Lleida Museum mixed direct observations, video observations with interviews (with curators and visitors) and usability questionnaires, to gain a picture of public interactions with ICT application on the whole (Carreras and Rius, 2011). The 'Talking Statues' audience research undertaken by the Research Centre for Museums and Galleries (RCMG) at UoL, investigated how to use NFC technology to enhance public engagement with statues. The audience research applied mixed methods of qualitative and quantitative research, conducting observations to understand public engagement with the Talking Statues, quick surveys and short interviews to find out users and non-users' experience with it, data and web analytics, and interviews with academics and project partners to test the data interpretation (Dodd et al., 2015).

## 4.4 Evaluating Sensory and Emotional Experience

The former section summarized the traditional, including questionnaires, interviews and observations. In Chapter 2, the thesis discussed the academic turn to human senses as well as emotions, and reviewed research in museums studies that addressed issues around sensory and emotional experience during museum visits. Chapter 3 explained the characteristics of new technology that are becoming more immersive, multi-sensory and shared, which may cause challenges for our current evaluation methods. On the one hand, the sensory and emotional turn inspired the study to evaluate sensory and emotional experience with in-gallery digital media. On the other hand, these characterises of new technology that immerse and communicate with visitors through multiple sensory channels require us to understand it from a sensory and emotional perceptive. The immersive experience is both engagement and the sense of physical presence, consequently, it is a mixture of intellectual, physical and emotional factors (Forte et al., 2006). Immersive experiences engage the physical senses and create a heightened emotional connection (Stogner, 2011). Studies also pointed out that feeling and emotion are as important as learning for visitors, as increasing emotional arousal has positive impacts on cognition and memory (Falk, et al., 2009; Stogner, 2011).

This reciprocity between the trends in museum studies and the feature of new in-gallery digital technology requires a new perspective of understanding and evaluating visitors experience with technology. However, there are very few studies that evaluate the sensory and emotional experience with museum digital technology. Only very recently, we see the study of Damala et al. (2016) discussing the multi-sensory engagement with museum objects and multimedia installations. And the ongoing EMOTIVE project, which investigated the design and evaluation of emotionally engaging experience in museums and the cultural sector using various forms of storytelling (Economou, et al., 2018).

As measuring emotions in museums is a new area that has only caught attention recently, relevant resources are limited. Therefore, in order to gather more practical and theoretical materials for evaluating visitors' experience, it is necessary to draw on and borrow from a range of disciplines. The combination of both verbal and non-verbal measurement of emotion is frequently seen in studies from other disciplines. For example, in marketing and advertising studies, emotional measurement tools using both verbal and non-verbal instruments were developed and utilised to measure customers' feedback (Desmet, 2005). The most prominent types of verbal scale to measure emotions includes the Likert scales and the Semantic Differential scale (Agarwal and Meyer, 2009). Generally speaking, Likert scales rate an object from 'strongly agree' to 'strongly disagree', while Semantic Differential scales use bipolar adjective pairs at each end of the scale and respondents choose anywhere between the two adjectives on the scale according to how they feel at a given moment.

The two main advantages to applying verbal instruments to measure emotions are that they can fit into different situations and measure complex sets of emotions (Desmet, 2005). More specifically, verbal measurement could be very flexible as the rating scale could be assembled to represent different sets of emotions. Besides this, compared to non-verbal instruments, which are considered difficult for measuring multiple emotions, verbal instruments could measure each emotion individually. On the other hand, the major disadvantage of this method is that it is difficult to apply to different cultures, as it is problematic to get one-to-one translation for many emotion-related words (Desmet, 2005).

Non-verbal instruments measure emotion through expressive reactions, including the facial, vocal and postural expressions that link to emotion (Ekman, 1994b). According to Ekman (1994b), every emotion is associated with a special pattern of expression, for instance, anger always comes with a particular stare: contracted eyebrows, compressed lips, vigorous movements and a rise in voice level (Ekman and Friesen, 1975). Facial expression instruments require video recording in order to capture every expression's features. Many systems have been developed to identify emotions via facial expressions. For example, Facial Action Coding System (Ekman and Friesen, 1978), Maximally Discriminative Affect Coding System (Izard, 1977) and Standardized Emotion Profile (Holbrook and Batra, 1987). Similar to facial instruments, the vocal instruments of measuring are also based on the theory that links emotion with patterns of vocal cues (Desmet, 2005). Also, the non-verbal measurement also includes the use of picture-oriented instruments, such as the Self-Assessment Manikin that rates the affective dimension of pleasure, arousal and dominance associated in response to an event or object (Bradley and Lang, 1994).

Both verbal and non-verbal measurements have their downsides. Therefore, in some studies, researchers would combine both methods. Desmet's (2005) and Agarwal and Meyer's (2009) studies are two good examples that applied these two methods in practice. Desmet (2005) designed a new tool called Product Emotion Measurement Instrument (PrEmo) to measure the emotional response to a product. PrEmo is a non-verbal self-reporting instrument that consists of 14 emotions that are often elicited by product design. The 14 emotions include 7 pleasant emotions: desire, pleasant surprise, inspiration, amusement, admiration, satisfaction and fascination; as well as 7 unpleasant emotions: indignation, contempt, disgust, unpleasant surprise, dissatisfaction, disappointment and boredom. After choosing one of the animations of emotion, a hidden rating scale is used to ask people rate whether 'I do feel like the emotion', 'to some extent I feel the emotion' and 'I do not feel the emotion expressed by this animation' by asking themselves how they feel again. Agarwal and Meyer's (2009) study used the PAD Semantic Differential Scale developed by Mehrabian and Russell (1974) and the Emocard. In this case, researchers picked up suitable bipolar adjective pairs from Mehrabian and Russell's original adjective sets and selected 16 emotions from the Emocard tool (human-like representations of emotion) designed by Desmet

(2000). The study used both of these two tools in online surveys to evaluate users' emotional responses to interfaces.

## 4.5 Summary

This chapter discussed the classic perspectives and methods of evaluating technology in museums. The educational value of the museum is a widely discussed topic, and many studies in this area aimed to investigate how technology could support learning in museums. In addition to educational value, another classic perspective is related to usability. The chapter then turned to look at the methods and tools that applied in evaluation studies. As shown in the examples discussed, most studies apply mixed methods of data collection, and the most frequently applied methods are questionnaire, interview and observation.

The trend of uncovering the understanding of human senses and examining the role of emotions in museum visits is reviewed in Chapter 2 and the characteristics of new and emerging types of in-gallery technology identified in Chapter 3 suggest to us that we understand and evaluate visitors experience with technology through new lenses of sensations and emotions. However, as noted in this chapter, the relevant evaluation studies of technology from this perspective are very few. Therefore, this chapter then viewed research in marketing and advertising studies of measuring customers' emotional responses to products. In these studies, non-verbal measurements that analysed facial expression and vocal characteristics, as well as emotional measurement tools such as SAM, PrEmo and PAD Scale were introduced.

Chapter 2 discussed trends in museums and heritage studies which aim for a more comprehensive understanding on the role of sense and emotions. These new academic trends of researching sensory and emotional experience has provided a new perspective on understanding the experience and impact of interacting with museum technology. Chapter 3 turned to review the trend of the employment of technology in museums and identified the characteristics of the new generation of digital media. These highly immersive, multi-sensory and multi-user digital environments are much more complicated than the traditional formats of in-gallery interactives, which means that it may require a new set of tools and frameworks to understand visitor experiences within it. Therefore, in this chapter, we examined the common tools of evaluating museum technology and searched for inspirations in measuring senses and emotions in other academic areas.

Next, in Chapters 5 to 7, the three cycles of evaluation are presented. The evaluation methods that were tested and analysed in the pilot study and Cycle 1 used both verbal and non-verbal measurements, starting with mixed methods of data collection using the three common methods discussed in this chapter. Additionally, the PAD Scale is used in the questionnaire, as it provides a list of words that describe emotions from three dimensions.

# Chapter 5 Pilot Study and Evaluative Design Cycle One

## 5.1 Introduction

The preceding chapters have mapped the requirements of frameworks and tools needed for measuring emotions and sensations during the experience of interacting with in-gallery digital media. Specifically, Chapter 2 focused on the sensory turn and emotional turn in social science and humanities, and their influence on museum studies. It discussed the literature around sight, touch, and less-explored senses of sound, smell and taste as well as the sense of embodiment respective in the context of museums. The chapter also shared the debates on the definition of 'emotion', listed related research and examples of design exhibitions and activities of emotional engagement in museums, and explained where this research stands in terms of understanding emotion. Chapter 3 then viewed five new technologies that have been employed by museums in recent years, and analysed various examples of new and emerging formats of interactives in museums worldwide. Three key characteristics of this new generation of technology in museum were noted, namely: multi-sensory, multi-user and immersion. Chapter 4, then, reviewed studies of measuring and evaluating the impact of in-gallery interactives. The current research in this area has shown there are two classic and common perspectives of analysing visitor experiences with in-gallery technology: educational value; and usability.

We see the 'sensory turn' and 'emotional turn' taking place in museum studies, while also noticing the 'new wave' of technology that has appeared in museums, galleries and science centres. These have left us questioning how to understand museum visiting experiences under the academic trend of sensory and emotional research. One possible consequence is to start measuring and evaluating the impact of in-gallery interactives from the perspective of physical and emotional engagement. Comparing the classic perspectives of learning outcomes and usability, this new perspective is largely new to the research of interactives and visitor studies. It has added the third pathway of understanding visitors' experience with technology, a pathway that might require new knowledge to understand concepts, definitions and terms in other academic disciplines; new tools to measure the complex subjects of emotions and senses effectively; and a new framework to evaluate the sensory and emotional engagement with in-gallery technology.

Drawing upon the research background in the preceding discussion, the fieldwork of this research aims to test the effectiveness of traditional evaluative tools, and more importantly, explore the possibility of applying models, tools and frameworks in other academic areas (including psychology, marketing, tourism studies, and HCI) to visitor research and in real museum environments. To achieve the research objective, the next three chapters (Chapter 5 through 7) follow the sequence of iterative design and share results of the design cycle 1 to 3 respectively.

This chapter first introduces the fieldwork institution and three representatives of new and emerging formats of in-gallery interactives. Then, it describes the aims and overview of a short pilot study and its implications for the main fieldwork. Next, the chapter views the process of research design of three common methods (questionnaire, interview and observation) that were used in cycle 1 and analyses the data collected. Additionally, as the research involves various methods with human participants, issues around research ethics are addressed. The chapter reflects upon methods tested in the first interactive design cycle and diagnoses limitations at the end.

## 5.2 Introducing the National Space Centre and the Three In-Gallery Interactives

The research for this project was conducted in cooperation with the National Space Centre (NSC). There are three main reasons for choosing NSC in which to conduct the research, as it is geographically accessible for a lengthy research study, it has a close partnership with the University of Leicester (UoL) in various aspects and it could represent the trend of new and emerging technology in museums and science centres.

Located on the north side of Leicester city centre, it is a landmark of the city and the East Midlands area. NSC is an exciting developments in the history of Leicester. This ambitious £52 million project was sponsored by the Millennium Commission, and opened to the public on the 30$^{th}$ June 2001. The site consists of an iconic 41-metre-high semi-transparent ‘Rocket Tower’, a Challenger Learning Centre and the main building where most of the exhibitions are located.[40]

The reason why the UK’s only attraction dedicated to astronomy and space science was built in Leicester is largely because of it being the brainchild of the UoL. UoL originally suggested the idea of establishing an educational institution and tourist attraction contributing to space science research and astronomy. UoL and Leicester City Council were also founding partners of the NSC initially, and the University continues its supports in this partnership. Specifically, the Space Research Centre in the University’s Department of Physics and Astronomy provides strong support for the NSC and its research projects, as well as its strong links with space programmes worldwide, including projects out of ESA, NASA, NASDA and the Russia Space Agency.[41]

Aside from its significant contribution to space and astronomy education and its close relationship with UoL, the in-house immerse media design studio NSC Creative is the third important reason of choosing NSC to test the evaluative methods. NSC Creative is in charge of development of in-gallery interactives in the NSC; this award-winning studio also provides design and consultancy services for immersive experiences for theme parks, museums and science centres.[42] Because the research aimed to measure visitors’ experience with new and emerging digital media, this leading computer animation studio is key to ensuring the NSC is one of the institutions that could represent and lead the trend of in-gallery digital media in museums and related institutions into the future.

As discussed in Chapter 3, there are some distinguishing trends of new and emerging formats of technology. Compared to traditional in-gallery interactives, the new generation of technology aims to access multiple sensory channels rather than focus on visual and audio experience only. The technology is more likely to be used by multi-

---

[40] University of Leicester Bulletin (2001) Available at: https://www2.le.ac.uk/offices/press/publications/other-publications/bulletins/bulletins-1/spacecentrejune2001.pdf (Accessed: 08 November 2019)
[41] Ibid.
[42] NSC Creative. Available at: https://nsccreative.com/about-us/ (Accessed: 08 November 2019)

users which creates an environment for visitors to talk and share their experiences. Also, it is able to immerse visitors in a digitally created environment.

After a joint meeting with Kevin Yates (Head of Exhibition and Design), Dan Kendall (Curator) and Gareth Howell (Exhibition Designer) in the NSC, three examples were chosen to test these evaluative methods based on the multi-sensory, multi-user and immersive characteristics of emerging and new in-gallery technology. The choice of examples is decided by the differences between new and traditional formats of in-gallery interactives. In these three examples selected, we could find all three characteristics of new interactives identified in Chapter 3 and, in addition, each interactive particularly represented one of the characteristics. To be more specific, the Sir Patrick Moore Planetarium, the Venus Simulator and the interactive table were selected as examples of a new generation of in-gallery technologies, and they represent the high immersiveness, multi-sensory and multi-user nature of new digital interactives respectively.

This research takes the three digital installations selected as three case studies. The research intends to investigate users' experience of using the new generation of interactives, therefore multiple case studies are beneficiary for this particular study and could avoid the limitation of the single case. Using a single case study normally raises concerns of the lack of case population and exaggeration of representativeness of data (Stake, 2003; Jaikumar and Bohn, 1986). While using multiple case studies has advantages in terms of improving the generalizability and reliability of research findings, according to Eisenhart and Graebner (2007). This research intends to form a basis of a new evaluative framework that helps museums understand the sensory and emotional aspects of the visiting experience, especially the experience of interacting with new in-gallery technology. Therefore, testing evaluation methods in various situations, especially with different formats of interactives, would help the development of evaluation tools and evolving of the framework. More importantly, the framework developed and tested in these three different types of digital environments would be more likely to be applicable in the digitally created environments in other museums.

The Sir Patrick Moore Planetarium (Figure 5.1) is a 360-degree fully domed planetarium and it is also the UK's largest planetarium. This installation is selected as a typical example of immersive experience that visitors could have in museums. The planetarium show that was selected for this research is called ‘We Are Stars!’ and it is an exhilarating journey to bring us back through time and space and tell the story of the beginning of the Universe to the beginning of life. This 25-minutes immersive show was made by NSC Creative and narrated by Andy Serkis.[43] With expert input from leading astrochemists, planetary scientists and astrobiologists, this animated film presents humans’ current understanding of where everything came from, including the universe, the Earth and humans. Equipped with the unique full-dome screen and surrounded sound systems, this cinema experience immerses audiences in the world of cosmic chemistry.

*Figure 5.1 Photo of Sir Patrick Moore Planetarium. Source: National Space Centre.*[44]

The second case chosen was the simulator (Figure 5.2) in the Immersive Venus Exhibit, as an example that represents the multi-sensory characteristic of new technology. Going inside the Venus Simulator is like boarding a spacecraft and the destination is our closest planetary neighbour and the brightest planet in the night sky, Venus.[45] To create the environment of a spacecraft, the simulation has wrap-around projections on curved walls at the front, right-side and left-side, and the screen on the back side of the room displays the current status of the spacecraft. Wrap-around projections, screens, together with surround sound system, allows the Venus Simulator to take the visitor experience

---

[43] NSC Creative. Available at: https://wearestars360.nsccreative.com/ (Accessed: 08 November 2019)
[44] National Space Centre. Available at: https://spacecentre.co.uk/whats-here/#!mg_ld=591 (Accessed: 08 November 2019)
[45] Yates, K. (2016) National Space Centre. Available at: https://spacecentre.co.uk/blog-post/new-immersive-venus-exhibit-opens/ (Accessed: 08 November 2019)

on a journey through the Venusian atmosphere, sulphuric acid rain, crushing pressure, oven-like temperatures and experience an otherwise deadly place for humans to visit. Other than its excellent visual and auditory effects, the vibrating floor developed by the in-house design team added the final touch to this impressive multi-sensory experience and creates the physical feeling of landing on the surface of Venus.

*Figure 5.2 Visitors in the Venus Simulator. Source: Photograph by the author.*

The Space Oddities gallery exhibits unusual objects and tells interesting but less well-known parts of space history.[46] Objects in this exhibition are regularly updated and curators are able to pick new objects for display. The Space Oddities gallery has showcases and objects exhibited around the room, but in the centre of the space is a big interactive table. This interactive table is the third example in this research. Developed by the in-house team, this table is actually not a touchscreen, but uses sensors under the table and projections from above. When users touch fixed spots on the table, they can explore the content they select. The interactive table (Figure 5.3) allows up to six individuals or small groups to explore the stories of objects, space oddities and astronauts at the same time. Similar with the big interactive tables in the Churchill War

[46] National Space Centre. Available at: https://spacecentre.co.uk/whats-here/#!mg_ld=608 (Accessed: 08 November 2019)

Museum and the Cleveland Museum of Art (see Chapter 3), this interactive table is also a multi-user installation that created a place of exploring, communication and sharing.

*Figure 5.3 The Space Oddities gallery with the interactive table in middle of the room. Source: National Space Centre.*[47]

## 5.3 Pilot Study

### 5.3.1 Aims and overview of the pilot study

This research aims to design an evaluative framework to measure visitors' sensory and emotional experience with in-gallery digital media. The study applies the method of iterative evaluation design, and tests various evaluative tools in three design cycles. Pilot studies allow researchers to practice sample strategies, data collection and analytical techniques, to re-think and re-consider research questions and objectives, and sometimes, it is an opportunity to gain specific experience of the research process (Mason, 2002). Therefore, a pilot study was conducted, to prepare for the first round of evaluative design, to become familiar with the fieldwork site, and to test data collection techniques.

[47] Ibid.

The aims of the pilot study mainly included:

1. To develop observational techniques, including deciding where the video camera should be placed, whether other equipment, for instance, a tripod was needed, whether it was possible to install the camera by the researcher or if help was needed from technicians.
2. To explore ways of approaching and recruiting participants for questionnaires and interviews. Including how to introduce the researcher and the research project, how to encourage visitors to participate in the research.
3. To test the initial design of the first draft questionnaire, interview questions and observation sheet.
4. To identify the practicalities of doing interviews in the NSC, where to do the interviews, the equipment needed, how long approximately each interview would take and so on.
5. To test the effectiveness of evaluation methods of measuring sensations and emotions.
6. To become familiar with the institution and its organizational structure.
7. To develop interview techniques and find out how to encourage and prompt participants to express their feelings and opinions freely.
8. To decide the logic and sequence of the data collection methods. Whether a participant would only take part in one aspect of the study or if following one participant and having them take part in the questionnaire, observation and interview was better.

The pilot study was conducted at the NSC for three days in March 2017, and the digital installation selected for it was the planetarium show ‘We Are Stars!’ in the Sir Patrick Moore Planetarium. In these three days of the pilot study, 35-minutes of observation, 3 interviews and 18 questionnaires were collected.

### 5.3.2 Lessons learnt from the pilot study

Throughout the pilot, some practical problems were identified:

a. **Light**. The light level was very low in the planetarium environment. It was difficult to see visitors’ facial reactions from a distance even for human eyes and the recordings collected were almost black. Therefore, a new camera that could be sensitive in low light condition was required.

b. **Positioning**. The camera was placed in the centre-front of the planetarium, and filmed a central area of the auditorium with around 15 seats; however, the auditorium is a large space with more than 100 seats. Audiences have their own preferences to decide where to sit, as a consequence, there was sometimes only a few people sitting in the filming area.

c. **Scheduling.** According to the NSC's film timetable, normally there are 4 'We Are Stars!' planetarium shows per day. The show in the midday was normally the peak time, and shows in the morning and afternoon were less busy.

d. **Space.** There were limited spaces for visitors to fill in the questionnaire. Especially as the show which started at 12:20 was very popular and had a lot of viewers who wanted to fill in the questionnaires. But the exit area of the planetarium is limited, all viewer exited within two minutes after the show, thus, too many participants led to crowding.

e. **Questioning.** Some questions in the questionnaire needed to be revised (Appendix 1.1). To consider whether it was necessary to keep both Q5 (Have you watched a 360-degree film before in your past visits to the National Space Centre?) and Q6 (Have you watched a 360-degress film before in other museums or attractions?), as they might be considered repetitive in some degrees. For Q8 (Which words do you think can best describe your feelings of watching the show?), to decide whether to includes all words in the PAD (pleasure, arousal and dominance) Sematic Scale or whether words under pleasure and arousal catalogues were sufficient to meet the requirements of the research.

Through practice of the data collection methods and analysed data collected, the pilot study fulfilled the aims set. The pilot developed my observational techniques, allowed me to practice participant recruitment methods, identified problems in the initial prototype of methods, tested the effectiveness of the data collection methods, gave me the opportunity to figure out equipment needs and the quantity of it and raised new questions to consider during the evaluative design cycle one.

After this initial test of the three evaluative tools in real gallery settings at the NSC, there were some thoughts and actions that needed to be taken in order to conduct Cycle 1 smoothly.

First of all, the great support from the NSC as vital in the data collection process. For instance, in the planetarium, the digital environment selected to conduct the pilot, space crews working in the planetarium played a key role in introducing the researcher and encouraging participation. During the pilot, space crews introduced the researcher and the research purpose in the announcements before and at the end of the film, so audiences would know what to expect when they left after the show. These announcements from museum staff contributed a great deal to increasing the participant rate. One thing should be noted, which is that the space crews were working in rotation in the planetarium and they might inform audiences in different ways. They might give an announcement about the research at the beginning of the show, announce it twice both in the beginning and the end, tell visitors one by one when they were waiting in the queue, or ask a visitor to take an interview directly. According to the result in the pilot, space crews that gave announcements both at the beginning and the end, and researcher asking visitors directly when the show finished worked very effective in getting interview participants.

Secondly, the response rates for different methods were different and time required may also vary. In this case, response rate for the questionnaire was much higher than interviews. With the announcement given by the space crew, visitors were very willing to help with questionnaires. In the pilot study, more than 50% of approached visitors agreed to fill in the questionnaire, while less than 10% of approached visitors agreed to take part in interviews. Besides this, because the audiences all came out of the planetarium at once, over approximately two minutes, it was very difficult to get more than one interviewee for each show.  This difference of doing questionnaires and interviews in the planetarium also suggested it might be more practical to gain a larger sample size for questionnaires for the Planetarium show in Cycle 1, and less data for interviews.

After analysing the questionnaire data, interesting results were found. There as a question that asked visitors to choose one to three words that could best describe their viewing experience from a set of words. This set of words as selected from the PAD

Semantic Differentiate Scale, a verbal emotional measurement scale developed by Mehrabian and Russell (1974). Although the question asked audience members to choose up to three words in the list, a certain number of participants selected more than three. This might be that some of them were not reading the question very carefully, or it might also be because our feelings and emotions are complex in nature. Also, in some questionnaires, words such as excited and calm, contented and melancholic, excited and sleepy were chosen at the same time. As can be found in the PAD dimensions, those words are bipolar adjective pairs or have opposite meanings. More than 35% of respondents chose at least one bipolar adjective pair, within the 18 questionnaire responses gathered in this pilot. Although this small amount of responses is not strong enough to draw a conclusion, it suggests a possibility that visitors' emotional experience are a mixture of many emotions and they might have different feelings as the show goes on. It was decided this assumption could be test in the design Cycle 1.

With consideration of the two points mentioned above, which are the fact that there would be limited amount of interview data of the planetarium show in Cycle 1 and the complexity of emotion was difficult to explain via questionnaires alone, the three methods tested in the pilot were modified in Cycle 1.

To be more specific, in the pilot study, interviews, observations and questionnaires were a set of data by itself. However, in Cycle 1, the amount of interview data is smaller than questionnaire and observation data, resulting from the feature of the show and planetarium. In addition, the complexity of visitors' emotional and sensory experience shown in the responses of the questionnaires in the pilot is hard to explain by relying on questionnaires only. Therefore, in order to gain a better understanding of data and establish a more reliable and convincing methodology, in Cycle 1, the data collection stage was divided into two phrases. Questionnaires and observations were conducted in phase 1, and interviews in phase 2. After analysing the phase 1 data, interview questions were designed with the aim to address and explain questions found in phase 1.

Although in the pilot study, the camera failed to provide clear video in low light condition, it did provide important information. The recording included about five minutes before the show began and continued to film four minutes after the show finished. Despite the footage during the show is black, visitors' behaviour before the show started was recorded clearly. Some people looked around to get familiar with the environment, some looked up the screen and talked with their companions, and some visitors also took photos in the planetarium. This suggested it might be necessary to include the period before and after the show in the next cycle.

## 5.4 Requirements of Methodology

Inspired by the sensory turn in museum studies, the aim of this project was towards an evaluative framework to measure visitor experience with in-gallery technology from a sensory and emotional perspective. As we known, traditionally there are two perspectives of evaluating in-gallery technology: educational value and usability. There are only a few examples of measuring the sensation and emotional engagement with technology in museum study literature. Therefore, this research planned to test various evaluation tools, and started with the traditional tools which are interviews, questionnaires and observations. Individuals' feelings with technology might be a comparatively new research area in museum studies, but in other disciplines, human emotions and senses are extensively researched. Thus, aside from the three traditional tools, the research needed to go beyond museums studies and learn from other related academic research areas, to explore the effectiveness of other evaluative tools in measuring visitors' feelings.

Considering the purpose of the project, the research needed to test various evaluation tools and come up with a workable framework, therefore the research required a methodology that could consistently test and improve current evaluation tools. This research applied the method of iterative design. Similar to iterative research cycle processes in software and interface development, the research used an iterative model for developing the evaluative framework. To be more specific, the study conducted three trials for method development. This means that, after the initial design and prototype of the evaluative method, it was tested and improved through trials. Therefore, the fieldwork phase of this field research consisted of a pilot study and three design cycles. After the pilot, the main fieldwork was divided into three cycles; in each design cycle, different tools of evaluation were tested.

## 5.5 Research Design

### 5.5.1 Requirements for the Framework

Ideally, the evaluative framework should meet the requirements below:

- **Format**. Able to measure visitor experience with different formats of interactives. The study chose three different digital environments at the NSC; on the one hand they represent three key characteristics of new and emerging in-gallery digital media, another reason is because the simulator, interactive table and 360-degree domed cinema are very different formats of digital environments. If the evaluation tools could prove its effectiveness of measuring feeling with these three formats of technology, it is more likely to be extended to various formats of in-gallery technology.
- **Scale.** Suitable to be applied in different scales of museums. The framework should be applicable for both national and local museums, in terms of time require to conduct the evaluation, training for staff and equipment needed.
- **Scope**. Able to provide feedback of both sensory and emotional experience. Although different tools in this framework might have a different focus on its own, the overall framework should be capable of evaluating both sensations and emotions.

### 5.5.2 Sampling

This research project tries to development a framework of measuring visitors' feelings with in-gallery digital media. Instead of focusing on the difference between different genders or age groups, the framework needed to be able to measure the emotional and sensory responses of all visitors. The target participants of the research were visitors over 18 years old. Although ideally the framework would be workable for both adults and children, it was considered that different techniques and methods would be required for gathering responses from children, therefore the research targeted only adult visitors.

In order to test the chosen evaluative tools in a more efficient and effective way, the sampling size varied depending on the tools and qualitative or quantitative data they generated. More specifically, in the Cycle 1, the sampling size for interviews, questionnaire and observation was 50 questionnaires, 6 interviews for each digital installation, 40 indirect and 60 direct observations. In total, the first round of the iterative evaluation framework design attempted to collect 150 questionnaires, 18 interviews and observe 100 visitors.

To avoid unconscious bias (Guthrie, 2010), for questionnaire and interviews, the researcher asked every adult visitor who finished their experience with the selected digital installations, without pre-selecting their age group, gender and race, until the required number of responses was reached. For observations, the researcher observed every visitor meeting the requirements who interacted with the selected digital installations.

### 5.5.3 Questionnaire

The one-page questionnaire designed for the Cycle 1 consisted of both open-ended and close-ended questions. Take the questionnaire for the planetarium show 'We Are Stars!' for example (Figure 5.4). To encourage participation, the questionnaire generally used an informal tone of asking questions, for instance: 'How was that?', 'Who are you?' and 'What you thought of the show?' This questionnaire could be divided into three parts. The first part is the square on the top, from Q1 to Q4, which aimed to collect demographic information. The square in the middle of the questionnaire asked questions relating to the visitors' experience. The third part was the last question at the bottom, which aimed to gather additional information.

## How Was That?

**Who Are You?**

1. Are you male or female? ☐M ☐F

2. Which age group do you fit into?
   ☐18-24 ☐25-34 ☐35-44 ☐45-54 ☐55+

3. Who are you visiting the museum with today?
   ☐By yourself ☐With family (☐With children) ☐With friend(s)

4. Have you been to the National Space Centre before?
   ☐No, first time. ☐Yes.
   (How many times? ☐1-2 ☐3-5 ☐more than 6 times)

**What You Thought of the Show?**

5. Have you watched a 360-degree film before?
   ☐No ☐Yes
   (☐In National Space Centre ☐In other museums or attractions)

6. What is your overall impression of this 360-degree film experience in the Sir Patrick Moore Planetarium?
   ☐Very Good ☐Good ☐Neutral ☐Bad ☐Very Bad

7. Which word(s) do you think can best describe your feelings of watching the show?

| | | | |
|---|---|---|---|
| ☐Annoyed | ☐Pleased | ☐Unsatisfied | ☐Satisfied |
| ☐Despairing | ☐Hopeful | ☐Melancholic | ☐Contented |
| ☐Bored | ☐Relaxed | ☐Unhappy | ☐Happy |
| ☐Stimulated | ☐Calm | ☐Excited | ☐Sleepy |
| ☐Wide awake | ☐Aroused | ☐Unaroused | ☐Dull |
| ☐Jittery | ☐Sluggish | ☐Frenzied | ☐Controlling |
| ☐Controlled | ☐Influenced | ☐Influential | ☐Submissive |
| ☐Dominant | ☐Guided | ☐Autonomous | ☐Cared for |
| ☐In control | ☐Awed | ☐Important | |

8. What part of the show made the biggest impression on you?
   ☐the 360-degree fulldome screen ☐the sound effects
   ☐the narrative and story of the show 'We Are Stars!'
   ☐the atmosphere Other___________

Is there anything else you want to say about this experience?

_____________________________________________________

_____________________________________________________

*Figure 5.4 Questionnaire designed for the planetarium show 'We Are Stars!'*

Also, individual questions focused on gathering different information. The first four questions asked about gender, age group, companions and frequency of visits to the NSC respectively, and these were questions about the visitors themselves. Q5 combined two questions that were considered repetitive in the pilot. This question focused on previous 360-degree film experience, because familiarity of this format of technology could be one factor that influenced visitors' experience. Q6 measured visitors' overall impressions of their experience.

Q7 and Q8 are the most important questions here, they targeted emotional and sensory experience. Q7 is designed based on the PAD Semantic Scale introduced by Mehrabian and Russell (1974). PAD refers to pleasure, arousal and dominance, and are three independent emotional dimensions to describe our state of feeling. Each dimension contains six adjective pairs (Table 5.1). As reviewed in Chapter 4, there are various tools and models designed for measuring emotions in social science. This research started with the PAD as a main framework of collecting emotional responses because of the following three reasons. Firstly, it is a well-developed and widely applied tools that has been used in abundant research. Since the scale was first published in the 1970s, it has been widely discussed in psychological research, and more recently, the scale has also been applied in research outside the scope of psychology and integrated to marketing and advertisement studies (Desmet, 2005). Secondly, it is a verbal-based tools that could, perhaps, be beneficial in terms of offering visitors a set of vocabulary to describe the various emotions they might have during the experience. Thus, compared to the non-verbal based self-reported tools which are normally designed by using human-like representations of emotion, PAD scale could feedback emotional responses in a more precise way under the three dimensions. Moreover, compared to the tools that designed based on the dimensions understanding of emotions (for instance, the Likert scale), which are more suitable for answering questions of the intensity of certain emotions, PAD scale is more efficient to showing the rich and diversity of emotions, which are considered to be more fit for the purpose of this questionnaire.

In the first draft of the questionnaire used in the pilot study, pairs in the dominance catalogue were discarded, in Cycle 1 all words were maintained in Q7 as each catalogue measured different aspects of emotional dimensions and were considered irreplaceable. An option list for Q8 gave respect for the key feature of the sensory experience of watching the planetarium show, including the technology aspect, sound effects, content and atmosphere. At the end of the questionnaire an open-ended question for visitor to give additional feedback of their experience was included.

*Table 5.1 List of words in the PAD Semantic Scale (Mehrabian and Russell, 1974).*

| **Pleasure** (Displeasure - Pleasure) | **Arousal** (Non-arousal - Arousal) | **Dominance** (Submissive - Dominance) |
|---|---|---|
| Annoyed – Please | Relaxed – Stimulated | Controlled – Controlling |
| Unsatisfied – Satisfied | Calm – Excited | Influenced – Influential |
| Despairing – Hopeful | Sleepy – Wide Awake | Submissive – Dominant |
| Melancholic – Contented | Unaroused – Aroused | Guided – Autonomous |
| Bored – Relaxed | Sluggish - Frenzied | Cared for – In Control |
| Unhappy – Happy | Dull – Jittery | Awed – Important |

Questionnaires designed for the Venus Simulator and the interactive table followed the same structure of the planetarium questionnaire. The main difference among them was the options provided for the sensory experience question. Based on characteristics of each experience, the simulator's Q8 choices included visual effects, sound effects, vibrations and atmosphere (Appendix 1.2) while the interactive table's Q8 included atmosphere, content, multi-user experience and the touch table itself.

### 5.5.4 Observations

Observation is a common method that is routinely used in the research of visitor studies. Observations can reveal behaviours of visitors and help the researcher to find out issues that are less visible (Yin, 2014). In Space Oddities, the researcher conducted direct observation. While considering the settings in the Venus Simulator and the planetarium, it was decided that conducting direct observation would be impractical, therefore indirect observation via video recordings was applied in these two setting.

One major practical constraint encountered in the pilot was the camera used for observational recording, as the video image were almost black, and visitors' faces and behaviours were invisible. Thus, the researcher set up a controlled environment to test the ability of two different cameras filming under low light conditions. In this experiment, a camera was placed to the right side of the room (Figure 5.5) and the observed target sat to the left side of the room. This environment was a recreation of the low light condition in the Sir Patrick Moore Planetarium; in this experiment, the door of the room was closed, and the lights were turned off.

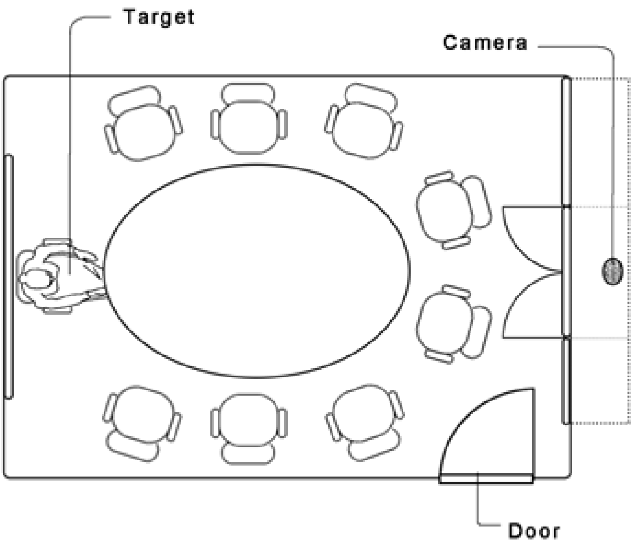



*Figure 5.5 Layout of the experiment room.*

First, the camera (Camera 1) provided by the university was been tested, it was the one used in the pilot study. Because the experiment room was smaller than the planetarium, the camera was zoomed in to imitate the real environment. The result of Camera 1 is almost the same as what happened in the pilot study. The video is almost black and failed to capture people's face (Figure 5.6). Then, a Sony SLR camera (Camera 2) was tested, the camera was set to the biggest aperture of 4, highest ISO of 25600 and highest exposure compensation of +3 to adjust to the dark environment. Although the recording has a lot of video noise, overall the image it produced was much clearer than Camera 1. Importantly, the human face could be identified in the recording. Therefore, in the Cycle 1, the Sony SLR camera was used to collect observation video in the planetarium.

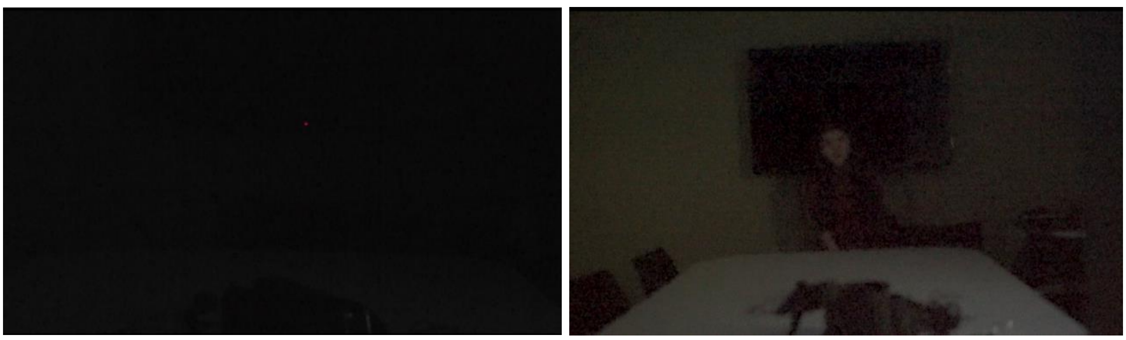


*Figure 5.6 Screenshots of video recorded by Camera 1 (left) and Camera 2 (right)*

The design of the observation sheet of direct observation in Cycle 1 was inspired by the observational form developed by the Family Learning in Interactive Galleries (FLING) project.[48] The goal of FLING'S observation toolkit is to understand how families use and interact with activities and how they interact with each other in an interactive space.[49]

Take the observation sheet of the interactive table for example (Figure 5.7). To fit the research content and objectives, the observation sheet needed five sections. The first section was about visitors' demographic information. Unlike the more specific age groups in the questionnaire, the observer only needed to choose from two categories (between 18-44 years old or above 45). This way of dividing the age groups might not be accurate in some cases, but it is necessary as familiarity with technology might vary between age groups. The second section as who they had visited the NSC with, as individual visitors, adult groups and groups with children might have different behaviours. The next section was used to calculate the time visitors spent in the Space Oddities Exhibition and with the interactive table. The fourth section was designed with the multi-user feature of the table, and three types of conversations regarding participation, content and operation of the table that might occur among visitors. The last section uses a five-point Likert scale to record valence and arousal level.

[48] Family Learning in Interactive Galleries (2010). Available at: http://www.familiesinartmuseums.org/research.html (Accessed: 09 November 2019)
[49] Ibid.

## Observation Sheet

Date: Place: Observer:

| | Gen-der | Age * | Visiting Group** | | | Time spent with the exhibition | | Time spent with the interactive | | Communication (V=Verbally; N=Nonverbally) | | | Pleasure | | | | | Arousal | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M/F | A/B | I | AG | GwC | In | Out | Start | End | Participation | Content | Operation | Displeasure | | | Pleasure | | Non-arousal | | | Arousal | |
| 1 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 2 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 3 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 4 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 5 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 6 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 7 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 8 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 9 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 10 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 11 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 12 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 13 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 14 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 15 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 16 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 17 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 18 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 19 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 20 | | | | | | : | : | : | : | | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |

*Age: A=18-44, B=45+ ** Visiting Group: I=Individual; AG=Adult group; GwC=Group with children.

*Figure 5.7 Observation sheet of the interactive table.*

### 5.5.5 Interviews

Interviews can maintain a sharp focus on a given topic and reveal the interviewee's feelings, opinions and attitudes to the interviewer in a direct way (Rubin and Rubin, 2012). As the research aimed to understand users' personal feelings of the digital environment, rather than the outcomes of engaging with these technologies, the interviews took place immediately after the visitor finished the activity. Short semi-structured interviews applied in this research used open questions to allow visitors to freely express their own opinion.

All interviews were audio recorded for later analysis. Each interview took approximately three minutes and consisted of six main questions. The interview for the planetarium show 'We Are Stars!', for example, had the following questions:

1. Is this your first time at the planetarium show here? (If yes, go to Q2; if no, how many times have you watched it in your past visits?)
2. How did you feel when you first walked into the Planetarium?
3. How did you feel during watching the show?
4. How did you feel after the show? When the show was finished and you made your way out.
5. How would you describe the physical experience of the show?
6. How would you describe your experience of watching the 360-degree planetarium show compared to other exhibits in the National Space Centre?

Similar to Q5 in the questionnaire, the first question in the interview asked their familiarity with the specific types of technology or experience, as this might influence their first impression with it. The following three questions aimed to understand visitors' feelings before, during and after the show. In order to emphasize the difference among these three questions, the participants were told the following questions were about when they first walked in, during and after the show. As we know, feelings can be difficult to describe because of a lack of vocabulary or simply because they are considered a private topic. Therefore, at least two prompts were prepared for each question to assist participants in sharing their feelings.

## 5.6 Data Collection

The first round of fieldwork was from 30th April 2017 until 30th June 2017; during these two months, 151 questionnaires (the planetarium show: 51 questionnaires, the Venus Simulator: 50 questionnaires, the interactive table: 50 questionnaires), twelve hours of video recordings (four hours recording of the planetarium and eight hours recording of the simulator), direct observation records of 60 interactive table users and 18 interviews (six for each interactive) were conducted.

Table 5.2 below lists the detailed data collection process of using traditional evaluative tools for the three exhibits.

*Table 5.2 Process of data collection in Cycle 1.*

| | **Planetarium Show 'We Are Stars!'** | **Venus Simulator** | **Interactive table** |
|---|---|---|---|
| Questionnaire | | | |
| *Location* | Outside of the planetarium exit | Outside of the simulator | In the Space Oddities Gallery |
| *Time needed (per each)* | 2 minutes | 2 minutes | 2 minutes |
| *Equipment needed* | Pens and clipboards (more than 10 sets) | Pens and clipboards (3 sets) | Pens and clipboards (2 sets) |
| *Procedure* | 1. Space crews inform audiences the research is taking place in the planetarium and introduce it briefly in the announcement before the show.<br>2. Space crews encourages visitors to participate at the end of show announcement.<br>3. The researcher hands out questionnaires outside the exit of the planetarium.<br>4. The researcher stays around when participants fill out the questionnaires and answer questions that they may have.<br>5. Collect questionnaires. | 1. The researcher introduces the project to visitors who finished the simulator experience.<br>2. If visitors agree to participate then ask them to fill out the questionnaire.<br>3. The researcher answers questions that visitors may have.<br>4. Collect questionnaires. | 1. The researcher introduces the project to visitors who interacted with the table.<br>2. If visitors agree to participate then ask them to fill out the questionnaire.<br>3. The researcher answers questions that visitors may have.<br>4. Collect questionnaires. |
| Observation | | | |
| *Location* | Camera has been set in the front-central area of the Planetarium, and films audiences who are seat on the selected seats (in the central of the planetarium, seats in deep blue colour). | Camera has been set in the up-front of the space, and filmed audiences stand in the central area of the simulator (lighted area). | The researcher stands in the corner opposite to the entrance of the Space Oddities gallery; observing visitors who use the table and face the direction of the researcher. |

| | | | |
|---|---|---|---|
| *Time needed (per each experience/ participant)* | Recordings for each show are around 30 minutes | Recordings for each simulator experience is approximately 7 minutes | Depending on the actual time visitors spent |
| *Equipment needed* | Camera<br>Tripod<br>Notice | Camera<br>Tripod<br>Notice | Pen and clipboard (1 set)<br>Observation sheet<br>Notice |
| *Procedure* | 1. The researcher places the camera before visitors enter the planetarium.<br>2. Space crews inform audiences observation is taking place in the planetarium and introduce it briefly in the announcement before the show.<br>3. The researcher collects the camera after the audience exits the planetarium. | 1. Technicians help to mount the camera before the NSC opens in the morning and adjust the angle.<br>2. Technicians help to take the camera down when observation finished. | 1. The researcher observes visitors' interactions with the table.<br>2. The researcher answers questions that visitors may have about their participation. |
| Interview | | | |
| *Location* | The café in the NSC | Outside of the simulator | In the Space Oddities gallery |
| *Time needed (per each)* | 3 minutes | 3 minutes | 3 minutes |
| *Equipment needed* | Information Sheet<br>Consent Form<br>Voice recorder<br>Pen and clipboard (1 set) | Information Sheet<br>Consent Form<br>Voice recorder<br>Pen and clipboard (1 set) | Information Sheet<br>Consent Form<br>Voice recorder<br>Pen and clipboard (1 set) |
| *Procedure* | 1. Space crews informs audiences the research is taking place in the planetarium and introduce it briefly in the announcement before the show.<br>2. Space crews encourage visitors to participate at the end of show announcement.<br>3. The researcher invites visitors to do interviews. | 1. The researcher introduces the project to visitors who finished the simulator experience.<br>2. Visitors who agree to participate read the Information Sheet and sign the Consent Form. | 1. The researcher introduces the project to visitors who finished the touch table experience.<br>2. Visitors who agree to participate read the Information Sheet and sign the Consent Form. |

| | | | |
|---|---|---|---|
| | 4. The researcher briefly introduces the research if the visitor is interested in the project.<br>5. Take the visitor to the café, if the visitor agrees to take part in it.<br>6. Visitors read the Information Sheet and sign the Consent Form.<br>7. Inform visitors the conversation will be recorded. | 3. Inform visitors the conversation will be recorded. | 3. Inform visitors the conversation will be recorded. |

## 5.7 Ethics

As this research is focused on evaluative design involving human participants, meeting the requirements of research ethics is vital to the whole process. To set a high standard was also an aim of the research. In the fieldwork stage, the research included three ethics application: for the short pilot, the main fieldwork and one specifically for physiological measurements in Cycle 3 (see Chapter 7).

In order to prepare for the research, and to ensure the NSC's support and permission, I met with key members of staff and gained full permission from the institution. The NSC were enthusiastic about the project, as the research fit well with their strategic aims about developing visitor studies research, particularly in regards to future exhibition design using digital media. This research was conducted with the NSC's consent and practical assistance, in terms of technical support and communication with visitors, as well as the practice co-ordination (time, placement) of the observation.

Following discussion with NSC staff, they requested that direct observation would not be used in the Planetarium, owing to the effect that this could have on visitors' experience of the show. Therefore, it was proposed (a joint decision with NSC staff, and solution co-designed with the Centre) that the study would instead place a discrete camera in the Planetarium and the Venus exhibition, and that the audience would be filmed, while the multi-user interactive table used direct observation.

With respect to visitors' privacy and confidentiality, several procedures were put into place. First, there was a sign at the front desk of NSC to inform visitors that visitor studies research was taking place in the NSC for academic purposes. As admission to the NSC is by ticket only, and as all shows in the Planetarium are pre-booked, all visitors (generally) and all audiences (specifically) were notified of the filming. In addition, all visitors had a choice to attend a screening of 'We Are Stars' that was not filmed. A more detailed information sheet describing the purpose of the research, contact details of the researcher, and the nature of the observation was also available at the front desk. All front desk staff were briefed by the Operation Team and able to answer questions on the nature of the research and the observation.

Second, in addition to notices on the information sheets on the seats of the auditorium, prior to the screening of the show in the Planetarium, the ‘space crew’ notified audience members that filming as taking place, and the area of the auditorium was being filmed. Importantly, audience members had an opportunity to move to another part of the auditorium prior to the start of the show if they did not want to be filmed. For the Venus and the interactive table, a notice was posted on the walls of the exhibition areas.

Third, the study only focused on adult visitors. For adults who were accompanying children in family groups, the video recording was only used to transcribe adult behaviour, while children shown in the film were not the subjects of the research and were not observed and coded.

Fourth, the research met the National Space Centre’s own policy on film and observation protocols inside the Centre, including the right for visitors to take part in or withdraw from visitor studies at any time for any reason.

For adult visitors who were invited to fill out the questionnaire they were also given the information sheet for them to keep that, again, provided details of the project, the researcher, and the purpose of the questions. The questionnaires were also anonymous.

Similarly, the short interviews were anonymised as well. All interviewees were, again, provided with an information sheet regarding the research project, and all interviews were conducted after the interviewee had provided signed informed consent.

Data emerging from this project was both digital and non-digital. The UoL’s Research Data Management Principles regards research data as a valuable asset. The management of research data is an integral part of good research practice that allows reliable verification of results, protects the intellectual and financial investment made in its creation, and enables it to be shared and prompts new and innovative research.

Digital data collected in this research was stored on a university computer, and the data uploaded to the university’s network on the day the data was collected. The data collected via camera was stored in the format of .MP4. Once the data had been uploaded, it was erased from the encrypted SD card. The recordings were only used to transcribe adult behaviour, and they will be deleted after the researcher fully submitted the thesis to the library. Data collected for this study will be kept securely on the university network, and will not be published, copied or distributed. Non-digital data will also be kept in a safe place and only available to the researcher.

## 5.8 Data Analysis

This section discusses the process of data analysis and how to make sense of the data collected. This analysis begins with a description of the process of analysing various types of data, and is followed by a presentation of the data.

### 5.8.1 Analysing questionnaires

During Cycle 1, 151 questionnaires were collected from the three digital interactives. The study used SPSS Statistics to analyse the questionnaires. After the data was collected, all questionnaire information was entered into SPSS, and coded following the below instructions (Table 5.3). Coding instruction for the Venus Simulator and the interactive table questionnaires were slightly different depending on the questions asked.

*Table 5.3 Coding instruction questionnaire of the planetarium show 'We Are Stars!'*

| SPSS variable name | Coding instruction |
|---|---|
| Gender | 1 = Male<br>2 = Female |
| Age | 1 = 18-24<br>2 = 25-34<br>3 = 35-44<br>4 = 45-54<br>5 = 55+ |
| Companions | 1 = By yourself<br>2 = With family (without children)<br>3 = With Family (with children)<br>4 = With friend(s) |
| NSC visit | 1 = No<br>2 = Yes, 1-2 times<br>3 = Yes, 3-5 times<br>4 = Yes, more than 6 times |
| Past full-dome film experience | 1 = No<br>2 = Yes, in NSC<br>3 = Yes, in other museums or attractions<br>4 = Yes, in NSC and other museums or attractions |
| Overall impression | 1 = Very Good<br>2 = Good<br>3 = Neutral<br>4 = Bad<br>5 = Very Bad |

| | |
|---|---|
| Emotions | 1 = Pleased; 2 = Unsatisfied; 3 = Satisfied; 4 = Despairing; 5 = Hopeful; 6 = Melancholic; 7 = Contended; 8 = Bored; 9 = Relaxed; 10 = Unhappy; 11 = Happy; 12 = Stimulated; 13 = Clam; 14 = Excited; 15 = Sleepy; 16 = Wide Awake; 17 = Aroused; 18 = Unaroused; 19 = Dull; 20 = Jittery; 21 = Sluggish; 22 = Frenzied; 23 = Controlling; 24 = Controlled; 26 = Influenced; 27 = Influential; 28 = Submissive; 29 = Dominant; 30 = Guided; 31 = Autonomous; 32 = Cared For; 33 = In Control; 34 = Awed; 35 = Important |
| Biggest impression | 1 = Sound<br>2 = Narrative<br>3 = Atmosphere<br>4 = Other |

According to the types of questions asked: single-choice, multi-choice and open questions, the answers were analysed in slightly different ways. The main statistical function used in SPSS questionnaire analysis was frequencies.

Figure 5.8 shows the gender of questionnaire participants. In 151 questionnaires collected, the percentages of female and male participants are marginally above or under 50 percent. Figure 5.9 demonstrates the age distribution of participants, and there are several differences among visitors of the three exhibits that participated in the research. For instance, the planetarium participants in the age group 18-24 is significant more than the participants of the Venus Simulator and the interactive table. While in the Venus Simulator, most visitors who filled out the questionnaire are from 25 to 44 years old. Although there are some differences of age distribution of participants, and the sample size might not be big enough to generate results that could entirely represent the age distribution of visitors of the three interactives, it might still reflect it to some degrees. Figure 5.10 shows who visitors visited the NSC with. As shown here, most people visited the NSC with their friends or families. Notably, more than half of participants of the interactive table are family groups with children.

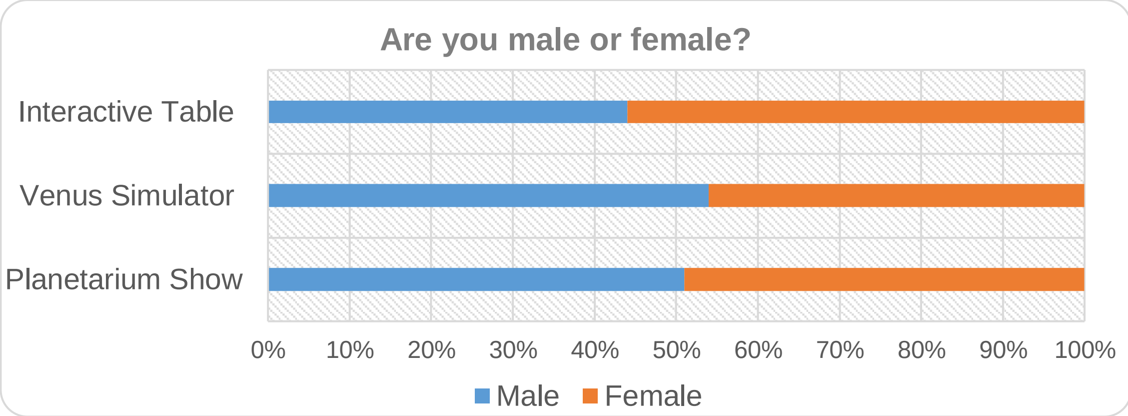



*Figure 5.8 Bar chart showing the gender of questionnaire participants.*

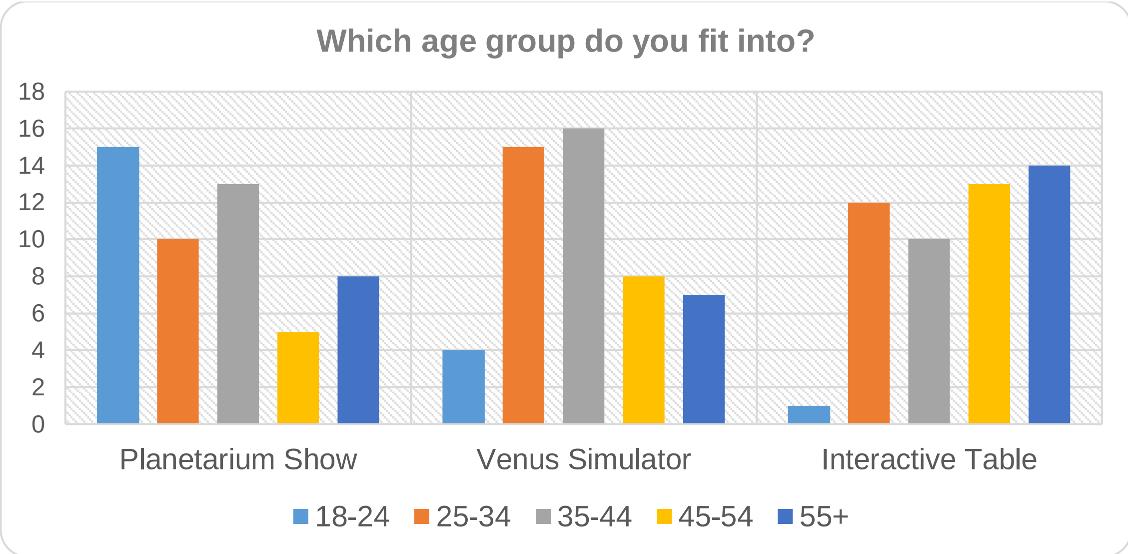



*Figure 5.9 Bar chart showing the age distribution of questionnaire participants.*

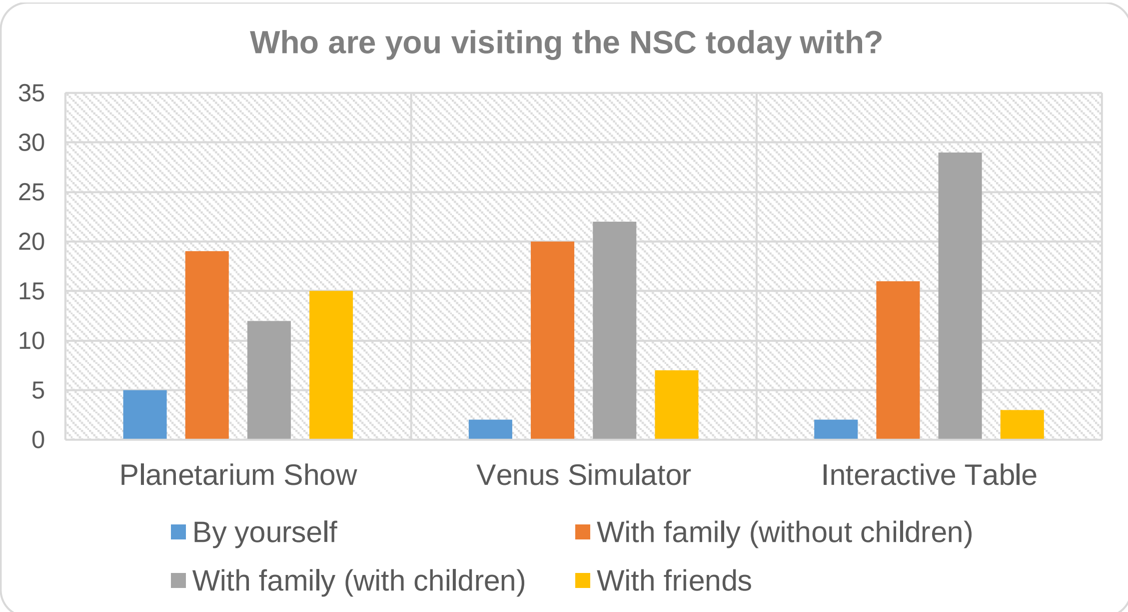



*Figure 5.10 Bar chart showing the visiting group.*

For the three interactives, the majority of visitors are first-time visitors to the NSC, as shown in Figure 5.11. Approximately 20 percent of participants had visited the NSC once or twice before, and frequent visitors that visited more than three times were relatively few. Figure 5.12 reflects participants' familiarity of the selected formats of technology; firstly, more than half of the visitors had not encountered the interactive, full-dome planetarium or simulator in their previous museum experience; and secondly, more than 20 percent of participants had similar experience with those types of in-gallery technologies before. These might suggest the three installations selected could represent the trend of the new generation of technology appearing in museums.

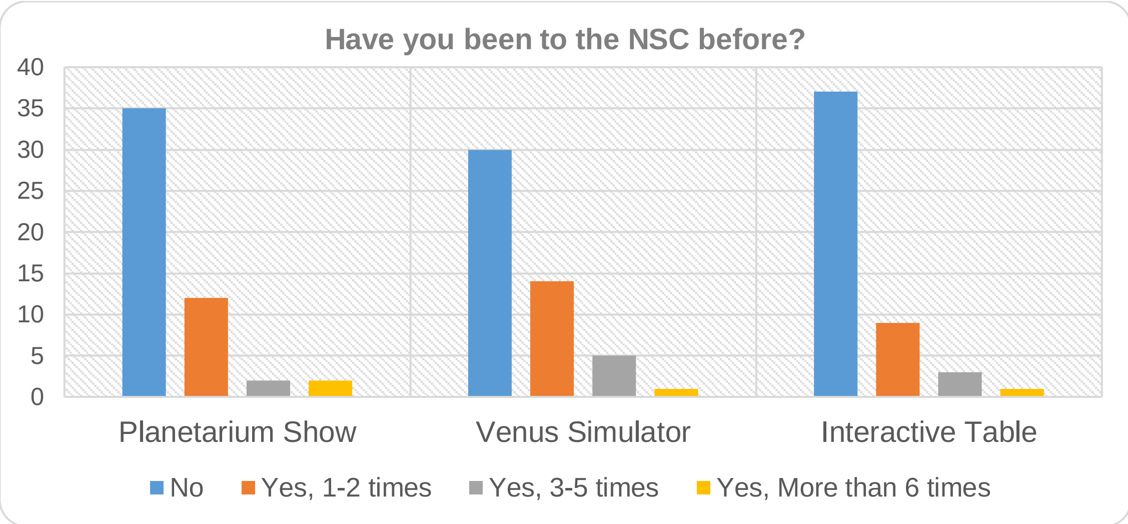



*Figure 5.11 Bar chart showing the previous visits to the NSC.*

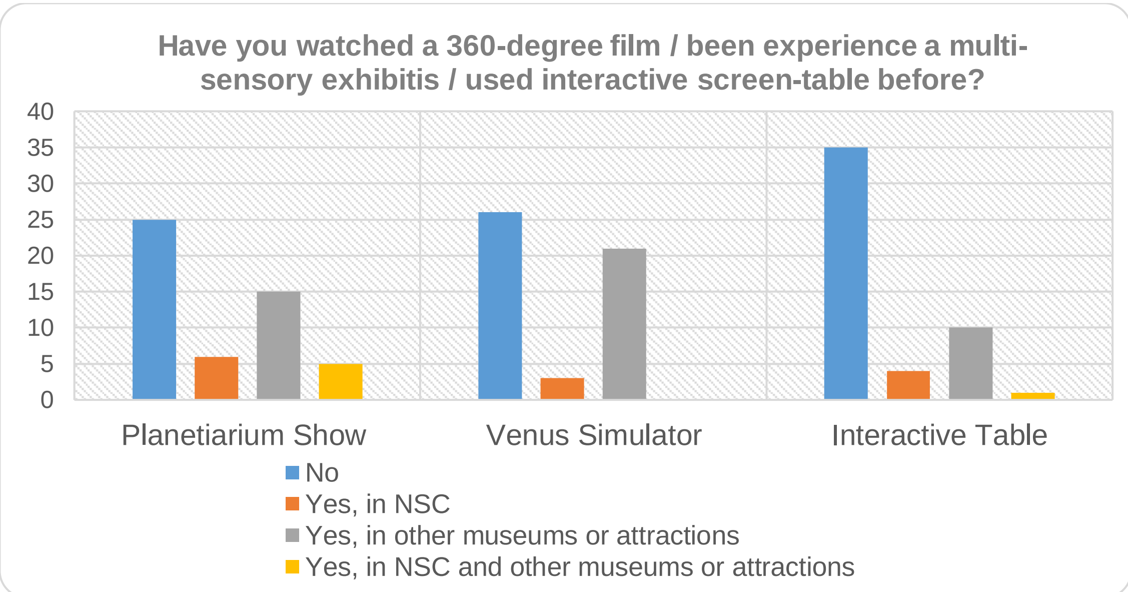



*Figure 5.12 Bar chart showing the previous experience of interacting with the selected formats of technology.*

The overall impression of the three selected interactives are very good as shown in Figure 5.13. The feedback of the planetarium show is even more positive than the other two.

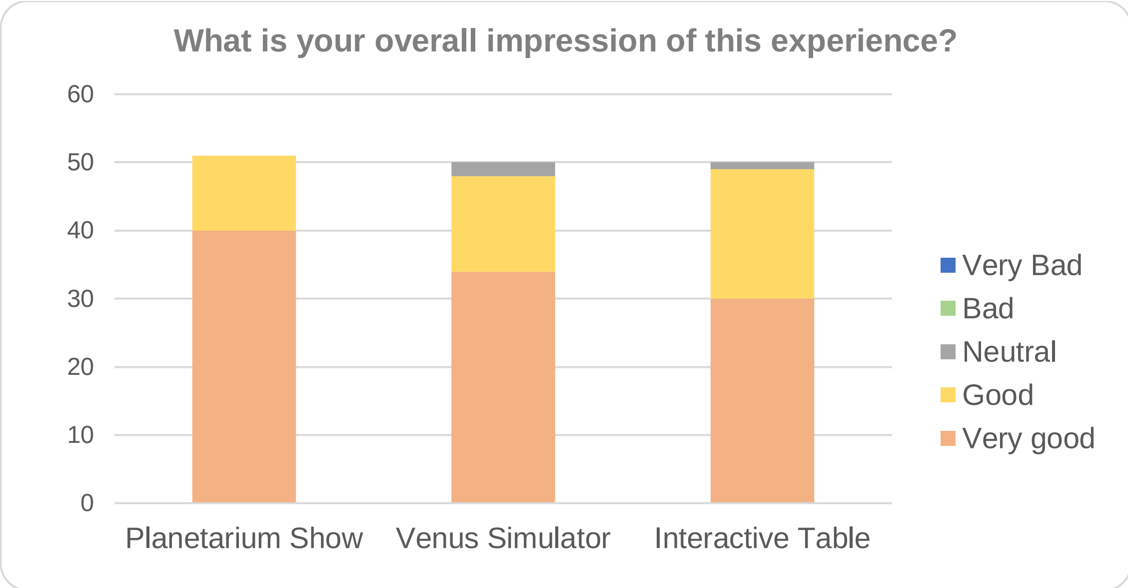



*Figure 5.13 Bar chart showing the overall of impression of three digital interactives.*

Figures 5.14, 5.15 and 5.16 show visitors' emotional experience of the planetarium show, the simulator and the interactive table respectively. All participants chose at least three emotions, as required; additionally, as found in the questionnaires collected, some visitors even chose five or six words. This suggests visitors had various emotions in their experience with digital technology. Apart from the variety of emotions visitors may have, visitors also tended to choose words from all three category to describe their feelings. In the pilot study, this question only used words from the pleasure and arousal category; the results shown below have proven it is necessary to include the words from the dominance category.

As shown in these three figures, visitors had various emotions across three categories towards each digital exhibit. Emotions from each category have been chosen at least 28 times among 50 participants of each interactive, therefore, it is fair to say that visitors have multiple emotions while interacting with in-gallery technology. When comparing the emotional experience in the three digital environments, the figures show some similarities. Although the number of times that the words have been selected varies a lot, the most picked emotions are almost the same, such as 'stimulated', 'pleased' and 'satisfied'.

This questionnaire used the words from the PAD scale to assist participants to describe their emotional experience. Although in the questionnaire words were not presented in pairs on a bipolar scale, as they were in the original PAD scale, some words are synonymous in meaning. For instance, ‘sleepy’ and ‘wide wake’ in Figure 5.14; ‘calm’ and ‘excited’, ‘relaxed’ and ‘stimulated’ in Figure 5.14 and Figure 5.16 have been selected multiple times. These emotions with opposite meaning suggest that individuals’ feelings of the same interactives could be diametric.

Moreover, the analysis reveals another interesting feature in Q7 that some participants chose words that are antonym to describe their emotions. For instance, in the planetarium show, 13 participants selected both ‘relaxed’ and ‘stimulated’, 3 participants selected both ‘calm’ and ‘excited’ and 4 other bipolar adjective pairs (Table 5.4). In total, there are 20 participants who chose words which have opposite meanings among 51 questionnaires collected for the planetarium show. This interesting fact suggests that visitors might have mixed feelings and their emotions might change during the experience.

*Table 5.4 Number of participants who selected bipolar adjective words to describe their feelings in the planetarium show questionnaires.*

| Bipolar adjective pairs | Number of participants |
|---|---|
| Awed – Important | 1 |
| Guided – Autonomous | 1 |
| Sleepy – Wide awake | 1 |
| Calm – Excited | 3 |
| Relaxed – Stimulated | 13 |
| Unsatisfied – Satisfied | 1 |

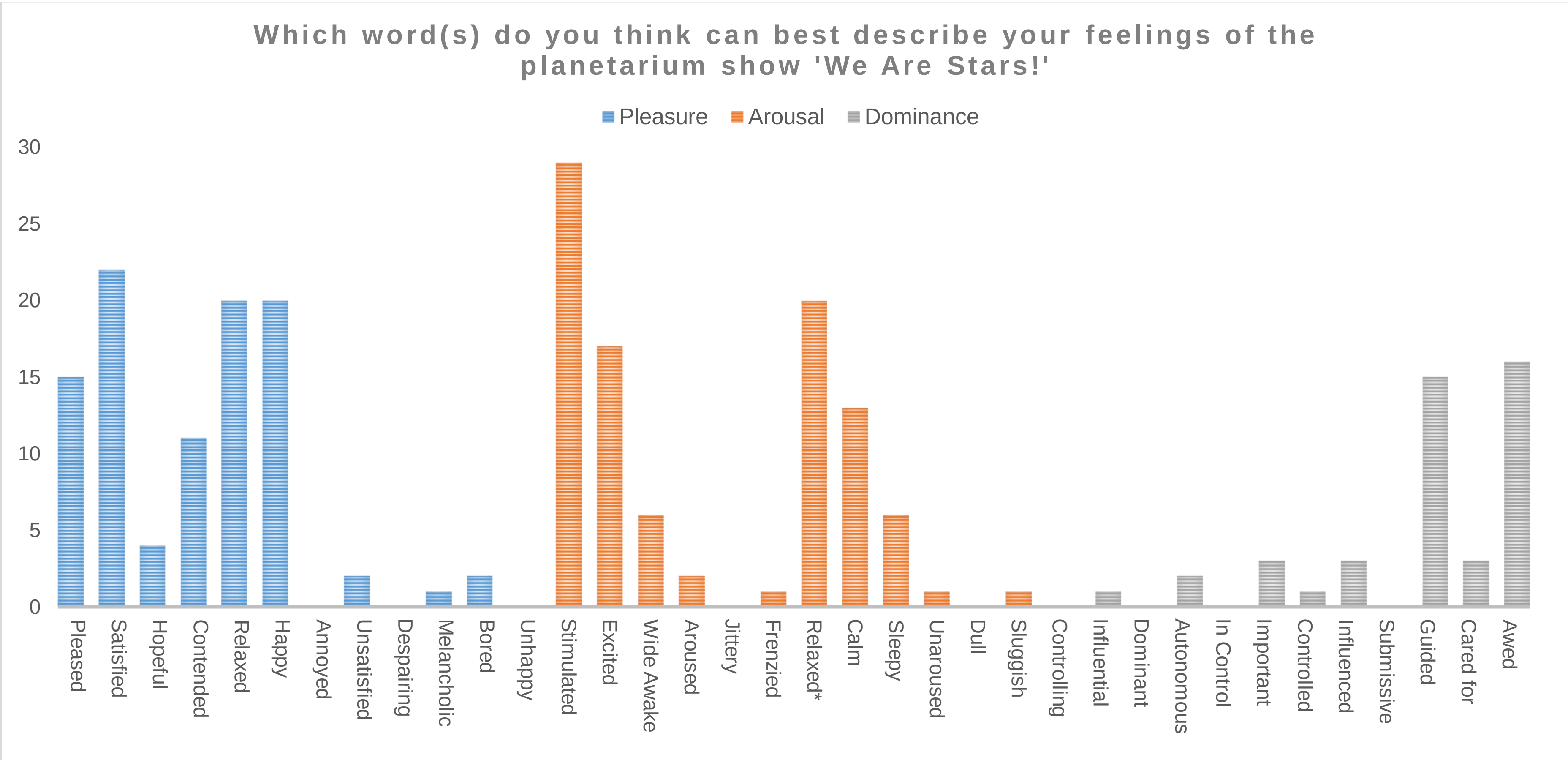



*Figure 5.14 Bar chart showing visitors' emotions of watching the planetarium show.*

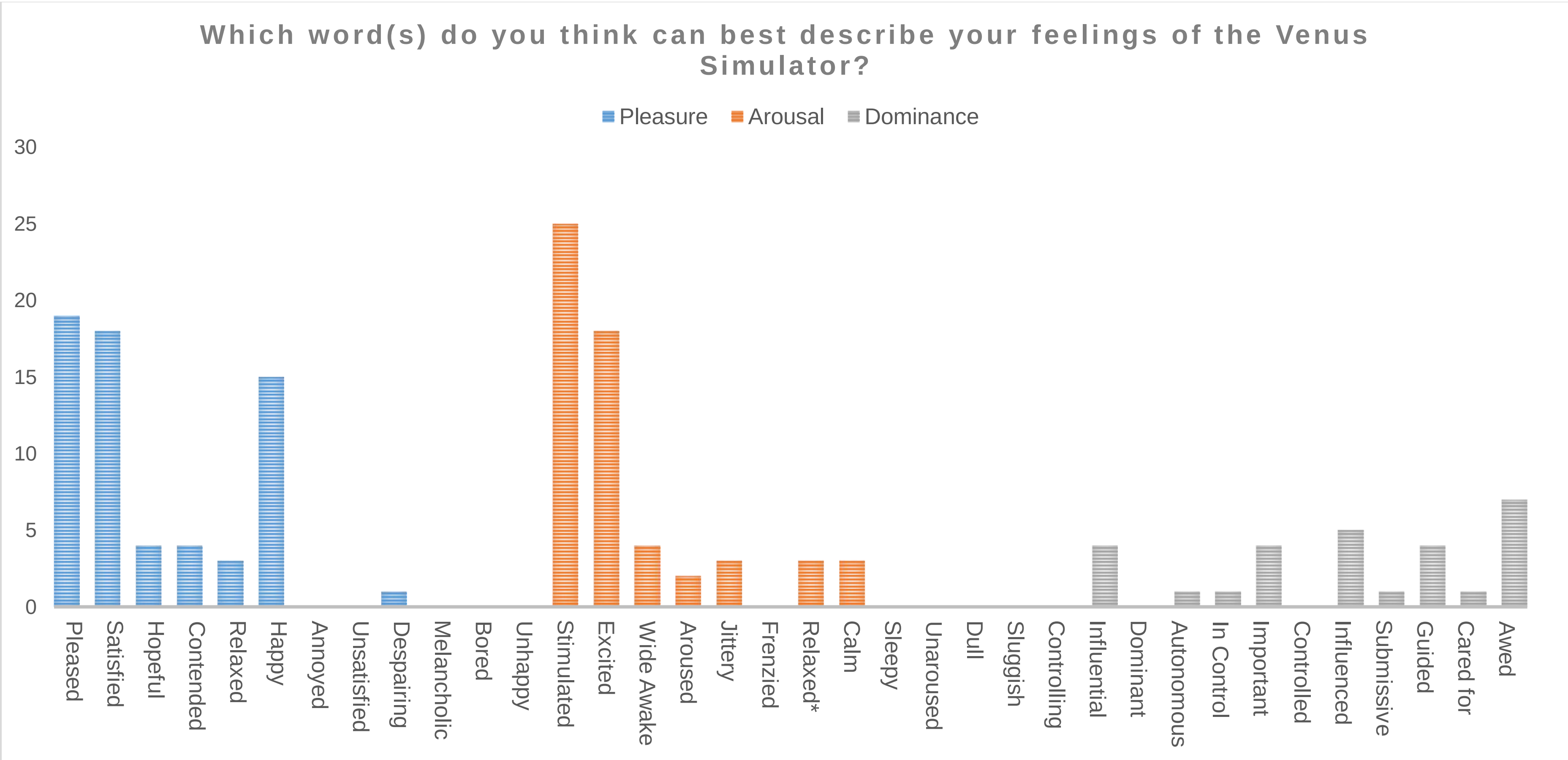


*Figure 5.15 Bar chart showing visitors' emotions of experiencing the Venus Simulator.*

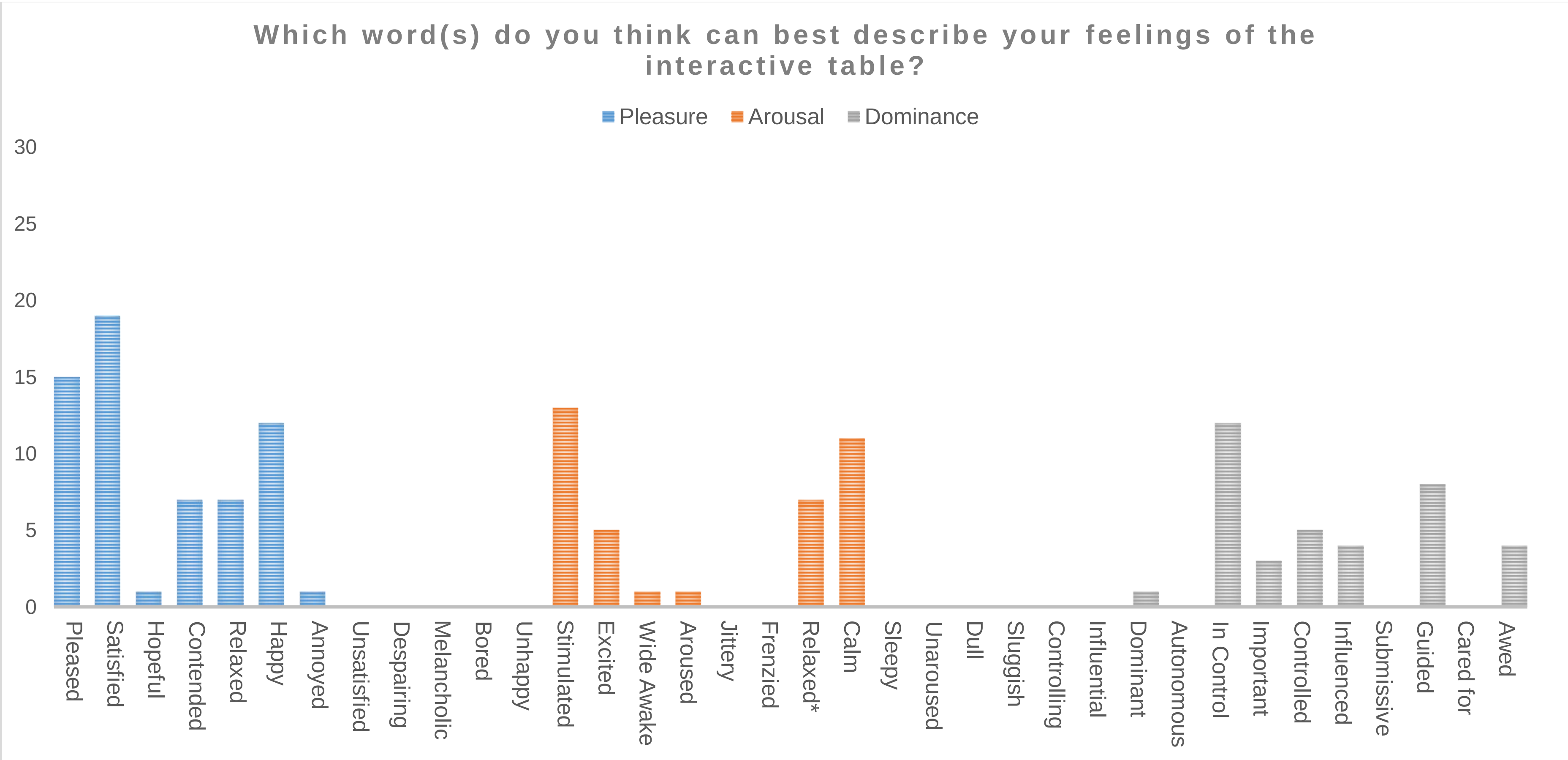


*Figure 5.16 Bar chart showing visitors' emotions of using the interactive table.*

In terms of which part of the interactives was the most impressive part for visitors, the data analysis results demonstrate that the full-dome screen and the narrative of the story were very impressive for the planetarium show audiences (Figure 5.17); the vibrating floor as well as the visual and sound effects left the biggest impression for simulator visitors (Figure 5.18); and users of the interactive table thought the information it provides and the big touch-screen were the best parts (Figure 5.19).

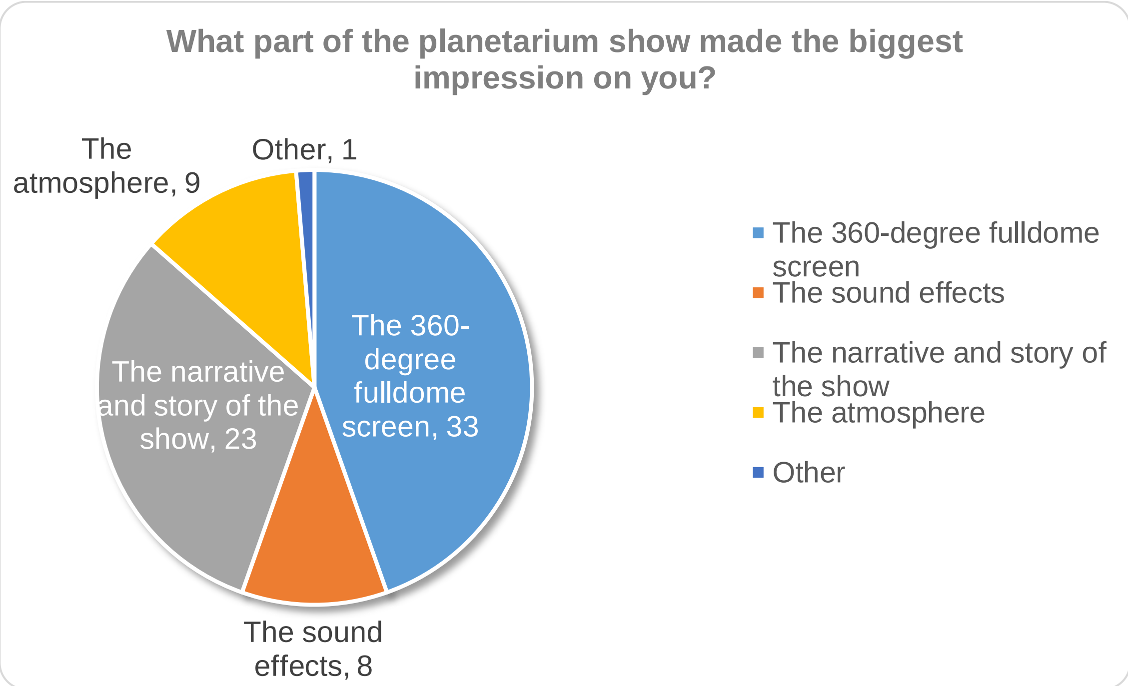



*Figure 5.17 Pie chart showing visitors' biggest impression of the planetarium show.*

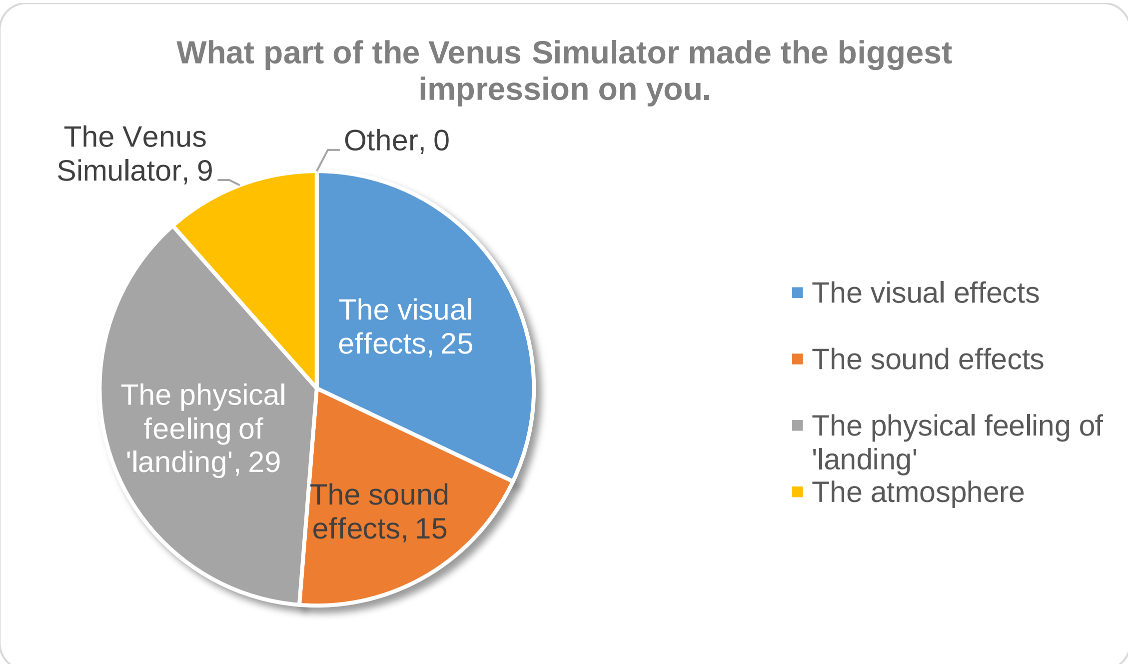



*Figure 5.18 Pie chart showing visitors' biggest impression of the Venus Simulator.*

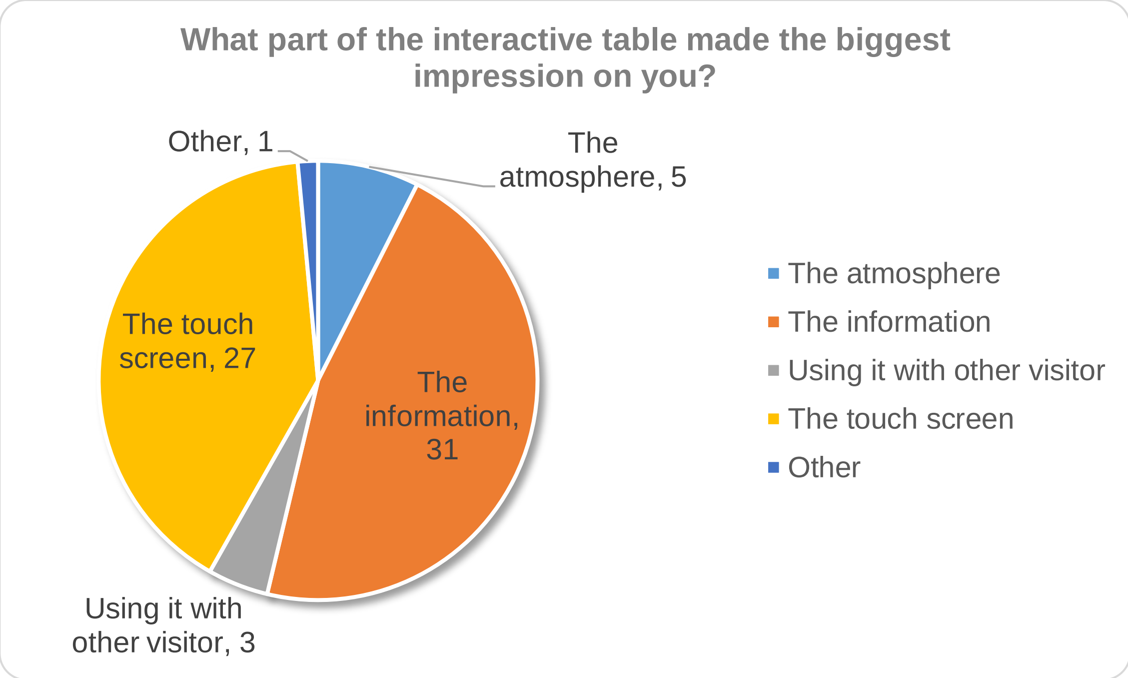



*Figure 5.19 Pie chart showing visitors' biggest impression of the interactive table.*

### 5.8.2 Analysing observations

In this section, both direct observation and indirect observation via video recordings were analysed. For the Space Oddities gallery, the researcher observed 60 visitor who visited the Space Oddities Gallery on the 31st May 2017. For the planetarium show 'We Are Stars!' and the Venus Simulator, a camera was placed in the front of the observed areas to record visitors' interaction with the selected digital media in the week of 1st to 7th May 2017. Although, the camera used in Cycle 1 recorded brighter footage than the camera used in the pilot in low light environments, it provided clear footage in the Venus Simulator and was able to identity visitors' interactions and facial expressions during the whole experience. However, some clips in the planetarium show recordings were still very dark. Therefore, in this section, the recordings collected in the Venus Simulator are analysed as examples of indirect observation in the first trail of iterative evaluation design.

Behavioural observation was conducted in the eight hours of footage of the Venus Simulator and 40 visitors' behaviours were analysed. In terms of the coding scheme, the study did not use an existing system developed and used in other studies. Although there are well-established coding systems of interaction of human-computer interaction, the existing systems were not considered to meet the needs for this study. As pointed out by Bakeman and Gottman (2006), the coding system should always begin with the privacy of one's own study and its own hypothesis. In this cycle, four types of information were coded:

A. Who they are?
   Gender (M/F), Age Group (18-44 years old / 44+ years old), Visiting group (individual visitors / adult group / group with children) and the size of group.
B. How long they spent?
   Unlike the interactive table which is located in the Space Oddities gallery where both the time spent in the gallery and the interactive should be noticed, the Venus Simulator is in a separate and independent room, thus, the time visitors enter and exit the simulator are recorded.
C. How they interact?
   - Verbal interaction (with other visitors),
   - Gesture interaction with the other visitor (pointing touching the projected wall, the floor, or the screen on the backside wall; taking photos; shaking, pointing, leaning and other bodily interaction with other visitors) and movement in the simulator
   - Eye contact (eye contact with others, looking at other visitors while taking instead of looking at the projection)
   - Looking around the space (looking around the projection on left and right sides, lights on the top and other directions while watching the video).
D. How did they feel?
   Using a 5-point Likert scale to record the pleasure and arousal level during the experience. The coding scheme of the 5-point Likert scale described as below:
   - 1 = Very calm (the participant is non-aroused during the whole experience, shows no sign of any excitement, and do not have any form of interaction with other visitors) / Very unpleasant (the participant shows obvious sign of extremely displeasure through facial expression or verbal expression).
   - 2 = Calm (the participant shows no sign of excitement during the whole experience, and has limited interactions with the exhibit or other visitor)

/ Unpleasant (the participant shows sign of displeasure through facial or verbal expression)

- 3 = Neutral (the participant shows no sign of excitement and has some interactions with the exhibit and other visitors) / (The participant shows no sign of displeasure or pleasure through facial and verbal expression)
- 4 = Excited (the participant shows some sign of arousal through verbal or bodily expression) / Pleasant (the participant shows some sign of pleasure, e.g. smile)
- 5 = Very excited (the participant shows obvious sign of high arousal through verbal or bodily expression, e.g. ‘Wow!’, ‘Look!’) / Very pleasant (the participant shows obvious sign of pleasure, e.g. laugh out loud).

Table 5.5 shows the number of female and male visitors observed is slightly different; the majority of adult visitors were in the age group of 18 to 44 years old (62.5%). Most visitors who took part in the activity were group visitors.

*Table 5.5 Demographics of the Venus Simulator visitors observed.*

| **Gender** | **Number (Percentage)** |
|---|---|
| Male | 17 (42.5%) |
| Female | 23 (57.5%) |

| **Age Group** | **Number (Percentage)** |
|---|---|
| 18-44 years old | 25 (62.5%) |
| 44+ years old | 15 (37.5%) |

| **Visiting Group** | **Number (Percentage)** | **Group size** | **Number** |
|---|---|---|---|
| Individual visitor | 4 (10%) | 1 visitor | 4 |
| Adult groups | 13 (32.5%) | Group of 2 | 11 |
| | | Group of 3 | 1 |
| | | Group of 4 | 1 |
| Groups with children | 23 (57.5%) | Group of 2 | 7 |
| | | Group of 3 | 9 |
| | | Group of 4 | 3 |
| | | Group of 5 | 3 |

| | | | |
|---|---|---|---|
| | | Group of 6 | 1 |

The video of the simulator is 4 minutes and 43 seconds long, Table 5.6 shows about 60% of visitors spent longer than 4 minutes in the simulator, which suggest the majority of observed visitors had a complete or largely completed experience of the simulator. Among all visitors observed, four of them spent less than 30 seconds, six visitors spent longer than five minutes and the average duration was 4 minutes and 5 seconds. Notably, the total time spent with the simulator is various: the shortest time spent is only 18 seconds, while there are also visitors who viewed the video twice and spent up to 10 minutes and 33 seconds.

*Table 5.6 Time spent of observed visitors in the Venus Simulator.*

| **Duration** | **Number** | **Cumulative Percentage** |
|---|---|---|
| Less than 30 seconds | 4 | 10% |
| 30 seconds to 1 minute | 3 | 1.5% |
| 1 minute to 2 minutes | 6 | 32.5% |
| 2 minutes to 3 minutes | 2 | 37.5% |
| 3 minutes to 4 minutes | 1 | 40% |
| 4 minutes to 5 minutes | 18 | 82.5% |
| More than 5 minutes | 6 | 100% |

The frequency of interaction with the simulator and other visitors was also distinctly different from visitor to visitor (Table 5.7). While the sample size of 40 people is not enough to reveal interaction models among the three types of visiting groups, the comparison of the interaction frequencies started to show a preference of different interaction types (Table 5.8). To be more specific, individual visitors were more likely to interact with the simulator by observing the environment and surroundings. Visitors in groups with children showed more frequent verbal and gesture interaction with other visitors in the group. Visitors in adult groups showed less interaction with both the environment and other visitors, and seemed to be more focused on the content and narrative of the video.

*Table 5.7 Lowest frequency, highest frequency and mean of the 4 types of interaction coded in the Venus simulator experience.*

| | **Verbal interaction** | **Gesture and movement** | **Eye contact** | **Look around** |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **Lowest frequency** | 0 | 0 | 0 | 1 |
| **Highest frequency** | 19 | 14 | 5 | 13 |
| **Mean** | 6.6 | 4.05 | 1.98 | 4.87 |

*Table 5.8 Comparison of mean frequencies of interaction among individual visitors, visitors in adult groups and visitors in groups with children.*

| | **Verbal interaction** | **Gesture and movement** | **Eye contact** | **Look around** |
|---|---|---|---|---|
| **Individual visitors** | 0 | 1.25 | 0 | 6.75 |
| **Adult groups** | 5.89 | 3.72 | 1.78 | 4.5 |
| **Groups with children** | 10.7 | 6.6 | 3.2 | 5.7 |

In terms of the pleasure and arousal level, most visitors were considered to be 3 or 4 in the 5-point scale and a few visitors showed high pleasure or arousal (Table 5.9). Similar to the interaction frequency, there were also noticeable differences of pleasure and arousal levels among visiting groups. As presented in Table 5.10, visitors in groups with children show more positive responses to the experience as well as higher arousal levels, while individual visitors' reactions are much more neutral. However, as the pleasure and arousal level were recorded by the observer, instead of self-reported by visitors themselves, the point may not accurately reflect how their feel. But it suggests that visitors in groups with children are more likely to express their emotions by facial expressions and gestures. Additionally, there were no significant differences between genders and age groups.

*Table 5.9 Pleasure and arousal level of the Venus Simulator visitors observed.*

| | **1**<br>(Displeasure / Nonarousal) | **2** | **3**<br>Neutral | **4** | **5**<br>(Pleasure / Arousal) |
|---|---|---|---|---|---|
| **Pleasure** | 0 | 0 | 20 | 14 | 6 |
| **Arousal** | 0 | 1 | 25 | 10 | 4 |

*Table 5.10 Mean of pleasure and arousal among three types of visiting groups.*

| | ***Mean of pleasure level*** | ***Mean of arousal level*** |
|---|---|---|
| ***Individual visitors*** | *3* | *3* |
| **Adult groups** | *3.5* | *3.33* |

| | | |
|---|---|---|
| **Groups with children** | *4.1* | *3.8* |

For the direct observation in the Space Oddities gallery, 60 adult visitors who viewed the gallery were observed. The observation sheet can be found in section 5.5.4, detailed observation records is in the Appendix 2.1.

In the total sample size of 60, the proportion of male (46.7%) and female (63.3%) visitors are predominately equal; 75% visitors observed were considered between 18 to 44 years old; most of them (78.3%) are in groups with children and the percentage of adult group visitors (13.3%) and individual visitors (8.3%) is much lower.

As shown in Table 5.11, the average time spent in the Space Oddities gallery was 3 minutes and 27 seconds, and the average time spent to use the interactive table was 1 minutes and 25 seconds. The duration was also significantly different in visitors: the table shows there were visitors who spent more than 26 minutes in the gallery while the shortest time spent was only 13 seconds; similarly, there are visitors who took almost 8 minutes to interact with the interactive table, as well as those who did not use it at all. The time spent in the gallery and to use the interactive between gender, age group and visiting group have insignificant variation.

*Table 5.11 Time spent in the gallery and with the interactive table of the 60 adult visitors.*

| | **Minimum** | **Maximum** | **Mean** |
|---|---|---|---|
| **Time spent in the Space Oddities gallery** | 0:00:13 | 0:26:05 | 0:03:27 |
| **Time spent with the interactive table** | 0:00:00 | 0:07:53 | 0:01:25 |

For the 53 visitors who used the interactive table, they preferred to communicate with their companions verbally to talk about whether to use the interactive or not and the content displayed on it (Table 5.12). However, regarding how to operate and navigate, more non-verbal communication by gesture was involved. In Table 5.13, the communication types of visitors in adult groups and the ones in groups with children show a large variation. More specifically, much less interaction occurred among adult groups, rather, it is very common for visitors with children to interact with each other through talking and body gesture.

*Table 5.12 Interaction among the interactive table users (N = 53).*

| | Participation | Content | Operation |
|---|---|---|---|
| **Only verbal communication** | 15 | 17 | 7 |
| **Only non-verbal communication** | 1 | 0 | 5 |
| **Both** | 6 | 1 | 13 |

*Table 5.13 The percentage of verbal and non-verbally communication in different visiting groups.*

| | | Participation | Content | Operation |
|---|---|---|---|---|
| Visitors in adult groups | Only verbal communication | 16.7% | 0% | 0% |
| (n = 6) | Only non-verbal communication | 0% | 0% | 0% |
| | Both | 0% | 0% | 0% |
| Visitors in groups with children | Only verbal communication | 32% | 39.5% | 16.3% |
| (n = 43) | Only non-verbal communication | 2.3% | 2.3% | 11.65% |
| | Both | 14% | 41.9% | 30.2% |

In terms of the emotional feedback of interacting with the touch table, visitors in the three groups tended to be neutral, in the 5-point Likert scale the pleasure and arousal mean values were 3.26 and 2.28 respectively.

### 5.8.3 Analysing Interviews

In the first round of the design cycle, 6 interviews were conducted for each digital interactive. All interviews were voice recorded. The recordings were then transcribed by the researcher for analysis. The results of analysing interview transcripts show that interviews do provide information regarding visitors' sensory and emotional experience.

Firstly, visitors were likely to describe their experience with similar expressions. Figures 5.20 to 5.22 below are word clouds generated from interview transcripts by using a text mining package and word cloud generator package in R. The word clouds show the frequency of words, larger font means the word has been mentioned multiple times while smaller size means lower frequency.

Across the three figures, we found frequent mentioned words were very similar, for instance ‘good’, ‘interested/interesting’ and ‘curious’. Compared to the questionnaire, where visitors could select words to describe their emotions belonging to three catalogues, in interviews, visitors were more likely to describe their feelings with the words that they were familiar with in everyday life. Thus, the responses have restricted ability to show emotions in different dimensions. Despite the similarity among the three figures, each of them provides information that reflects the characteristics of the digital interactives. In Figure 5.20 we see ‘screen’, ‘sleepy’, ‘comfortable’, ‘information’; in Figure 5.21 we find ‘vibration’, ‘immerse’, ‘floor’, ‘underneath’; and ‘bright’, ‘easy’, ‘big’, ‘bottoms’ in Figure 5.22. These variations in the visualization of interview data suggests, although visitors’ responses to the questions used more general words or words they were more familiar with, interviews do provides useful insights that cannot be shown in observations and questionnaires.


Figure 5.20 Word cloud of the planetarium show interview transcripts.


Figure 5.21 Word cloud of the Venus Stimulator interview transcripts.

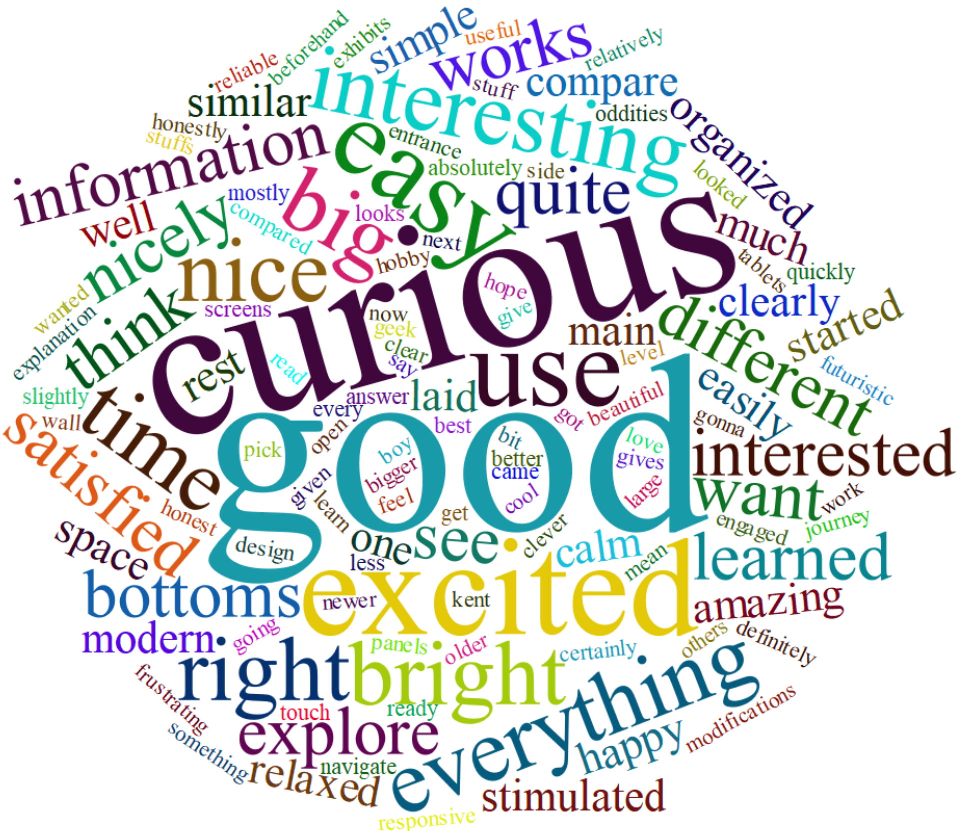



Figure 5.22 Word cloud of the interactive table interview transcripts.

Secondly, aside from the visualization, the interview transcripts also provided a great deal of useful feedback. One of the biggest strengths of the interviews was that they were able to collect rich data of visitors' sensory experience of interacting with the three in-gallery technologies. The response list below shows visitors' responses about the before-during-after experience. Although Q2-4 were designed to gather feedback of both sensory and emotional experience, very few descriptions were found about their emotions and participants were more willing to share their sensory experiences, about the physical senses, how they felt about the atmosphere, the layout and decoration of the space, as well as the technology. Compared to the other two evaluative tools, interviews gave participants more freedom to express how they felt from various aspects.

*Q2: How did you feel when you first walked into the planetarium/ simulator/ Space Oddities exhibition?*

> Planetarium show audience response: "It's smaller than I expected, but it looks clean, quite comfortable, and luxury in a way."
>
> Venus simulator visitor response: "It's quite cool. It's a good experience, I guess. It is just right, if it is any bigger you would have same experience. I think when you stand at the edges it's quite scary, it works quite well."
>
> Interactive table user response: "Good, it's nicely laid out, pretty clear. I like a lot of open space, which is nice. And, curious, it's pretty big, so yes curious, it's good."

*Q3: How did you feel during watching the show / using the table?*

> Planetarium show audience response 1: "I get very bad motion sickness, so I was quite nervous beforehand, I will feel sick, and I didn't feel sick at all, I was absolutely fine. I was interested that she warned people they might feel a little motion sickness, and she advised us to close our eyes, I actually didn't need to, but I thought it was very good advice."
>
> Planetarium show audience response 2: "I've been in big screen cinema before, but it's really an impressive one, to lie back and look properly. I knew it probably be the best to sit towards the middle, so I did sit with my family towards the middle, we had a very good view. And I think it starts really well

and I like the way it started with the zooming in, I think it's a really good way of getting people used to this experience."

Venus simulator visitor response 1: "It was really interactive, because of the floor, the vibrations and everything like that, you felt like part of it, because it feels completely separated like nicely from the rest of there. It was good, really interactive."

Venus simulator visitor response 2: "I was really interested and excited. Yeah, really excited. Because I think the movement of the floor, and the screen all around you, and make you feel you are actually there and actually moving."

*Q4: How did you feel after the show / using the table?*

Planetarium show audience response: "As we walked out, both my husband and my children said they find a little bit loss of balance, I actually found it was ok, but the three of them said they felt a little bit unsteady on their feet, which is interesting."

Venus simulator visitor response: "Relieved. Yeah, no, it's a really good start, and I like all the way through. You felt like you didn't know what was going to happen. And I generally did feel relieved when I came out. I felt quite immersed in the experience."

Interactive table user response: "It's just right really. The good thing is it's quite big, so my boy can see clearly. It's big and easy to use, that's the main thing about it, yeah."

Interviews are also an effective tool to help us reveal visitors' physical feelings in different stages of their experience. For instance, the planetarium show audience response to Q5 explained the mixed feelings of watching the show, and the two responses from visitors of the Venus simulator described how they were immersed in this combination of visual-sound effects and the impressive vibrating floor.

*Q5: How would you describe the physical experience of the show?*

Planetarium show audience response: "I guess my body felt really comfortable, because I felt sleepy, you know what I mean? Yeah, it was really comfortable,

> sometimes I felt dizzy maybe because you know, when the camera is moving around, so yes, I closed my eyes for several seconds."
>
> Venus simulator visitor response 1: "I think everything came together really well, so the visual side of things, the vibration on the floor, and the fact the screen surrounding you. I think the combination of all of those really put you in the scenario. I think if I just watch that on a flat screen, I'll just have one of them, I won't have the experience that put everything together."
>
> Venus simulator visitor response 2: "It was really good. Really cool. The vibration makes you feel like you are actually moving there. And it moves a lot like the feeling and the motion like matches the picture, so you're kind of like all in it like completely."

In addition to gathering sensory and emotional feedback, interviews provided other valuable information. Firstly, it gave advice about how the exhibition could be improved. For instance, for the planetarium show visitors suggested:

> "After you got through the tunnel it was quite dark, I think you need a few more lights to find seats and stuff like that."
>
> "I feel I would quite like an information sheet afterwards to look at, to recall all of information, I would like just a little bit of information sheets to take away that I could look at, and it can remind me and help me to recall it."

Although these suggestions are not the main targeted objectives of the research, it did provide useful information for the institution.

Likewise, the interviews gave more space to explain how visitors felt, and more importantly, why they felt that way. A good illustration of this could be the one response found in the interview of a planetarium show viewer; the question asked how they would describe their experience of watching the 360-degree planetarium show compared to other exhibits in the NSC. The visitor replied:

> "I think it was nice, but I prefer the Venus, because I think that one is more convincing, because when I walked into the planetarium, maybe because of my previous experience, I think it would be more interactive. And in many parts the narratives are, you know, animations, and you know, it's not really, you know, just like watch an animated film. And I don't think they make a good use of the

> planetarium in that sense. But for the parts, you know, they show you the universe and stars, that's really cool, like you're really going into the space, so I like that part, but I don't like the part with the cartoons and chemicals."

Detailed explanations of their feelings and impressions may be hard to obtain from both questionnaires and observations. In this aspect, interviews are one of the best tools for us to understand the emotional and sensory experience in a more comprehensive way and with more depth.

Moreover, the transcripts also show that educational value and usability are not only the classic perspectives when we understand and analyse in-gallery digital media from the academic point of view, they are also familiar two perspectives when visitors assess and describe their experience with interactives. We found participants kept referring to these two aspects, for example, 'I learned something, so pretty happy', 'easy to navigate', 'leaned a lot', 'it is pretty useful, I learned some interesting information. And the bottoms mostly work, which is quite cool', 'it's good, you can learn something from it', 'we've enjoyed it, and learnt a lot', when they describe their experience.

## 5.9 Limitations of Cycle 1 Evaluation Tools

### 5.9.1 Limitations of Cycle 1 questionnaires

After testing the questionnaire design in the first round of evaluative design, they have shown it is still an effective method to of measuring visitors' emotions and sensations with in-gallery digital media in some extend. More specifically, a one-page questionnaires enabled large sets of data to be collected in a comparatively short time period. In this research, it provided a great deal of demographic information which allowed us to know the profile of museum visitors. Also, when the sample set is large enough, these demographics might further support us to see certain patterns of emotional and sensory experience or preferences of interactives among different age groups, genders and visiting groups.

Another main strength of questionnaires is, by applying the PAD scale (Mehrabian and Russell, 1974), we started to see what emotions visitors may have while they are interacting with digital installations. Marketing and advertising studies have suggested it is a valuable verbal-based tool of measuring customers' emotional responses to products. By testing the PAD scale with three completely different formats of in-gallery technology, this has shown it is also an effective model to help us understand visitors experience in museum settings. It allows us to see the variety of emotions and the mixed feelings that visitors may have during the whole experience for the first time.

Acknowledging the strengths of questionnaires as an evaluative tool for this research, we may also see some limitations. For instance, although we are able to see what types of emotions people may have and start to see the emotional landscape in museum experience, it is difficult for us to understand the reasons of why they have certain types of emotions while relying on questionnaires alone. Additionally, while we see the success of measuring emotions in the questionnaire designed, it seems to lack an equal framework or model for evaluating the sensory aspect of the visiting experience. Although we could gather some sensory feedback in Q8, the choices provided are designed and selected by the researcher, therefore, visitors had limited choice and space to express how they physically felt.

### 5.9.2 Limitations of Cycle 1 observations

The analysis of data collected in the first trial of evaluative design has shown the value of using observation as a tool in visitor studies, as it provided a distinct set of data from the questionnaires and interviews. One of the most highlighted advantages as an evaluation tool is it be able to keep detailed track of the amount of time spent by each visitor on exhibitions and interactives, which might show associate learning, attention and many other factors (Serrell, 1997). Additionally, it allows us to see the interactions between visitors and between visitors and technology. For instance, in this round of research design, the verbal communication, non-verbal communication, as well as gestures and movement were coded, and in video recordings, frequencies of different types of interactions were observed.

On the other hand, there are also issues that need to be detailed. From the practical point of view, the challenge of capturing a clear image in low light conditions that are not uncommon for highly immersive digital environments like the planetarium, still exists. This problem could be solved by using a night vision camera, but this research would could not use this method due to limited budget. The second weakness of observation is the difficulty of presenting and coding various emotions and sensations. As the observation was conducted in the public space, it is practically impossible to set up cameras from multiple directions and have a closer look at participants' faces, consequently, it is hard to analyse specific emotions by tracking facial muscle. Meanwhile, it is difficult to capture sensory feedback. As mentioned in Chapter 2, senses are either our human body perceived from the external environment or derived from the internal body. In simple words, it is how our body feels, therefore it is more suitable to collect these by self-reporting methods instead of observation.

Overall, despite the fact that observation is less effective at collecting sensory and emotional responses of visitors' experiences with digital media in the museum environment, it is the only method in the three common evaluation tools that allowed real-time feedback of visitors' experience to be seen and recorded by observing facial, body and verbal expression.

### 5.9.3 Limitations of Cycle 1 interviews

In Chapter 2, we discussed the trend of the sensory turn and emotional turn in social sciences and humanities, as well as in museum studies. As a consequence, scholars need to be prepared to re-understand the sensations and emotions, and start to ask questions around this discourse. Actually, this might not only raise new requirements for scholars and researchers, visitors may also need to be prepared for this new conversation they might have between museums and themselves. The interview responses remind us that the two classic perspectives of learning and usability are also the topics that visitors are familiar with and might even feel more comfortable to talk about. Therefore, for this new perspective of sensation and emotion, they might need more support from us in order to understand and respond to the questions more precisely.

One main strength of the interviews is that it enabled us to collect detailed feedback of visitors' physical experiences. With interviews, we were able to know how they felt about the visuals, the sound, the lighting, the layout of the space etc., and more excitingly, enabled us to understand the reason behind it, to see what was the specific element in the experience that impressed them the most, to know how their bodies reacted to those sensory stimuli.

While noticing the effectiveness of gathering sensory responses, on the other hand, we found it is less efficient in measuring emotions. Although in the interviews, several prompts were prepared to encourage participants to share more emotional experiences, the results still show that less feedback was collected in this area. This may be due to the fact that emotions can be difficult to describe, it might also be because visitors have limited or not familiar with the set of vocabulary for describing emotional experience. Moreover, the one-word responses could also be a shortcoming that occurred in this round of interview design.

This chapter introduced the case study site at the NSC and the three digital installations, as well as describing the pilot study and the first cycle of the evaluative design. This evaluative design started with three common methods in visitor studies: questionnaires, interviews and observations. The analysed results show these classic tools could be used to measure visitor experience from the new perspective of sensations and emotions. Yet, this cycle also shows observing visitors in low light conditions is difficult, questionnaires should be improved in order to collect sensory feedback, and interviews should consider how to support and encourage participants to answer questions more precisely. These issues needed to be addressed in the next round of evaluative design.

# Chapter 6  Evaluative Design Cycle Two

## 6.1 Lessons Learned from Cycle One

### 6.1.1 Lessons learned from Cycle 1 questionnaires

In Cycle 1, the PAD scale used in the questionnaire to collect emotional responses was very efficient and provided rich data to help understand what kind of emotions visitors have while they were interacting with in-gallery digital technology. At the same time, compared to the effectiveness of measuring emotions, questionnaires in Cycle 1 lacked an equal method and model to gather sensory feedback. Therefore, the priority was to solve this in Cycle 2 and find a way of measuring sensory experience.

The second aspect that needs to be reconsidered is the open-ended question at the end of the questionnaires. Originally, the open-ended question was set to collect additional feedback that had not been covered by single-choice and multi-choice questions above. However, from questionnaires collected in Cycle 1, most visitors left this question blank or gave single word responses, e.g. 'interesting', 'good', 'great', which meant very limited information could be collected. Therefore, the idea of getting additional feedback through general open-ended questions may not suitable for this type of study.

Thirdly, the results show a mixed experience of multiple emotions that visitors had during the whole experience. In order to understand visitor' various feelings in more detail and more accurately, it was worth considering how to design the questionnaire so that it also included the ability to reflect. Asking participants to read and write during the activity was not considered in this research, as it would largely influence and disturb their engagement with the interactive, which did not fit the requirements of the NSC and the purpose of the study. Therefore, the most likely way of improving the questionnaire was by designing questions that targeted the measurement of emotions and sensations over a specific period of time.

### 6.1.2 Lessons learned from Cycle 1 observations

Although observation via video could be problematic in low light conditions, such as at the planetarium show, Cycle 1 has shown observation plays a significant role as an evaluative tool. Because it could present a different set of data compared to the other two tools, which were self-reported by visitors. Observation allows us to keep track of the time each visitor spent on the selected interactives and see the interactions among visitors and between visitors and the interactive.

Comparing these two types of observation conducted in Cycle 1, which are the direct observation in the Space Oddities gallery and the observation via video recording in the Venus Simulator, the indirect observation is considered more suitable for this research. It provided video recordings that made more detailed observational coding and analyses possible. Therefore, in this cycle, indirect observation via camera were used for both interactives.

In this cycle, the coding methods in observation should be improved. In Cycle 1, only the frequency of occurrence of verbal and non-verbal behaviours was recorded. This cycle aimed to identify specific types of interaction, record the occurrence of the behaviour, as well as the time point when the behaviour happened.

### 6.1.3 Lessons learned from Cycle 1 interviews

Interviews gave visitors more space to share how they felt. In Cycle 1, in order to encourage participants to tell more about themselves, several prompts were prepared for each question related to emotional and sensory experience. The main reason of giving prompts is to encourage, remind and inspire, however, some responses received after the prompts were still very short and brief. Therefore, if this test method is continued then additional supports, such as providing an instruction sheet before starting interviews or offering examples of how to describe sensory and emotional experience with interactive, would perhaps be a good approach.

However, another reason why it is difficult to describe sensory and emotional experience is because these feelings are only kept in our memory for short periods of time and might be hard to recall. For instance, the Venus Simulator experience is only 5 minutes long, but it is still very challenging to recall the feelings of a specific scene. It may not be hard for visitors to recall how they felt when they first walked into the simulator, but it could be challenging for someone to remember and describe about how did they feel in the scene that happened at the 1 minutes 10 second, or how did they feel when they saw the stunning view of Venusian skyline. In this sense, interviews when the activity is finished might not be the best tool to collect detailed responses of sensory and emotional experience. Therefore, as an alternative of post-experience interviews, this cycle investigated the potential of using concurrent think-aloud.

### 6.1.4 Improvements from Cycle 1 to Cycle 2

As already mentioned, a key component considered in this iterative design process of emotional and sensory evaluation framework is the temporal dimension. Why our evaluative framework needs to have the ability to capture visitors experience with in-gallery digital media concurrently? The idea of ‘two selves’, proposed and popularized by the Nobel Prize-winning psychologist Daniel Kahneman, may help to find the answer.

In order to get a clearer understanding about the idea of ‘two selves’, we need to take a look at the two famous experiments Daniel Kahneman (2011) conducted to prove his theory. The first experiment applied two measures of experienced utility and the results show an unexpected systematic difference between hedonimeter total and retrospective assessment. This study was designed by Kahneman and Redelmeier, who is a physician researcher at the University of Toronto. 154 patients participated in this experiment of a painful colonoscopy, the longest procedure lasting 69 minutes and the shortest lasted 4 minutes. They were asked to indicate the level of pain every 60 seconds during the process, zero being ‘no pain at all’ and ten ‘intolerable pain’.

Figure 6.1 shows the profile of two patients’ experiences of this process. These two patients had varied experiences, as you can see in the figure. Patient A had a procedure lasting about 8 minutes, and the experience ended at the highest pain level 8. While patient B had a much longer procedure of 24 minutes, and same as patient A, the highest pain level was 8, but the experience ended at pain intensity 1. This report of momentary pain the patient had in their procedure is what Kahneman called ‘hedonimeter totals’. If we assume that patient A and B used a similar scale of pain intensity to report their experience, then who suffered more in this experiment? Of course, in Figure 6.1, the majority of us would agree that B had a worse experience than A, as the total amount of pain (shaded area under the curve) is more than A, and more importantly, B had more than 2 times longer a procedure time compared A.

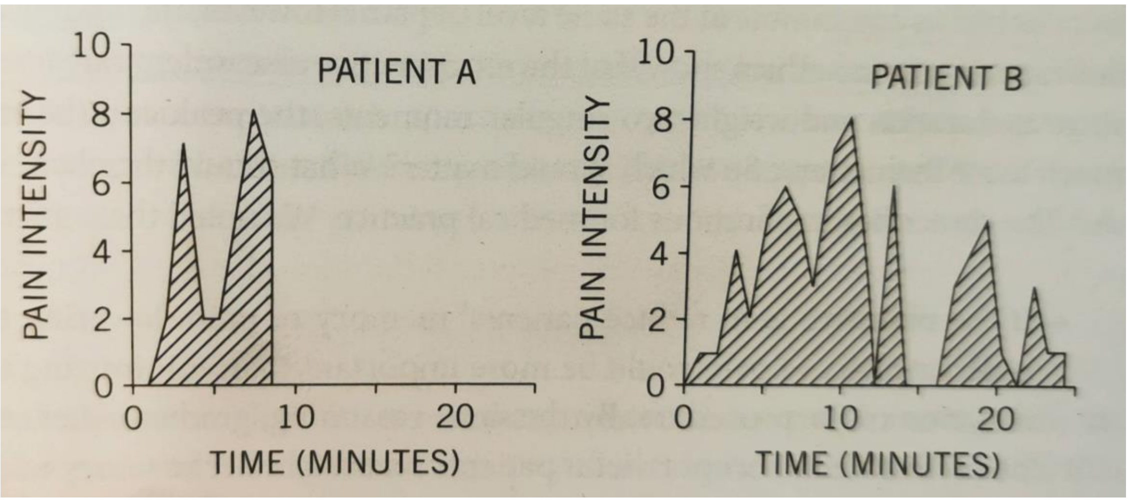



*Figure 6.1 Experience of two patients taking a colonoscopy (Kahneman, 2011: 379).*

Did patient A and B feel the same as the results of hedonimeter totals? To understand this, the participants were asked to rate the total amount of pain they experienced in the whole procedure. An instructor encouraged them to think of the pain intensity they reported, however, the results of the retrospective assessment were surprisingly different with the hedonimeter total reported. After statistics analysis of data collected, this experiment revealed two key findings that could explain the difference between hedonimeter total and retrospective assessment: peak-end rule and duration neglect. Peak-end rule means 'the global retrospective rating was well predicted by the average of the level of pain reported at the worst moment of the experience and its end' (Kahneman, 2011: 380); and duration neglect suggests 'the duration of the procedure had no effect whatsoever on the rating of total pain' (Kahneman, 2011: 380). Applying these two rules to the procedures of patient A and B, the retrospective assessment results of them could be easily understood. The duration neglect tells us that although B had a longer procedure, the rating of total pain would not be influenced. Applying the peak-end rule to their experience, the peak-end average of patient A is 7.5 (the peak is 8 and ends at 7), while patient B had a much lower average 4.5 (the peak is 8 and the end is 1). From this perspective, patient A had a worse memory of this experience than B.

Which measurement reveals the experience of patients? The hedonimeter total shows patient B experienced more pain during the procedure, and the retrospective assessments tells us that patient A had a worse memory of pain. This distinguished difference between two measurements, according to Kahneman (2011), is caused by the results that were reported by two different selves. The report from the patient is every 60 seconds, it is reported by the 'experiencing self', it is the self that answered the requisition of ‘Does it hurt now?’ On the other hand, the retrospective report is answered by the ‘remembering self’, and the question is ‘how was it, on the whole?’

Therefore, the fundamental difference between the two selves is the difference of our experience and memory. The ‘experiencing self’ speaks for our moment-based experience, it reports how we feel at a specific moment. On the contrary, the ‘remembering self’ speaks for our memory, it reports the overall impression of the experience and stores it in our memory. Just as shown in the first experiment, where the ‘experiencing self’ does not have a voice. In the meantime, the ‘remembering self’ keeps records and governs what we learn from our past experience for living, it is the one that speaks and makes decisions although it may be wrong sometimes.

Which voice should we listen to: the voice of our ‘remembering self’ or the ‘experiencing self’? To answer this question, Kahneman (2011) carefully designed controlled experiments with his colleges, which he named ‘cold-hand situation’ (the technical name is cold-pressor). In this experiment, participants were asked to put their hand up to the wrist in cold water at 14-15 degrees Celsius, until they were invited to remove their hand, and then were offered a warm towel. During this process, participants continuously record their pain by using the control arrows on a keyboard by the free hand. Each participant is told they will have three cold-hand trials, but actually, they only endured two episodes; a short episode of 60 seconds and a longer episode of 90 seconds. Each episode was with a different hand and the episodes were separated by 7 minutes. The short trial consisted of the immersion of the hand in cold water at 14 Celsius. Participants experienced painful cold, but not intolerable, and at the end of the trial the instructor asked them to remove their hand and offered a warm towel. For the longer trial, the first 60 seconds were the same as the shorter trail. In the last 30 seconds, the instructor opened a small valve which allowed slightly warmer water into the tube. The temperature of the water rose by approximately 1 degree and this rise of water temperature as just enough for most participants to detect a decrease of the intensity of pain. When participants finished these two trials, they were asked to choose to repeat one of the experiences they had with their left hand or their right hand.

The purpose of this controlled experiment was to create a conflict between the ‘experiencing self’ and the ‘remembering self’, but also, a conflict of the experienced utility and the decision utility (Kahneman, 2011). As learned from the first experiment, we could predict that because of the peak-end rule, participants would more likely repeat the shorter episodes, as it was the trial that was less painful when they recalled the experience retrospectively. Meanwhile, the duration neglect suggests that participants might ignore the 30 seconds difference of experiment duration. Did participants choose to repeat the longer episode instead of the shorter one? Yes, they did. The results show that more than 80% of participants decide to repeat the longer trial. Additionally, Kahneman (2011) proposed another question, what would happen if the instructor asked them whether they wanted to repeat the full episode or just the first 60 seconds of it? Kahneman believed participants answers would be only the first 60 seconds of it, naturally. Here, although participants knew which trial was longer, they still would not use this knowledge and made the decision to choose the more favourable memory or less unfavourable memory.

Through the two famous experiments conducted by Kahneman, the difference of 'remembering self' and 'experiencing self' and their influence of our decision-making process is explained. This idea of two selves is inspiring for visitor studies and evaluations as well. In Cycle 1, both questionnaires and interviews could be seen as retrospective assessment, therefore, it is where we see the feedback from the 'remembering self'. The results of analysing this type of assessment, provided access to see how visitors felt about the selected interactives in general, while on the other hand, it lacked the ability to present their momentary-based experience. In this study, both momentary-based experience and memory-based experiences are considered equally important. Although memory is part of the experience that visitors will take away with them and keep for the future, only the 'experiencing self' could tell us how they felt emotionally and how their body felt with the environment, atmosphere, the sound, the visual etc. when interacting with in-gallery technology. The evaluative tools applied in Cycle 1 are more effective to collect overall feedback on the digital experience, as they are reported from the 'remembering self'. Therefore, this cycle aims to find an approach that could allow us to hear the feedback from the perspective of 'experiencing self' and to understand visitors' emotional and sensory experience at each stage/moment during the activity.

## 6.2 Designing Evaluative Tools

After testing the first prototype of three traditional evaluation methods in museum studies, guided by the results of analysing the first round of data, and while reflecting on the limitations and lessons learned from Cycle 1, this section discusses the design of evaluative tools in Cycle 2. Firstly, the second version of questionnaires has been improved in two key aspects: introduction of a new model for measuring sensory experience and a re-design of the PAD question. Secondly, the mix of direct (in the Space Oddities Gallery) and indirect observation (in the Venus Simulator and the Planetarium) has been changed to indirect observation via video recording in all three digital environments. Thirdly, inspired by the idea of 'two selves', the interviewer has been replaced by 'think-aloud' method.

### 6.2.1 Questionnaires version two

The design of the second version of questionnaires, compared to Cycle 1, has four main changes. Take the questionnaire designed for the planetarium show, for example (Figure 6.2). Firstly, the layout of the questionnaire has been improved. As you can see on the top of the questionnaire, the 'Who you are?' part has been simplified. To be more specific, Q4 ('Have you been to the National Space Centre before?') in Cycle 1 questionnaire has been deleted, this is mainly because compared to gender, age, and visiting groups, previous visiting experience is comparatively unnecessary for this particular research. Also, 'What You Thought of the Show?' part has been split into two sections: Body and Mind. In the meantime, Q5 (Have you watched a 360-degree film before?) and Q6 (What is your overall impression of this 360-degree film experience in the Sir Patrick Moore Planetarium?) have been removed. Deleting Q5 is because the main purpose of this questionnaire is to gather sensory and emotional feedback of visitors in general, instead of focusing on understanding the difference between visitors who are new or familiar with the full-dome planetarium. Deleting Q6 is based on the results of Cycle 1, as the general response and overall impression was not contributing to the main questions of sensations and emotions. Moreover, the sequence of the sensory and emotional questions has been exchanged. This is because, unlike in Cycle 1, main questions are multi-choice or single-choice questions, the 'Body' part here are open-ended questions. Visitors start with sensory experience questions, then fill in the easier multi-choice questions in the end.

**How Was That?**

**Who Are You?**

Are you male or female? ☐ Male ☐ Female

Which age group do you fit into?

☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55+

Who are you visiting the National Space Centre with today?

☐ By yourself ☐ With children ☐ With adults

**What You Thought of the Exhibit?**

BODY

First, we would like to know about your **sensory and physical experience** of the show.
Tell us the three things that first come to mind about the physical sensation of being inside the Planetarium.

1. ☐ 2. ☐ 3. ☐

When you first walked inside the Planetarium, how did the environment make you feel?

When you were watching the show, what did you think of the visual experience?

What did you think of the sound experience?

MIND

Next, we would like to know more about your **feelings and emotions** of the show.
Look at the following words:

| | | | |
|---|---|---|---|
| 1. Annoyed | 2. Pleased | 3. Unsatisfied | 4. Satisfied |
| 5. Despairing | 6. Hopeful | 7. Melancholic | 8. Contented |
| 9. Bored | 10. Relaxed | 11. Unhappy | 12. Happy |
| 13. Stimulated | 14. Calm | 15. Excited | 16. Sleepy |
| 17. Wide awake | 18. Aroused | 19. Unaroused | 20. Dull |
| 21. Jittery | 22. Sluggish | 23. Frenzied | 24. Controlling |
| 25. Controlled | 26. Influenced | 27. Influential | 28. Submissive |
| 29. Dominant | 30. Guided | 31. Autonomous | 32. Cared for |
| 33. In control | 34. Awed | 35. Important | |

OK, choose <u>up to 5</u> words (in each case) that best describe how you were feeling

- <u>before</u> the show ☐ ☐ ☐ ☐ ☐
- <u>during</u> the show ☐ ☐ ☐ ☐ ☐
- <u>after</u> the show, when you were making your way out ☐ ☐ ☐ ☐ ☐

*Figure 6.2 Version 2 of questionnaire designed for the planetarium show 'We Are Stars!'*

The most important improvement in this second version of questionnaire is the sensory questions. These questions are based on the Sensory Experience Elicitation Protocol (SEEP) developed by Gretzel and Fesenmaier (2010). Designing sensory questions based on SEEP is because the results from Cycle 1 show the first version of questionnaires lacked the ability to present a clear image of visitors' sensory experience, and SEEP seemed to be a solution for this shortcoming. As pointed out by Gretzel and Fesenmaire (2010), one feature of sensory experience is it is processed unconsciously. In this research, if visitors perceive sensory information unconsciously, it would be difficult for them to describe sensory stimuli that they are unaware of. Thus, using traditional approaches to capture the 'unknown' experience could be problematic.

The SEEP is an elicitation technique designed by combining the advantages of metaphor elicitation and laddering (Gretzel and Fesenmaire, 2003). The metaphor elicitation and laddering are two types of elicitation techniques. The metaphor elicitation normally uses an image that represents a visual metaphor as the initial probe (Zaltman, 2003). Participants are required to describe the visual metaphor provided and explain how it could relate to the domain in the question. Then, they are queried again to encourage further feelings and thoughts based on their responses (Zaltman, 2003). According to Grunert and Grunert (1995), laddering specifically aims to understand the cognitive structure of consumers' minds. Typically, it applies a series of direct questions that are designed in a strict sequence in order to lead consumers to consider things from a concrete concept to a more abstract concept (Reynolds and Gutman, 2000). Both of these two elicitation techniques are normally applied in the context of qualitative research, such as the in-depth one-to-one interviews. The SEEP is developed based on the advantages of these techniques to reveal sensory attributes associated with a product or a destination that act as a part of a quantitative survey questionnaire (Figure 6.3).

**We would like to learn about the way you think and feel about pleasure trips to Destination X**

When you think about Destination X, what are the **three things or feelings** that **first come to**

1. 2. 3.

**Imagine** that you have just arrived at Destination X. You walk inside your hotel room, and you open the window…what do you see?

**Now imagine** that you have finished unpacking. What are you going to do next?

**You are ready for dinner**. The waitress comes to your table to take your order. What are you going to order?

**Close your eyes** and think about a vacation to Destination X. What color dominates your mental image?

What kinds of scents do you smell during this pleasure trip to Destination X?

What sounds do you hear?

*Figure 6.3 SEEP questions (Gretzel and Fesenmaire, 2003: 142)*

In the original study, the SEEP was used to measure sensory association with travel destinations in consumers' minds. The Cycle 2 questionnaire designed sensory experience questions following the key concept and structure of the SEEP framework, to lead visitors to recall their sensory feelings during the activities. As you can see in Figure 6.2, the sensory questions start with a sentence that briefly introduces this section, and then asks respondents to write down three words or phrases that can describe their physical and sensory experience during the activity. After the comparatively easy questions to start the conversation around senses, the questionnaire tries to encourage respondents to share further sensory feelings by answering specific questions targeted on major individual senses that evolved in the selected activity. Therefore, compared to the initial version, the structure and model drawn from the SEEP added a new element to the questionnaire, that could lead participants to recall their sensory feelings of interacting with in-gallery digital media.

Additionally, the second version of the questionnaire expanded the emotion questions by asking them before, during and after the experience. In the first version of the questionnaire, participants were asked to choose word(s) that they thought could best describe their feelings, however, there was no suggestion or limit in terms of how many words they should select. In the feedback collected, there were participants who only chose one word from the list, while there were also others who selected up to six words. Therefore, in the second version, five boxes for each emotional experience question were given, to give participants a clear guideline.

The distribution of questionnaires follows the same process that has been done in Cycle 1. For the Venus Simulator and the interactive table, the researcher distributed questionnaires to small groups and individual visitors with notice placed in the exhibit areas that informed visitors research was going on. For the planetarium show, with the supportive announcements given by the space crew, the researcher waited outside of the exit of each selected show and distributed questionnaires to audiences when they finished the show.

### 6.2.2 Observations version two

In Cycle 2, indirect observation via video recording was applied in the Venus Simulator and Space Oddities Gallery. In the simulator, a camera was placed in the same place as in Cycle 1, on the top of the curved wall and with a focus on the centre area of the room. In the Space Oddities, the camera was secured on a metal rack facing the entrance of the gallery. The camera recorded visitors who used the interactive table and faced to the camera. A notice was placed in the observed area.

In Cycle 1, the frequency of the occurrence of four types of interactions were coded: verbal interaction, gesture and movement, eye contact, and looking around. In this cycle, behaviours occurred during the activity have been divided into two types: verbal communication and non-verbal interaction. Verbal interaction including conversation between the observed subjects and other visitors and the text reading (e.g. read out the content on the interactive table). Non-verbal interaction including the interactions among visitors (including body language such as pointing to somewhere and touching someone, and other interactions such as taking photos); interaction with the exhibition (for the simulator, this included looking to different sides of the room, touching the screen at the back of room, holding the glass barrier etc.; and for the interactive table, this included touching the table and walking around the table).

### 6.2.3 Concurrent think-aloud

Additional to the improved versions of observation and interview methods, the third tool tested in Cycle 2 was a think-aloud protocol. It is a method that asks participants to constantly verbalize their thoughts during the test. It is a widely used tool in cognitive science and Human Computer Interaction (HCI). Think-aloud method has its roots in cognitive psychology, since it was popularized in the 1980s (Cooke, 2010). With guidelines prescribed by Ericsson and Simon (1993), think-aloud was originally used to understand the human information processing system.

The two frequently used types of think-aloud methods are concurrent think-aloud (CTA) and retrospective think-aloud (RTA) (van den Haak et. al, 2003). The main difference between them is the time that protocol data is collected. In CTA, participants verbalize their thoughts while doing the task and reflect ongoing cognitive activities, including information and thoughts processed and how it is processed (Hannu and Pallab, 2000). In RTA tests, participants report their thoughts when the task is completed. To conduct think-aloud protocol retrospectively, participants behaviours during the process of the finished task are video recorded and then watched in retrospect. Each think-aloud method has its advantages and drawbacks. First of all, CTA is more timesaving than RTA, however, this also led to the result that participants in CTA tests might perform better or worse than usual. Participants might perform better because of the structured working process or they might perform worse due to the double workload (Russo et al. 1989). One the other hand, in RTA tests, participants can manage the pace by themselves and focus on one task at a time. This difference is particularly noticeable when the participant is verbalizing in a non-native language. The second key difference is the ability to reflect details and specific things occurring during the test. As stated by Ericsson and Simon (1993), vital information might be missed in RTA, as participants may forget specific details during a task when they recall their thoughts based on video recordings. The third difference is the concern of bias and reliability. In this aspect, participants in RTA have more opportunity to modify and edit their thoughts for reasons of social desirability and self-representation (van den Haak et. al, 2003).

Nevertheless, both RTA and CTA have their strengths as tools for research and in some usability tests, they are considered as equal alternatives (Nielsen, 1993). After comparing the features of the two types of think-aloud methods, CTA was considered more suitable for this research. Firstly, it is because emotion and sensory experience are details and specific feelings that participants have during the process of interacting with the selected digital exhibits, and participants are more likely to report more details in CTA. Another reason is, ideally, to improve the validity of RTA, participants should verbalize their thoughts right after the activity is finished, however, this requirement is difficult to achieve in the exhibition space.

According to Ericsson and Simon (1993), there are three levels of verbalizations; level 1 and level 2 verbalizations are valid for task performance, while level 3 verbalization is not reliable. This difference in validity is because of the additional processing required in the process of verbalization. To be more specific, level 1 verbalization is a direct report of participant's inner speech from short-term memory. This type of information is one that is already in the participant's 'present focus of attention in verbal form, as described by Hertzum et al. (2009). Level 1 verbalization is the most reliable because it does not involve intermediate processes and special effort to communicate them. For example, reading text provided on a screen and reporting a sequence of numbers while calculating simple mathematic questions. Here, the second example involves more effort than the first one, it still belongs to the level 1 verbalization as the numbers reported are in the same form as the result of calculation. Level 2 verbalization compares to level 1, but involves explication of information that is not originally in verbal form. Therefore, it requires additional processing to transfer image or abstract concepts to verbal form before reporting the information. For instance, verbal coding of smell, visual stimuli, and movement are level 2 verbalizations (Whitehead et al., 2015). Contrasted to level 1 and 2 verbalizations, level 3 verbalizations introduce new information to the participant's focus of attention. Moreover, it requires additional cognitive processing from long-term memory (Cooke, 2010), for instance, as participants explain their thoughts and behaviours and to retrieve further information from their memory (Hertzum, et al., 2009). Also, the verbalizations prompted by the facilitator during the test, such as 'go on…' or 'anything else?' are level 3 verbalizations (Cooke, 2010).

The procedure of CTA in this research was straightforward. The researcher approached visitors who intended to view the selected digital installations and briefly introduced the research project. If the visitor was willing to participate, they were asked to read and sign the Information Sheet and the Participant Consent Form. Next, participants had 2 minutes to read the instruction sheet carefully. Figure 6.4 is the example of a guide to participants who took part in CTA. Participants were asked to read it before the test. As shown on the figure, participants were encouraged to verbalize their emotional and physical experiences during the activity. According to the levels of verbalizations discussed above, CTA in this research is a level 2 verbalization, which is considered to be valid data about task performance as defined by Ericsson and Simon (1993). Once participants understood what they were expected to verbalize, they were given the clip-on microphone to wear and began the test. During the process of CTA, the instructor did not interrupt or prompt participants. When the test was finished, the instructor asked two follow-up questions, which were:

1. How would you describe the overall experience of the Venus Simulator / interactive table?
2. How would you describe your experience with the Venus Simulator / interactive table compared to other exhibits in the National Space Centre?

The two follow-up questions aimed to understand how the participants felt about the selected interactives in general and how they felt it compared to other digital installations at the NSC.

**Think-Aloud**

We would like to know about your experience of the Venus Simulator. Please tell us your thoughts and feelings while experience and interacting with the exhibit.

| | |
|---|---|
| 1. Describe how you feel when you walk into the exhibit area.<br><br>(For example, 'I feel excited, because the screen is very big'; 'I feel a bit unhappy, the room is too dark'; etc.) | 2. Describe how you feel during the experience.<br><br>(For example, 'I am curious about what is going to happen'; 'I start to feel sleepy'; etc.) |
| 3. Describe the physical experience of the activity.<br><br>(What it sounds like, looks like, how does your body feel? Is the show loud, bright, dark, cold, warm etc.?) | 4. Describe how you feel when the activity is finished.<br><br>(For example, 'Feel released'; 'Unsatisfied, it is not as good as I thought'; etc.) |

*Figure 6.4 Example of instruction sheet provided for CTA participants.*

In terms the sample size of think-aloud, we refer to the studies of Virzi (1992) and Nielsen (1994), as a small sample size of five or six participants would be enough to generate a considerably large result. Therefore, Cycle 2 planned to recruit five participants to conduct think-aloud tests for the interactive table and the Venus Simulator. The nature of the test needed participants to verbalize their thoughts and speak about how they felt while there are interacting with the selected installations. However, the planetarium show was similar to a cinema environment, where viewers were supposed to remain quiet. Therefore, the think-aloud test was not conducted in the planetarium show, as it was determined it might influence other visitors' experiences.

## 6.3 Data Analysis

### 6.3.1 Analysing questionnaires

In the second round of evaluative design, 125 questionnaires were collected for the three selected digital interactives. This section follows the structure of the questionnaire, and presents results of data analysis of demographics, feedback of the sensory experience and the emotional experience, respectively. The Cycle 2 questionnaire followed the same methods of approaching visitors as that of Cycle 1 (see Chapter 5).

The first part of the questionnaire asked three basic demographic questions: gender, which age group they belonged to and who they visited the NSC with. The major purpose of this part was to make sure that the participants who took part in the research included visitors from different demographic groups and data collected could represent general adult visitors. This part of the questionnaire was analysed in SSPS, the coding instructions were similar to the ones used in analysing the first version of the questionnaire (see Chapter 5): the main statistic function used was frequencies. Table 6.1 below shows visitors' demographic information collected in the three in-gallery interactive technologies.

*Table 6.1 Visitor's demographic informational collected in the Cycle 2 questionnaires.*

| | | Planetarium show (N = 45) | Venus Simulator (N = 40) | Interactive table (N = 40) |
|---|---|---|---|---|
| Gender | Male | 24 | 19 | 19 |
| | Female | 21 | 21 | 21 |

| | | | | |
|---|---|---|---|---|
| Age Group | 18-24 | 5 | 7 | 7 |
| | 25-34 | 10 | 13 | 8 |
| | 25-44 | 7 | 9 | 14 |
| | 45-54 | 6 | 6 | 5 |
| | 55+ | 17 | 5 | 6 |
| Visiting Group | Individual | 1 | 2 | 3 |
| | With Adults | 31 | 13 | 19 |
| | With Children | 13 | 25 | 18 |

Table 6.2 to Table 6.4 show the results of the first sensory experience question, which asked visitors to write down things that first came to their minds about the physical sensory of being inside the chosen digital environment. The feedback collected for this question was first entered into a txt. file and then imported to R (The R Project to Statistical Computing). The main function used in R is ‘frequencies’ to record frequencies of words in the target text. It is a simple and efficient tool to analyse the word frequency, especially for this question, as all feedback was either a single word or a short phrase.

As discussed in section 6.1.1, the noticeable limitation of questionnaires designed in Cycle 1 was, although there were able to show various emotions across three dimensions, they did not have an equal framework or model that could help to show the physical and sensory experiences. Therefore, the SEEP elicitation protocol has been introduced into Cycle 2. As you can see in Table 6.2 to Table 6.4 there are still many words participants used to answer physical and sensory experience that still belong to the category of ‘emotions’ instead of ‘sensations’. For instance, in Table 6.2 participants wrote ‘exciting / excited’ and ‘happy’, in Table 6.3 we see ‘happy / happiness’, ‘calm’, and we find ‘exciting / excited’ and ‘interesting / interested’ in Table 6.4. Additionally, adjectives such as ‘good’, ‘amazing’ and ‘cool’ also appear multiple times here. These might be because it was an unfamiliar topic of thinking and talking about sensory experience or it was hard to distinguish the difference between emotions and sensations for most visitors.

*Table 6.2 Physical sensation of being inside the Planetarium.*

| Term | Frequency |
|---|---|
| Comfortable / Comfy / Comfortable | 9 |
| Dizzy / Dizziness | 6 |
| Immersive / Immersing / Immersiveness | 6 |
| Disorientating / Disorientated | 4 |
| Exciting / Excited | 4 |
| Happy | 4 |
| Motion | 4 |
| Moving / Movement | 4 |
| Amazing | 3 |
| Flying | 3 |
| Large | 3 |
| Spinning | 3 |
| Expected | 2 |
| Fun | 2 |
| Interesting / Interested | 2 |
| Peaceful | 2 |
| Realistic | 2 |
| Seats | 2 |
| Space | 2 |
| Warm | 2 |
| Wow | 2 |

Despite the fact there are a few words that describe visitors' emotional feelings, this question gave us a great deal of insight to participants' physical and sensory experience. Unlike the multi-choice question in Cycle 1, this first question in the SEEP applied here allowed visitors to recall their memory and tell us how they felt being inside the three digital environments. The most frequently mentioned words used by the planetarium show audience include: ‘comfortable / comfy’, ‘dizzy / dizziness’ and ‘immerse / immersiveness’; while six users of the interactive table described their experience by using ‘informative / information’ and ‘interactive’; and many participants used ‘realistic / realism / reality / real’ to describe their feelings of being inside the Venus Simulator. These frequently mentioned words are able to reflect the key feature of each installations.

Also, the questionnaire gave even more detailed feedback on individual senses. For instance, in the planetarium (Table 6.2), participants used many words relating to the visual effects. They described their experience using ‘motion’, ‘moving / movement’, ‘disorientating / disorientated’, ‘flying’ and ‘spinning’. The sense of ‘moving’ and ‘flying’ are linked to the visual effect of the immersive full-dome screen, at the same time, this strong and vivid visual effect may also cause dizziness and disorientation for some visitors. Moreover, it allows us start to see that actually the comfort is an essential part of physical experience, the temperature (‘warm’), the space and the seats could be the parts that first come to visitors’ minds when they recall the planetarium show experience. Similarly, some interactive table users (Table 6.3) used words such as ‘quite’ and ‘light / lighting’ and viewers of Venus Simulator (Table 6.4) used ‘dark / darkness’, ‘noise / noisy’, and ’quiet’, which are related to the environment of the exhibition space. Additionally, in the Venus Simulator, eight participants wrote words or phrases relating to the vibrating floor, including ‘shaking / shaky’ and ‘vibration / vibrates’.

As these three tables show, the first question in the sensory experience section of the Cycle 2 questionnaire were not able to embody the main characteristics of each experience, but also collected feedback of visual, sound, sense of movement, temperature and other details of sensory and physical experience of being inside the digital exhibits.

*Table 6.3 Physical sensation of using the interactive table*

| Term | Frequency |
|---|---|
| Informative / information | 6 |
| interactive | 6 |
| Interesting / interested | 6 |

| | |
|---|---|
| Happy / happiness | 5 |
| calm | 4 |
| Excited / exciting | 4 |
| Quiet | 4 |
| Fun | 3 |
| Big | 2 |
| Curiosity / curious | 2 |
| Easy | 2 |
| Lighting / light | 2 |
| Modern | 2 |
| Space | 2 |

*Table 6.4 Physical Sensation of Being inside the Venus Simulator*

| Term | Frequency |
|---|---|
| Exciting / Excited / Excitement | 10 |
| Realistic / Realism / Reality / Real | 7 |
| Fun | 5 |
| Interesting / Interested | 5 |
| Good | 4 |
| Immersive / Immersed | 4 |
| Shaking / Shaky | 4 |
| Vibration | 4 |
| Cool | 3 |
| Dark / Darkness | 3 |
| Vibration / Vibrates | 3 |
| Awesome | 2 |
| Different | 2 |

| | |
|---|---|
| Noise / Noisy | 2 |
| Quiet | 2 |
| Screen | 2 |
| Stimulated | 2 |
| Tense | 2 |

Tables 6.5 to 6.7 are the analytical results of specific aspects of physical sensations of the activity. These questions are analysed in R, as before, where the main package used is ‘text mining’. Unlike single works or short phrase collection in the first sensory question, answers to these questions are in the form of a sentence. Therefore, the ‘text mining’ package helped to remove content that did not directly describe the experience, such as ‘I’, ‘and’, ‘for’, ‘to’, ‘think’ etc. Then, I used the ‘frequency’ function to record the frequencies of each related term.

For the planetarium show and the interactive table, three questions were designed to target the environment of the space, the visual experience and the auditory / touch experience. For the Venus Simulator, because of its multi-sensory features, four questions were instead designed.

Two of the same questions were asked in all three installations, which are: ‘when you first walk inside the planetarium / Space Oddities / Venus Simulator, how did the environment make you feel?’ and ‘what did you think of the visual experience?’ For the first question, the planetarium show audience described things like ‘comfortable / comfy’, ‘welcome’, ‘large / huge’ and ‘small’; the table users wrote ‘intrigued’, ‘lighting’ and ‘spacious’; and the simulator riders said ‘curious’, ‘enclosed’ and ‘scary / scared’. These responses were related to difference aspects in the environment, including lighting, atmosphere, the size of the space etc. The feedback starts to show us a high-definition image of how visitors experienced the environment. In terms of the visual effects of the planetarium show, some visitors thought it was ‘amazing’, some felt a little bit ‘dizzy’ and ‘disorientated / disorientating’, others thought this effect of the full-dome screen above the planetarium was ‘strange’ and felt like they were ‘travelling’. In the Space Oddities, visitors found the interactive table to be ‘bright’, ‘clear’, ‘informative’ and ‘easy’ to navigate, and in the Venus Simulator, visitors mentioned ‘quality’, ‘realistic’ and ‘screen’ when they were asked about the visual experience.

Aside from the environment and the visual, the Cycle 2 questionnaire offered new insights and deeper understanding of visitors’ reaction to the sound, the touch experience and the vibrating floor. For instance, the ‘narration / narrative’ of the ‘We are stars!’; the ‘interactive’, was ‘easy’ to use, and they noted the ‘responsive’ touch screen; the simulator was a little bit ‘noisy’ and the ‘realistic’ feeling of landing on the surface of Venus were mentioned, as shown in Tables 6.5 to 6.7.

In Cycle 1, where visitors chose one word from the pre-designed options. The only gained feedback was on which aspects of the experience were most impressive for visitors, without knowing the reason behind their choice.  In the version 2 questionnaire, with the structure of SEEP, participants were given more guidelines to support and encourage them to express their sensory experience in more detail and allow us to see different aspects of individual senses that are equally important, but a less-noticed part of the visiting experience.

*Table 6.5 Sensory domain description – Planetarium*

| Environment | | Visual | | Sound | |
|---|---|---|---|---|---|
| *Term* | *Frequency* | *Term* | *Frequency* | *Term* | *Frequency* |
| Excited | 12 | Amazing | 6 | Good | 19 |
| Comfortable / Comfy | 11 | Excellent | 6 | Sound | 6 |
| Relaxed | 6 | Good | 5 | Great | 5 |
| Interested | 2 | Great | 5 | Excellent | 4 |
| Large / Huge | 2 | Dizzy | 3 | Brilliant | 3 |
| Small | 2 | Immersive | 3 | Narration / Narrative / Narrator | 3 |
| Space | 2 | Brilliant | 2 | Clear | 2 |
| Welcome | 2 | Disorientated / Disorienting | 2 | Hearing | 2 |
| | | Fantastic | 2 | Little | 2 |

| | | | | | |
|---|---|---|---|---|---|
| | | Fascinating | 2 | Loud | 2 |
| | | Incredible | 2 | Surround | 2 |
| | | Strange | 2 | | |
| | | Travelling | 2 | | |

*Table 6.6 Sensory domain description – Interactive table*

| Environment | | Visual | | Touch | |
|---|---|---|---|---|---|
| *Term* | *Frequency* | *Term* | *Frequency* | *Term* | *Frequency* |
| Interested / interesting | 7 | good | 11 | good | 9 |
| calm | 5 | informative | 7 | use | 9 |
| intrigued | 4 | Easy / easily | 6 | easy | 8 |
| relaxed | 4 | clear | 4 | Work / worked / works | 6 |
| excited | 3 | interesting | 3 | experience | 4 |
| good | 2 | use | 3 | Responsive / response | 4 |
| lighting | 2 | Brightness / Bright | 2 | ease | 3 |
| like | 2 | excellent | 2 | great | 3 |
| spacious | 2 | read | 2 | interactive | 2 |
| wanted | 2 | | | navigate | 2 |
| | | | | quick | 2 |
| | | | | touch | 2 |
| | | | | well | 2 |

*Table 6.7 Sensory domain description – Venus Simulator*

| Environment | | Visual | |
|---|---|---|---|
| *Term* | *Frequency* | *Term* | *Frequency* |
| Interested / Interesting | 7 | Good | 15 |

| | | | |
|---|---|---|---|
| Curious | 4 | Quality | 3 |
| Intrigued | 4 | Realistic | 3 |
| Cool | 2 | Clear | 2 |
| Enclosed | 2 | Cool | 2 |
| Good | 2 | Engaging | 2 |
| Mission | 2 | Excellent | 2 |
| Scared / Scary | 2 | Great | 2 |
| Spacecraft / Aeroplane | 2 | Imagine | 2 |
| | | Immersive | 2 |
| | | Interesting | 2 |
| | | Screen | 2 |
| Sound | | Vibrating Floor | |
| *Term* | *Frequency* | *Term* | *Frequency* |
| Good | 12 | Good | 11 |
| Excellent | 6 | Real / Realism / Realistic / Reality | 6 |
| Great | 4 | Added / Adds | 5 |
| Noisy | 2 | Experience | 5 |
| Sound | 2 | Excellent | 2 |
| | | Expect / Expected | 2 |
| | | Fun | 2 |
| | | Great | 2 |
| | | Nice | 2 |

The second part of questionnaire introduced a new framework, SSEP from tourism studies. The third part of the questionnaire aimed to reveal the emotions that visitors have before, during, and after the activity. Here, this emotion-related part continued using the PAD Sematic Scale, because after the testing in Cycle 1, it showed various emotions across three different dimensions, and it was the first opportunity to see the variety of emotions visitors may have when interacting with in-gallery technology. There are two key improvements made from the Cycle 2 emotion questions analysis: first, enhanced visualization, and secondly, the results divided the whole experience into three stages to allow us to further compare the differences of before, during, and after experience.

Figure 6.5 is an example of the new visualization that was designed: it is a polar chart that shows visitors' emotions before watching the planetarium show. The questionnaires collected were entered and statistically analysed in SPSS, and the frequencies of each emotion were then imported into R. Next, I wrote code based on the requirements of the data presentation and drew polar charts in R. The six colours in the chart represent the six emotional dimensions, starting with the right side from the top; they represent pleasure, arousal, dominance, displeasure, non-arousal and submission, respectively. The antonymous dimensions located on the opposite side of the polar chart, are also correlated with the six bipolar adjective pairs in each dimension. Higher coloured bars mean higher frequency. In this figure, for example, the most picked emotions are hopeful, relaxed and exciting, while an empty bar means the emotion was not selected among the 40 participants, such as melancholic, aroused, dull and controlling.

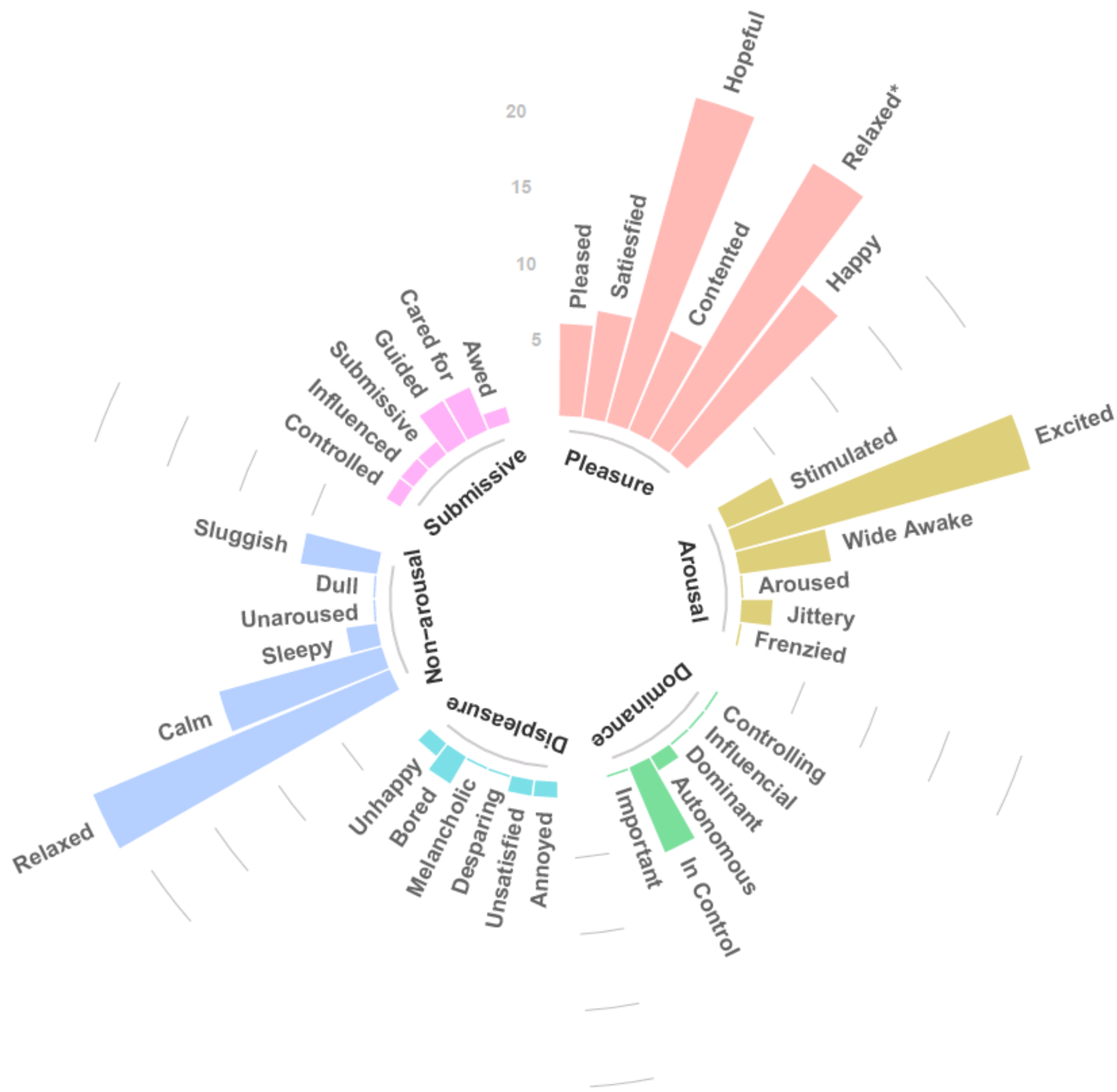



*Figure 6.5 Polar Chart shows the visitors' emotions before the planetarium show.*

Figure 6.6 shows the visitors' emotions before (the left section of the figure), during (the middle section of the figure) and after (the right section of the figure) of the planetarium show (on the top), the Venus Simulator (middle) and the interactive table (on the bottom). Larger images of these 'emotional wheels' can be found in Appendix 5.

By viewing the figure horizontally, from left to right, the change of participants' emotions as their experience went on can be seen. For instance, in the planetarium show, before the show starts, participants felt hopeful, happy, relaxed, excited and other words belonging to pleasure, arousal and non-arousal dimension; while during the show, many visitors felt awed, guided, stimulated and excited, which are words in submissive and arousal categories; then, when the show finished, visitors selected words from the pleasure category, including pleased, satisfied and happy. Analogously, the significant change among the before, during and after experience can be seen in the other two in-gallery digital technologies. For the Venus Simulator emotional experience, there was a change from non-arousal to arousal, and then to pleasure. For the touch-screen table, visitors' experience started with non-arousal, and changed to dominance, arousal and happy while interacting with it, and in the end, they left with pleasure.

Viewing the figure vertically can present the different emotional patterns among the three digital interactives. For example, in the submissive and dominance dimensions, many planetarium show audiences picked words from the submissive category, while users of the interactive table were more like to choose words from the dominance category. Another good example could be the change in arousal level as the experience goes on. In the interactive table experience, the number of participants who picked arousal emotions did no change much in the whole experience, while the Venus Simulator participants seem to have a distinct pattern. Before the show starts, only a few of them felt stimulated and excited, while during the experience more than half the participants felt stimulated, more than fifteen of them felt excited, and more than five participants felt wide awake, aroused or jittery. When the show finished, only a small number of participants used words from the arousal category to describe their feelings.

Replaying the single question around emotional experience, by dividing it into three questions, enables us to understand visitors' emotions in different stages of the experience and to discover the change in their emotional journey. At the same time, the improved data visualization not only gives more intuitive feeling of the variety and multi-dimensional emotions visitors have on the whole, but also makes it possible for us to compare changes in each stage of the experience and analyze the difference in visitor emotional experience when interacting with different formats of in-gallery technology.

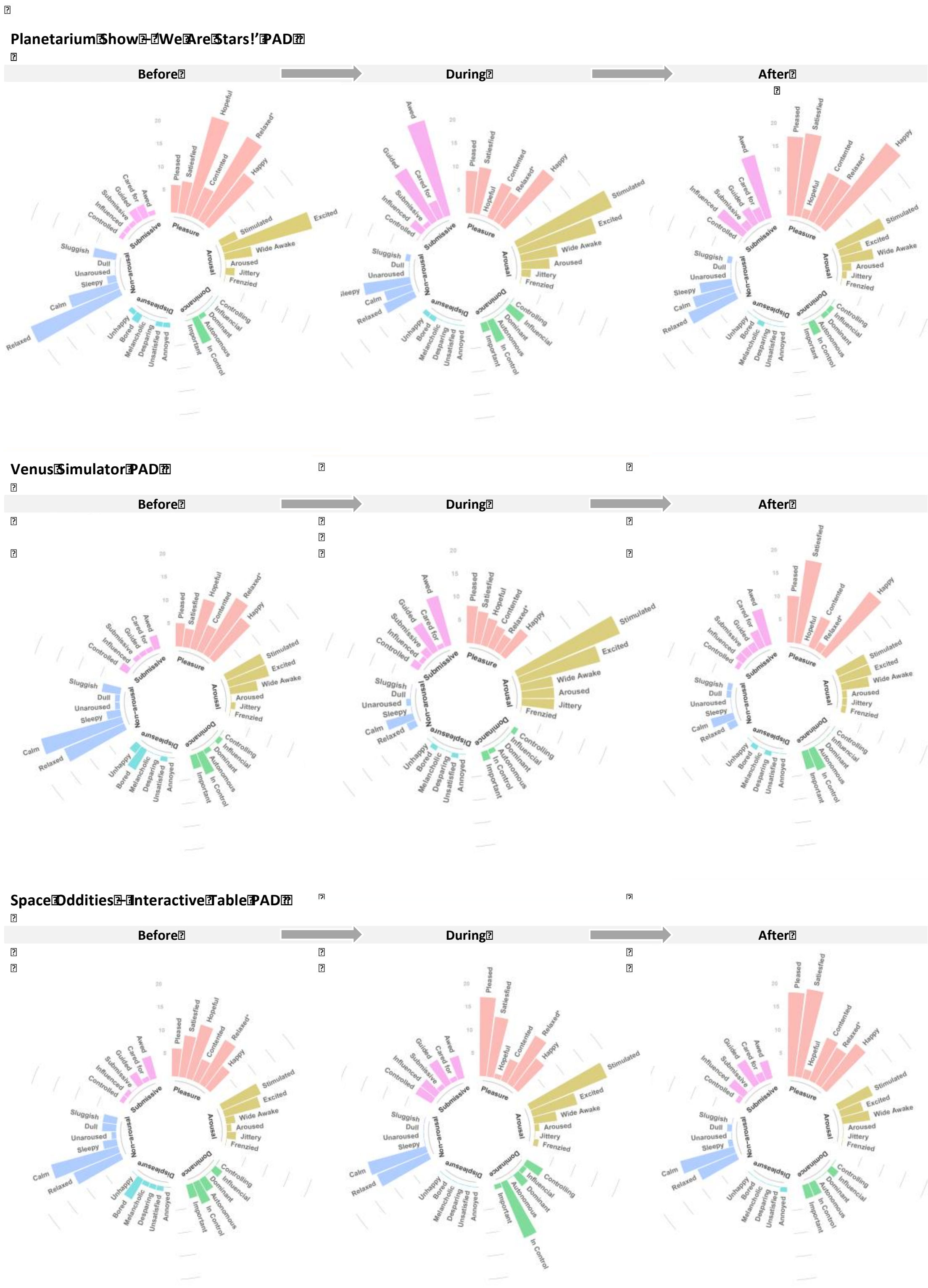



*Figure 6.6 Polar chart of before, during, and after planetarium show, the Venus Simulator and the interactive table.*

### 6.3.2 Analysing observations

In Cycle 2, three hours of video recordings in the Space Oddities and ten hours of recordings in the Venus Simulator were collection, and recordings of ten separate visitors' interactions with each digital technology were coded and analysed.

For the interactive table, observation recordings of users were analysed individually as each of them explored the information on the interactive table in different sequences and spent varied amounts of time with it. The observation focused on visual, verbal, gestural and special interaction. Table 6.8 shows guidelines of coding interactions between the observed visitor and other visitors, and interactions between the participant and the interactive table. Table 6.8 summarizes interactions shown in the observational recordings of the 10 users. Interaction between visitors could be divided into verbal interaction and non-verbal interaction. This table only included interactions shown in the recordings, but more types of verbal or non-verbal interactions could be added to the list when needed. Interaction with the table mainly consisted of content viewing, gestural interaction and spatial interaction.

*Table 6.8 Summary of interactions of using the interactive table.*

| | | |
|---|---|---|
| Interaction with visitors | Verbal Interaction | Participation<br>(Talking with other visitors regarding participation, e.g. invite others to use the table.)<br>Content<br>(Talking with other visitors regarding the content shown on the table, including discussion of text and images.)<br>Operation<br>(Talking with other visitors regarding the operation of the table, e.g. asking or answering questions about where to start; discussing how the table works etc.)<br>Laughing<br>(Laughing during conversation with other visitors.) |
| | Non-verbal Interaction | Eye contact<br>(Making eye contact with other visitors)<br>Pointing<br>(Interaction with other visitors by pointing at the context or images on the table) |

<table>
<tr><td rowspan="3">Interaction with the interactive table</td><td>Content Viewing</td><td>Viewing content by oneself<br>(Reading text silently or aloud; viewing images on the table.)<br><br>Viewing content with other visitors<br>(Sharing the table with other visitors, reading content on the table together.)</td></tr>
<tr><td>Gestural Interaction</td><td>Touching<br>(Touching images or other content shown on the table)<br><br>Tapping<br>(Tapping the blue ‘button’ to select content page or back to homepage.)<br><br>Pointing<br>(Pointing at text while reading.)</td></tr>
<tr><td>Spatial Interaction</td><td>Walking<br>(Walking around the table.)</td></tr>
</table>

Table 6.9 and Figure 6.7 demonstrate observation recorded of a visitor in the Space Oddities. Individuals’ experiences with the interactive table were analysed in two parts. The first part was similar to the observation analysis in Cycle 1, as shown in Table 6.9, which recorded the time participants spent in the gallery and with the table, demographic information and ratings of arousal and valence.

*Table 6.9 An example of observation record of time spent, arousal and valence of a visitor.*

| Interactive table user 1 | |
|---|---|
| Male; Age group: 18-44; Adult group | |
| Time spent in the gallery | 5 minutes 47 seconds |
| Time spent with interactive table | 1 minute 30 seconds |
| Arousal (1-5) | 4 |
| Valence (1-5) | 4 |

The second part of analysing observation was coding interaction of the visitor using the guidelines. Figure 6.7 is an example of using the guidelines to code interactions occurring in User 1's experience with the interactive table.

The figure shows detailed information of User 1's experience of using the interactive table. For instance, the figure shows the visitor used the interactive table three times, and they spent a comparatively long time reading content on the table the first time using it, while they only spent a few seconds looking at it the third time. The figure also shows another visitor was sharing the table with User 1 during the process; they discussed the content on the table and User 1 laughed out loud during their conversation. In terms of the gesture interaction with the table, except for tapping 'buttons', the user also touched the surface of the table.

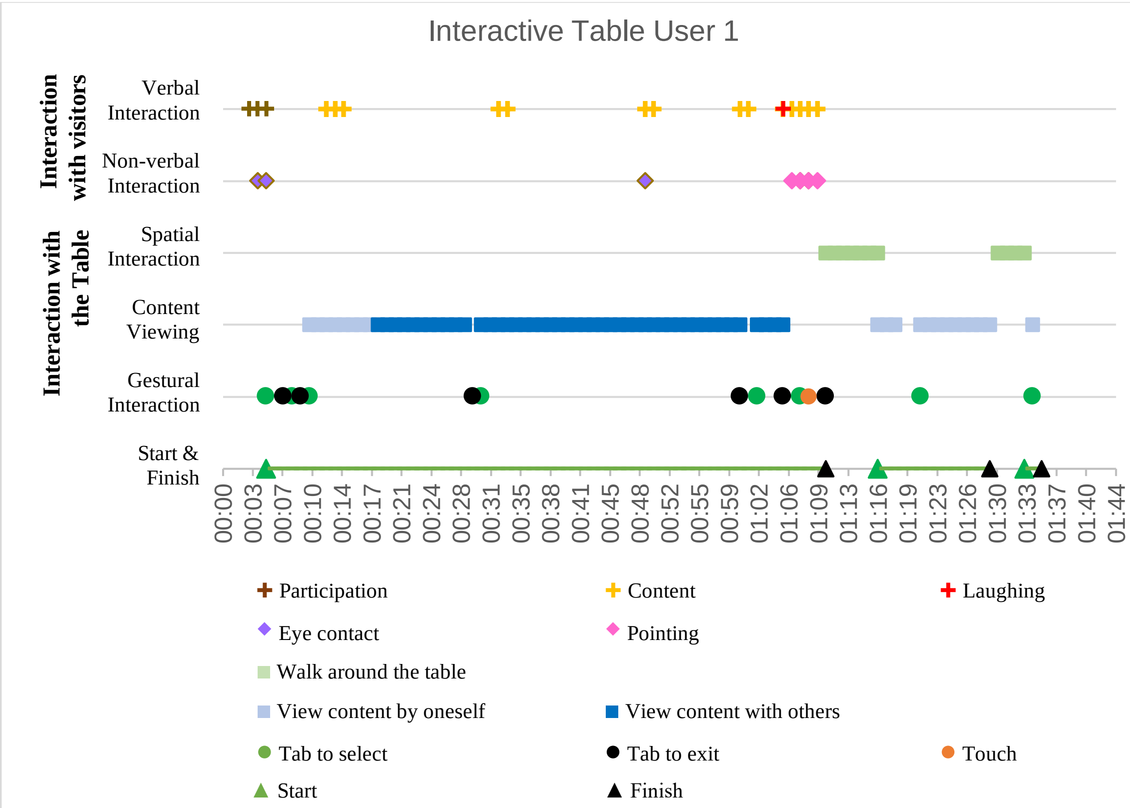



*Figure 6.7 Interactions coded of a visitor who used the table.*

The observation recordings in the Venus Simulator follow similar observational guidelines to that of the interactive table. As shown in Table 6.10, the interactions were divided into interactions with visitors and the digital exhibit. For verbal interactions with visitors, these mainly include talking and laughing; for non-verbal parts, these include related behaviours occurring in the recording e.g. eye contact, pointing or taking a photo. The interactions with the digital exhibit differ from the guidelines of the interactive table, and focus on observing which part of space visitors were looking at. Except for time spent on looking at the projections on the front wall in the room, the time (in seconds) a visitor spent on looking at the two sides, top, floor, and back of the room were recorded.

*Table 6.10 Summary of interactions in the Venus Simulator.*

| | | |
|---|---|---|
| Interaction with visitors | Verbal Interaction | Talking |
| | | Laughing |
| | Non-verbal Interaction | Eye contact |
| | | Pointing |
| | | Taking a photo |
| | | Swaying<br>(swaying when feeling the vibration coming from the floor) |
| Interaction with the digital exhibit | Viewing/Observing | Sides<br>(Looking at the left or right side the room) |
| | | Top<br>(Looking at the top of the room or observing the projectors on the top) |
| | | Floor<br>(Looking at the floor) |
| | | Back<br>(Looking at the back of the room or viewing content on the screen monitor placed on the wall in the back of the room) |
| | Spatial Interaction | Walking<br>(Walking around inside the simulator) |

Figure 6.8 is bubble chart presenting the looking direction of ten visitors. The overall simulator experience is divided into ten timeframes, each frame is 30 seconds. The size of the bubble represents the length of time visitors spent on looking at these four directions in the room. Analysing the observations coding records of visitors in one chart gives a more direct visualization to show viewing preference.

a. Visitors were more likely to observe the environment and explore different parts of room in the first 2 minutes and 30 seconds and in the last minute. In the middle of the experience, visitors were more concentrated on the main projection in the front of room.
b. Individuals' preferences: visitors, like participant 1, were more focused on the content projected on the central part of the wall in the front, while there were also visitors, such as participant 2 and 9, who looked to different directions throughout the activity.
c. The screen on the back wall attracted a lot of attention. Half of the observed visitors spent a comparatively long time looking at the information presented on the screen in the back of the room.
d. The extended projections on the two sides of the room contributed a lot to this immersive experience. Most visitors spent a certain amount of time looking at the sides.
e. Visitors were interested in the projector, lighting and the vibrating floor. Almost all of the ten visitors looked up and down to observe the environment and technology.

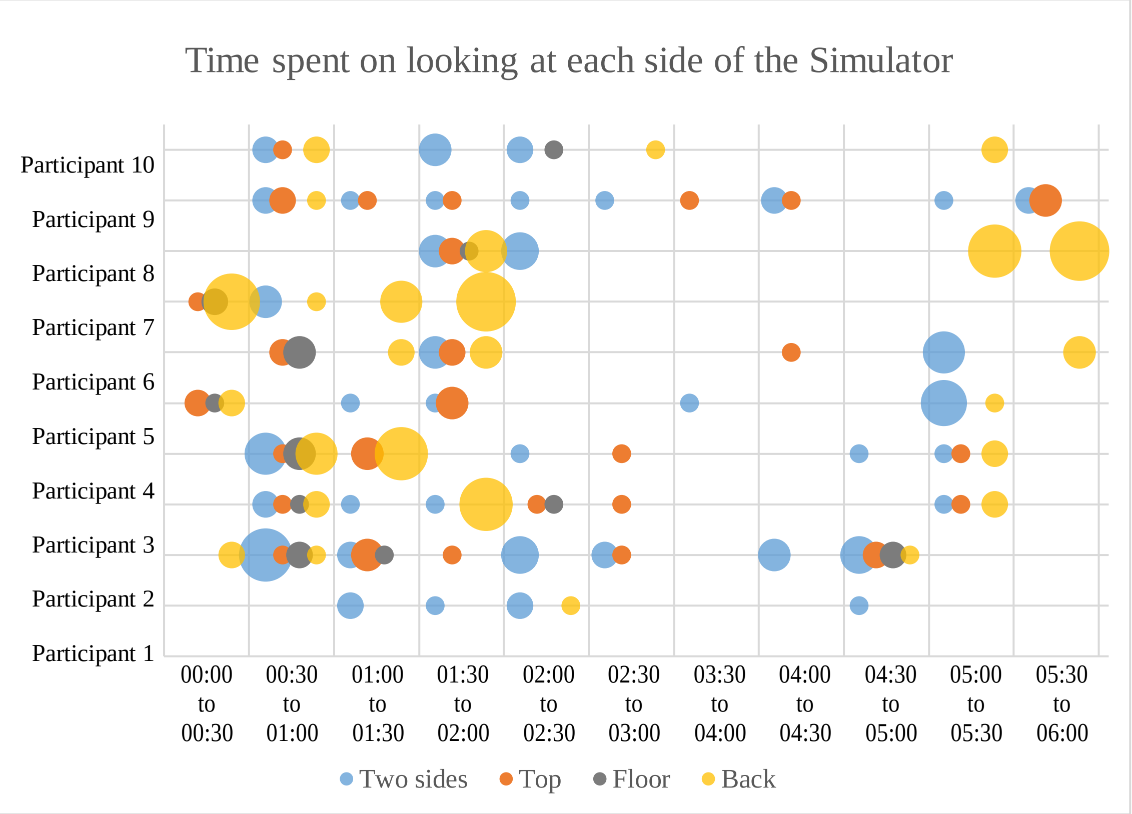



*Figure 6.8 Time spent on looking at the two sides, top, floor and back side in the Venus Simulator.*

This figure is an example of how observational data could help to understand visitors' interactions with the digital exhibit, the detailed observation record can be found in the Appendix 2.2.

### 6.3.3 Analysing 'think-aloud'

Following the procedure mentioned in section 6.2.3, concurrent think-aloud was tested in Cycle 2 with two in-gallery interactives: the Venus Simulator and the interactive table.

In the simulator, seven participants were invited and agreed to take part in the test. However, two participants left during the process: one participant did not like the type of experience with intense visual and sound effects, so he left the simulator after 2 minutes, while another participant felt uncomfortable speaking to the clip-on microphone while there were other visitors in the simulator. Among the five visitors who did participate in the whole process of CTA, one participant was not able to fulfil the task due to limited language ability, she felt it was challenging for her to receive external English input and verbalize thoughts in a foreign language at the same time. Therefore, her CTA transcript was not analysed in this second round, but the feedback of the two follow-up questions have been included and analysed.

Table 6.11 below is the transcript of a participant who visited the NSC with a young child and took part in the CTA in the simulator. The transcript reflects how the participant felt throughout the experience. In the beginning of CTA, the participant's feedback shows they were excited and looking forward to the experience. Then in the journey to Venus, they were intrigued and wondering whether they were going to crash or not. In the end, after the ship landed, they felt it was a bit scary but an enjoyable experience. The transcript shows vivid descriptions of the participant's reactions to the simulator and feedback to specific parts of the plot. Yet, most responses are brief and short in length. Actually, when the participant first went into the simulator and waited for the count down, a more detailed description can be found, such as the first two sentences in the table where the participant observed the environment and described their feelings and commented on the 'screen'. However, after the spaceship took off, the description became brief. For example, they said 'Oh, no' several times without further verbalizing their thoughts. This difference between verbalizing in the waiting stage and after departure might largely be because the viewing experience and the verbalization of thoughts are two separate sets of tasks. The participant was very excited and integrated themselves into the mission heading to Venus. On the other hand, this also suggested is could be challenging for participants to keep the balance of enjoying the experience and conducting CTA.

*Table 6.11 Transcripts of a Venus Simulator participant's think-aloud recording.*

| | | |
|---|---|---|
| 1 | 'This looks interesting, because it is a big screen, and I wonder what's going to happen next.' | 00:00 |
| 2 | 'Find out, we're just gonna count down, and see if something exciting gonna happen.' | 00:09 |
| 3 | 'Counting down, are you getting excited?' | 00:18 |
| 4 | 'See what happens?' | 00:20 |
| 5 | 'Wait.' | 00:23 |
| 6 | 'Wow, where we are going now, it is exciting.' | 00:29 |
| 7 | 'Oh, we are taking off.' | 00:49 |
| 8 | 'Wow, it is a spaceship.' | 01:02 |
| 9 | 'Oh, shaking, are we going to crash?' | 01:08 |
| 10 | 'Exciting, how do you feel, is it exciting?' | 01:12 |
| 11 | 'Interested to find what's going to happen.' | 01:17 |
| 12 | 'This is exciting isn't it?' | 01:35 |
| 13 | 'Is this scary?' | 01:40 |
| 14 | 'No, not scary isn't it?' | 01:42 |
| 15 | 'That's cool, I like the video.' | 01:54 |
| 16 | 'Oh, it's cool.' | 02:18 |
| 17 | 'Oh, no.' | 02:24 |
| 18 | 'Are we going to crash?' | 02:29 |
| 19 | 'Oh, no.' | 03:14 |
| 20 | 'Are we gonna get rescued or are we're gonna to crash?' | 03:24 |
| 21 | 'Oh no, we're gonna fall over.' | 04:16 |

| | | |
|---|---|---|
| 22 | ‘Oh, oh, oh, we are landing.’ | 04:41 |
| 23 | ‘Landed.’ | 04:48 |
| 24 | ‘We made it!’ | 04:54 |
| 25 | ‘It is a bit scary.’ | 04:56 |
| 26 | ‘We are saved.’ | 05:19 |
| 27 | ‘Wow.’ | 05:39 |
| 28 | ‘That was good, we got saved, wasn’t it?’ | 05:40 |
| 29 | ‘Enjoyed it.’ | 05:43 |

The think-aloud also shows us the how participant felt and responded to key scenes in the simulator experience. Table 6.12 shows examples of participants’ comments given or the same scene. These four examples are scenes of important elements and development of the plot shown in the Venus story. It is interesting to see the difference of how participants respond to the scene. For instance, in the first example, Participant A noticed there were vibrations coming from the floor, Participant D also noticed the vibrating and gave feedback about the projections on the curved wall, while at the same time, Participant B was wondering whether they were going to crash. Also, in the fourth example, where Participant A gave a simple phrase, Participant D gave more detailed description about the sense of movement and travelling, Participant B was in the intense atmosphere of landing, and Participant C laughed out loud. Think-aloud in the Venus Simulator collected real-time feedback of visitors’ sensory and emotional feelings and their different responses to the experience.

*Table 6.12 Examples of how participants respond to four scenes in the Venus Simulator.*

| | |
|---|---|
| **Example scene 1**<br>Vibrations came from the floor. | Participant A: ‘I can feel the vibration, can you?’<br>Participant B: ‘Oh, shaking, are we going to crash?’<br>Participant D: ‘I think the extension of the screen is good, with the vibration as well.’ |
| **Example scene 2**<br>Plumes of smoke began to rise from Drone 2. | Participant A: ‘You feel you are just in there really, don’t you?’<br>Participant B: ‘Are we gonna get rescued or are we gonna to crash?’<br>Participant D: ‘I feel like really tense, what’s gonna happen?’ |

| | |
|---|---|
| **Example scene 3**<br>Landing module started, Drone 3 falls to the ground. | Participant A: 'I think you need to further in it, just do it.'<br>Participant B: 'Oh no, we're gonna fall over.'<br>Participant D: 'You actually feel you are turning with it.' |
| **Example scene 4**<br>20 seconds before landing, altitude: 300 meters. | Participant A: 'It's quite cool.'<br>Participant B: 'Oh, oh, oh, we are landing.'<br>Participant C: 'Oh my god, we are burning now, (laughter).'<br>Participant D: 'It does feel your body are travelling, even though you are standing on a flat floor.' |

Follow-up Question 1: How would you describe the overall experience of the Venus Simulator / interactive table?

Participant A: "I thought it was quite good actually. I felt I was part of it, especially when it went further in.  I am so swaying. Felt quite unsteady on the feet. And you didn't want to go forward, did you? No, coz you could feel the vibration."

Participant B: "Yeah, I liked it. Because it is more interactive, coz the floor and vibration and that sort of thing. And relieved at the end, as you were rescued, and you made it through to the end. And I liked the 3D, it makes it more immersive."

Participant C: "Sometimes you don't know what is going to happen next, so it's keeping you in suspense. An emotional level, because you don't know, so you were taking everything that will happen."

Participant D: "It is interesting, it is really immersive. It is a bit like when you are wearing VR headset, but you are not wearing one here. Because the floor is vibrating; your whole body feels like it's spinning, it is such a weird feeling really."

Participant E: "Extremely confusing, I don't know what I am doing in there, and I don't know what I am supposed to do. Maybe because I am not English, yeah, confused a lot."

The answers for the first follow-up question from five participants are very interesting. Here, three participants described their feelings of the vibrating floor with difference expressions, 'unsteady on the feet', 'more interactive', 'more immersive', 'whole body feels like spinning' and 'such a weird feeling'. In a question which asks the overall impression of the simulator, these responses show the vibrating floor is an irreplaceable element in this multi-sensory experience, and it is the most impressive part during the entire experience for most visitors. The other two visitors' answers pointed to other aspects of the experience. Participant E was a visitor from non-English speaking country, and they found it difficult to figure out the story by the conversation among the pilots. In this circumstance, information that gives an overview of the simulator (e.g. what the experience is about, what the mission is) could assist international visitors who have limited language ability. However, for native speakers, such as the participant D who felt it was an intriguing experience that kept them in suspense, the fact that no additional information was provided in advance was the key to trigger curiosity.

Follow-up Question 2: How would you describe your experience with the Venus Simulator / interactive table compared to other exhibits in the National Space Centre?

> Participant A: "That was the best so far, but we've only just walk through that area. I think it is a bit different, a lot different actually. Because of the movement, you were a sort of involved in it, yeah, it is the movement."
>
> Participant B: "I've not been here that long yet today. But we did go to the planetarium and I like that, that was a little more disorientating, it's more 3D and the feeling of disorientation is more in there. Compared to the planetarium, it's different but it's a similar type of experience, it's good."
>
> Participant C: "I think the simulator is a new experience, most people may never have this kind of experience before. This one you don't know what will happen, so it's something you don't expect. It's like put you in a situation you don't know what to expect but you will deal with it."
>
> Participant D: "It's really good, because it is immersive and it visualized that feel. And yeah, it gets your attention. It got lot of senses and stuff, and it is different from all the other things, rather than buttons and stuff. It is what you feel and experience, that was good."
>
> Participant E: "We really have try very much here, we just came. But the film (planetarium show) here was amazing. But it was really nice of the floor, doing that stuff (vibration)."

Likewise, feedback about the 'movement' of the floor and the intriguing way of engaging viewers was mentioned in the second follow-up question. To compare the simulator with other exhibits, more than one participant (participants A, B and D) gave very positive feedback and thought it was different from other exhibits, because it was more engaging and interactive. Moreover, it was interesting to notice that two among the five think-aloud participants compared the Venus Simulator with the planetarium show and thought they were similar, as both are immersive experiences.

In the Space Oddities, five CTA were conducted. Table 6.13 is an example of CTA transcripts of a participant. Comparing the transcripts of this interactive table user with the example of the simulator participant (Table 6.11) shows the challenge of balancing the two tasks, which are interacting with the in-gallery technology and verbalizing thoughts, still exists here. In Table 6.11, the simulator participant pulsed verbalizations when receiving a lot of visual and auditory input from the video and immersing themselves in the story. Similarly, as shown in Table 6.13, the participant was reading out the text unconsciously while using the interactive table.

*Table 6.13 Transcripts of an interactive table participant's think-aloud recording.*

| | |
|---|---|
| 1 | 'It's quiet here, nice.' |
| 2 | 'The table looks amazing, it's quite big, and a lot of pictures.' |
| 3 | 'Where I should start? Oh, here, 'start'.' |
| 4 | 'Ok, let me have look.' |
| 5 | 'Um, space toilet, that's interesting.' |
| 6 | (Reading out text on the table) |
| 7 | 'Finished this page, tabbed 'back'.' |
| 8 | 'How it works?' (started reading this page) |
| 9 | 'That's interesting. I'm enjoyed reading this. It is quite informative, and the space toilet is interesting, isn't it? The buttons are responsive. It works well. Very simple and easy to use.' |
| 10 | 'What else. Um…' (tabbed 'back') |
| 11 | 'Backed to the home page, um, Spacesuit.' |
| 12 | 'Um, Design.' (started reading this page) |
| 13 | 'That's cool.' (backed to the Spacesuit page) |
| 14 | 'American.' (started reading this page) |

| | |
|---|---|
| 15 | (Reading out text on the table) |
| 16 | ‘Um, Orlan? What’s this?’ |
| 17 | ‘Orlan DMA, (reading the text), Ok, it is a type of spacesuit. Cool.’ |
| 18 | (Reading out text on the table) |
| 19 | ‘Interesting.’ |
| 20 | ‘I like it, it is informative and interesting as well, text and images. And texts are clear.’ |
| 21 | ‘Yeah, enjoyed it.’ |

Although CTA raised challenges for participants in the two interactives, there is a main difference which should be noted. Unlike the description of feelings that were only found in the beginning of simulator experience, the simulator participant followed the requirements on the instruction sheet, describing how they felt before starting using the interactive table and also reported their feelings during (when they finished reading the second context page of ‘How it works?’) and at the end of the experience (the last two rows in Table 6.13).

## 6.4 Limitations of Cycle 2

### 6.4.1 Limitations of questionnaire version 2

A new sensory experience evaluation technique was introduced and a visualization of the emotional experience as presented in the second version of the questionnaire. First, learning from tourism studies, the questionnaire designed sensory questions backed by the structure of SEEP. With warm-up questions of imaging the key elements when the participant first walked into the exhibit, followed by open-ended questions targeted on individual senses, the questionnaires encouraged visitors to recollect the details of sensory information they processed unconsciously during their experience. Compared to the multi-choice questions in Cycle 1, the new technique inspired by SEEP allowed participants to recall their sensory experience and express their physical experience with in-gallery technology from various aspects (e.g. lighting, brightness, movement, noise level etc.) using their own words. Secondly, dividing the whole emotional experience into three stages of before, during and after the activity, together with the new polar chart visualization, the resulting questionnaire analysis presented a clearer image of the emotional landscape of visitors in different stages of the experience and in different formats of interactives.

In addition to collecting demographic information of visitors, the improved version of the questionnaire was capable of collecting both sensory and emotional feedback. Yet, some challenges in the questionnaire could be considered if further developing the tool. For instance, in terms of the design of the questionnaire, it is how to encourage visitors to share more detailed feedback for open-ended questions instead of one word responses; for data analysis, how to identify differences of sensory and emotional journeys between gender, age and visiting groups; for data visualization, it is how to present and visualize the sensory experience feedback.

### 6.4.2 Limitations of observation version 2

This round of observation mainly focused on enhancing the data analysis. The direct observation in the Space Oddities in Cycle 1 has been replaced by indirect observation via video recording in this cycle. The video recordings provided an original source to further code and analyse the interaction among visitors and between visitors and interactives. In the data analysis, specific types of verbal and non-verbal interactions were identified and coded to the occurrence of certain behaviours based on timeline and linked to the content of the in-gallery digital technology.

Similar to the limitation in Cycle 1 observation, the video footage collected from a single direction and under the special lighting in the gallery space resulted in difficulties of analysing discrete emotions from visitors' facial expressions. This cycle applied the five-point Likert scale of rating arousal and valence too. In addition, it is also hard to analyse individuals' physical feelings during the activity from the video recording. Nevertheless, observation is still a significant tool to evaluate experiences with in-gallery digital technology, as it is the only method that is able to see how visitors interact with others and the digital exhibit.

### 6.4.3 Limitations of think-aloud

Enlightened by the idea of 'remembering self' and 'experiencing self', questionnaires differentiated overall experience into three phases, behaviours and interactions in observation recordings were time-based coded, while the third evaluative method in Cycle 2 was applied in attempting to hear the voice of 'experiencing self'. Therefore, instead of continually improving the traditional evaluation tool of interviews, which only allow visitors to share their thoughts retrospectively after their actual experience finished, CTA was conducted in order to collect real-time responses during the experience. CTA collected self-reported responses of participants' thoughts concurrently during the activity. It provided detailed feedback at specific moments and let us hear what participants felt throughout the experience with the verbalization of their thoughts. For example, the think-aloud of Venus participants shows expectation, curiosity and intrigued feelings when they first started, their real-time thoughts of the plot, movements and projections during the experience, and the release and satisfaction when they had safely landed.

However, the major limitation found in the CTA is that it requires visitors to manage two tasks at the same time. Participants are required to giving feedback while exploring the interactive. This test distracted visitors from enjoying their experience, and reversely, this resulted in the pulse of verbalization when participants were focused on the activity, such as the silence periods found in voice recordings. Furthermore, this method could be even more challenging if there are language barriers.

The second round of evaluative design focused on the issues found in Cycle 1, and more importantly, aimed to collect real-time feedback and reflect on the temporal dimension in visiting experience. In this cycle, questionnaire was improved by drawing from the SEEP and introducing new data visualization of the 'emotional wheel'; the new method 'think-aloud' has been applied to collect momentary-based responses; and in observation, more detailed guidelines were developed. Notably, this cycle pointed out the challenges for using verbal-based measurements and limitations of rating and coding behaviours in observations.

# Chapter 7 Evaluative Design Cycle Three

## 7.1 Lessons Learned from Cycle 2

Kahneman's idea of the 'two selves' was (as we saw in Chapter 6) the key influence on the research design from Cycle 1 and 2. Inspired by this idea, we found the two self-reported methods applied in Cycle 1, which were interviews and questionnaires, only allowed us to hear the voice of 'remembering self' and, as a result, all feedback collected with these methods was based on memory. The 'remembering self' is still the dominant self in this case, and the response from the 'experiencing self' has not been heard. Therefore, in order to gain the momentary-based feedback from the 'experiencing self', improvements were applied to in Cycle 2.

Although it is difficult using questionnaires to collect momentary-based feedback, Cycle 2 was designed with this added consideration of time, and so asked a series of new questions based on experiences before, during and after the activity. Additionally, by introducing the SEEP framework (used in Cycle 2), working together with the PAD scale (used in both of the first two Cycles of the study), and version two of the questionnaires also provided information for both sensory and emotional experience of interacting with the in-gallery digital technology. In the meantime, the interview method (that took place when the experience with the in-gallery technology was finished), had been replaced by the 'think-aloud' method (used during the experience). The 'think-aloud' method offered access to communicate with the 'experiencing self' and collect momentary-based responses from participants. And, more importantly, unlike both the interview and the questionnaire methods that only collect data post hoc, with think-aloud, feedback was collected partially concurrently whilst the experience took place.

The three evaluation tools mentioned above (questionnaire, interview and think-aloud) were self-reported by participants based on their subjective experience. Observation, on the other hand, is based on the observer's rating and coding of verbal and bodily expression of participants. Although in both cycles, the observer only coded the occurrence of behaviour and did not code the intensity of that behaviour, the rating of valence and arousal were still based on the observer's subjective judgement of participants' expression. The analysis of observation recordings has therefore been improved, from the record of the frequencies of the occurrence of certain types of interaction among visitors and between visitors and interactive in Cycle 1. Cycle 2 analysed the occurrence of specific behaviours, matching the behaviour on the timeline of the activity, and tried to identity behaviours that appeared on a particular time point.

The data collected in Cycles 1 and 2 share some similarities. Firstly, the data collected was either 'filtered' by the participants or the observer as they were either self-reported by the participants or rated by the observer. Secondly, most tools are verbal based (e.g. interviews, questionnaire, think-aloud) and expressed by language. Thirdly, rather than collecting concurrently, the collected feedback was non-current or partial concurrent. According to Bradley and Lang (2002), emotion output can be measured through three complete systems: language, behaviour and physiology. Language is the output that is frequently measured in visitor studies. Behaviour is less evaluated compared to language, but still a common output that has been investigated in evaluations. However, the measurement of physiological output in visitor studies is very rare.

Therefore, Cycle 3 tested the possibility of conducting physiological measurement in museums, and it is this important modification to our evolving evaluative framework that this chapter discusses. The chapter first introduces three types of physiological measurements: the autonomic nervous system, central nervous system and muscle movements. Then, the chapter discusses the practicality of measuring these three types of physiology, and why skin conductance measurements (electrodermal activity) is the most suitable physiological measurement for evaluating visitors' experience with in-gallery digital technology. Next, the research design of using GSR+ to collect skin conductance in the NSC is addressed and how to read and analyse the skin conductance signal is explained. In the end, the chapter discusses the limitation of measuring skin conductance in this research.

## 7.2 Introducing Physiological Measurement

The roots of emotion recognition can be traced back to landmark studies such as Darwin's *'The expression of emotions in man and animal*' (1890). Here Darwin described the importance of emotion and how they are recognized through expressions.

For over a century, emotional recognition and measurement have aroused the interests of researchers from various academic disciplines.

To measure emotions, Cycles 1 and 2 applied four types of evaluation tools. As we have seen, think-aloud, questionnaires and interviews are tools to collect individuals' subjective experience by self-reporting measures, while in observations, facial and body behaviour were recorded and coded by the observer. These tools are measures of visitors' experience by their verbal feedback and their behaviour. But, emotional output is not only through language and 'overt act' (Bradley and Lang, 2002: 244); the third broad output of system physiology is as important as the other two. Physiology output of emotions refers to the activities of somatic muscles and the nervous system that are accompanied by affective displays, or logistic support, or preparation of overt acts in emotions (Bradley and Lang, 2002). Our discussion here introduces methods to measure the physiology output of emotions, including autonomic nervous system and centre nervous system measurements of emotion, as well as to measure emotions through behaviour (vocal, facial muscle movement and body gesture).

### 7.2.1 Autonomic nervous system measurements of emotion

There are general assumptions regarding the ways in which emotions arouse the autonomic nervous system (ANS) (Westerink et al., 2008). According to Öhman et al. (2000), ANS is a general-purpose physiological system that is responsible for modulating peripheral functions and consists of branches associated with activation and relaxation. The ANS activity is related to a variety of functions, including attention, effort, digestion, and the function of emotional response (Berntson and Cacioppo, 2000). Stimulated through the ANS, emotions are expressed in a wide range of physiological activities (Scerbo et al., 2001). The major advantages of using autonomic physiological measurement is that the autonomic variables are regulated by the ANS, which is a system that is separate and free of the control of individuals' consciousness (Scerbo et al., 2001). For this research, this advantage is particularly significant, as it is able to provide a new dimension of measuring visitors' experience, except from the self-reported measurements and interpretation from researcher, and to report the subjective personal feelings in a more objective way.

Measuring human emotions through autonomic responses has a comparatively long history, as stated by Brown and Fee (2002); the first known research of physiology of emotion is the work of Walter Cannon in 1915. In the last three decades, there is an abundance of research conducted around this topic. As summarized by Kreibig (2010), the autonomic measurements of emotions could be categorized into three main types: cardiovascular measures; respiratory measures; and electrodermal measures.

In the category of cardiovascular measures, the heart rate is the most reported variables of cardiovascular responses (Kreibig, 2010). For example, the study conducted by Allen et al. (1996) assessed the emotional responses to social rejection and achievement failure by combining self-reported techniques and the psychophysiological measures of heart rate and facial movements. It is also common for researchers to investigate emotions by applying several types of cardiovascular measurements, for instance, Waldstein's experiment of assessing cardiovascular reactivity in happiness-including tasks and anger-including tasks (Waldstein et al., 2000). In this study, systolic and diastolic blood pressure, and heart rate responses are measured during positive and negative emotions. Similarly, multiple types of cardiovascular variables including heart rate, cardiac output systolic blood pressure and stroke volume were investigated in the study of Montoya et al. (2005). The study provides evidence to support the hypothesis that emotions of fear and anger elicit differential patterns of physiological responses.

Likewise, to the cardiovascular response, respiratory measures are also applied in various types of research. The frequently reported index including the rate, period and depth of respiration. In the research that investigates the influence of arousal and valence in triggering hyperventilation responses (Van Diest et al., 2001), inspiratory and expiratory time, respiration depth and pulse rate were measured when participants were imagining different scripts that depicted relaxation, fear, depressive, action, and desire situations. Also, the response of respiratory rate, expiratory and inspiratory time were investigated in a study conducted by Vlemincx et al. (2009). These breathing parameters helped to analyse the sign rate in released and stress conditions.

As important as the ANS measures by the cardiovascular and respiratory variables are, the third main category is electrodermal measures. Electrodermal activity (EDA) is a general term that describes electrical phenomena on the skin (Johnson and Lubin, 1966; Boucsein, 2012). In electrodermal measurements, skin conductance level (SCL), rate and amplitude are investigated in numerous studies related to emotions. Examples of using electrodermal measures could be found in Kring and Gorden's (1998) research of comparing the difference in emotional expression between male and female, where patterns of skin conductance were demonstrated to distinguish emotions of disgust, fear, sadness and amusement. In another study, Williams et al. (2005) identified distinct response patterns of fear, anger and disgust by employing simultaneous skin conductance and functional magnetic resonance imaging (fMRI).

All of these examples listed here may be applied by multiple types of measurements, though they used a single type of ANS activity (cardiovascular, respiratory and electrodermal measures). However, in many recent studies on the theories of emotions mixed measurements of ANS responses were employed. Blechert's study (Blenchert et al., 2006) combined variables including electrodermal, behavioural, respiratory and cardiovascular responses to identify anxiety states. The findings demonstrated the key role of respiratory parameter in assessment of anxiety state and pointed out the significant of measuring through multiple response domains in anxiety for the assessment (Blenchert et al., 2006). Mixed measurements of the frontal and temporal EEG, skin conductance, heart rate, heart period variability, and respiration rate were also recorded and analysed in the experiment to compare the effects of pleasant and sad music in post-stress recovery (Sokhadze, 2007). The study demonstrated the influence of positive and negative emotions of the change of ANS responses (Sokhadze, 2007). Also, the research of Stemmler et al. (2001) investigated psychophysiological responses to the emotion of fear and anger by measuring 29 variables in a controlled environment.

### 7.2.2 Central nervous system measures of emotions

The central nervous system (CNS) is another response system that is associated with the emotion state. The question of how to define emotion has been discussed in Chapter 2, but there are two mainstream understandings worth noticing again here: the discrete (specific) emotions; and the dimensional view of emotions. Both views are valuable to form a basis of understanding emotions in differing research areas and contexts. Mauss and Robinson (2009) summarized ANS studies more often relating to the idea of dimensional emotions of valance and arousal instead of the discrete aspects of the emotional state. In contrast, CNS responses are more likely to correlate with discrete emotions (Mauss and Robinson, 2009). In the literature, measurements for this response system are basically done through electroencephalography (EEG) or fMRI technology.

Numerous studies have suggested the link between regions of brain activation and emotions. For instance, the greater left-sided hemispheric activation links to the emotion of anger, while the greater right-frontal activity is considered to link with worry (Mauss and Robinson, 2009). A certain part of research in this domain focuses on emotional recognition from EEG. Lin's (Lin et al., 2010) study analysed specific EEG feathers in combination with self-reported emotional states in music listening, and further classified four types of emotion (joy, anger, sadness and pleasure). Similar examples of EEG-based emotion recognition can be seen in the research of Petrantonakis and Hadjileontiadis (2010), where the patterns of basic emotions of happiness, surprise, anger, fear, disgust and sadness have been shown, as well as a more recent study of feature extraction from EEG signals for recognition of specific emotions of happy, curious, angry, sad and quiet (Jenke et al., 2014).

Unlike an EEG, which measures the large regions of the brain, fMRI technology allows us to investigate much more specific areas (Mauss and Robinson, 2009), thus, fMRI is considered to be more suitable for revealing emotions (Panksepp, 1998). Examples of using this technology in emotion detection and generation can also been found in the study conducted by Koelsch et al. (2006) that applied this technology to investigate participants emotional responses of positive and negative musical stimuli, and the research of Ochsner et al. (2002) that employed fMRI to understand the cognitive regulation of emotional responses.

### 7.2.3 Measure emotion through behaviour

Aside from self-reporting measures, which are more commonly applied in visitor studies, and the physiological measurements introduced in the two sections above, another equally important aspect of emotional measurement is behaviour. Categorized by Mauss and Robinson (2009), behaviour that refers to an individual's emotional state mainly includes vocal characteristics, facial displays and body gestures.

It is common in museum studies to transcribe and analyse the actual content of data collected in interviews. The content is part of the information of verbal feedback, of which there are other variables related to emotions, such as: voice amplitude (loudness); pitch (higher or lower sounding voices); and speech rate. The evidence of acoustic characteristics to emotions can be found in Johnstone and Scherer's work (2000). In this study, they analysed the speech tempo, pitch, amplitude and combined vocal characteristics in relation to emotions, and viewed various studies to demonstrate how these characteristics correlate to specific emotions of stress, fear, sadness, joy, angry, disgust and boredom. Additionally, pointed out by Bachorowski (1999), there are consistent associations of emotional arousal and vocal pitch; to be more specific, high arousal emotions link to higher pitch, while lower vocals are more likely to be associates with low arousal levels of emotions.

The second type of behaviour that closely links to emotion is facial expression. This connection is examined in many early studies of Ekman and Izard (Ekman and Friesen, 1971; Izard, 1971), and universal expression patterns of basic emotions e.g. disgust, sadness, anger, fear, happiness and surprise were identified (Ekman and Friesen, 1971). Many componential coding systems of facial expressions have been developed to identify human emotions. The most widely used system is the Facial Action Coding System (FACS) published by Ekman and Friesen (1978). FACS identified 44 different muscle movements in emotional expression, and coded muscle movements in three action units: main action units, head movement action units, eye movement action units. Certain combinations of facial muscle movements are recognized as expressions of basic emotions. Despite the manual coding system, facial expression of emotion could also be assessed by facial electromyography (EMG). The corrugator supercilii muscle (associated with eyebrow movement) and the zygomaticus muscle (associated with movements of the corners of the month) are two facial muscle groups that are targeted for measuring emotional responses. As described in the literature, the raising of the zygomaticus muscle is associated with positive affective stimuli and controls a smile, while the activity of the corrugator supercilii muscle responds both to positive and negative stimuli (Bradley and Lang, 2002).

Emotions that link to direct facial muscle movement, such as the FACS, are survival emotions in the social function of emotion categorized by App et al. (2011). It is the type of emotion that is supported by the facial channel. The other two types of emotion in the social-functional analysis are social-status emotions, including embarrassment, guilt, shame and pride, which are normally expressed through body channelling and intimate emotions, such as love and sympathy are supported by touch (App et al., 2011). Thus, facial activity could be coded to identify basic emotions, while body posture indicates certain emotions with social-status hierarchy, for example, expansive body posture is connected to pride (App et al., 2011).

## 7.3 Requirements for Conducting Physiological Measures in Museum Settings

However, these different research studies (all showing examples of measuring emotions through the physiology output), share an important similarity: they were all tested in a laboratory setting. All studies listed in the section 7.2 that used physiometric measurements were conducted in strictly controlled laboratory settings, and most of them were research in the field of neuroscience. Indeed, physiological measurements are a common tool in academic areas such as neuroscience, psychology, HCI and consumer behaviour research, while in recent years, a few museums and researchers have begun to try certain types of physiometric studies in the cultural heritage environment. It is a result of the increasing interests of museum professionals and researchers to understand emotional aspects and affective experiences of museumgoers, which are part of experiences that are considered associated with memory and informal learning.

The academic interests of emotions and emotional experience in museum studies has been discussed in Chapter 4.

The abundant research has shown the direct connection between physiological response and affect, therefore, exploring the practicality of conducting physiological measurements in museums could be one way to work out the puzzle.

The Research and Evaluation Department at the Museum of Science, Boston, has conducted focus groups with museum staff members across various departments to share and reflect on questions around emotions in the museum visiting experience (May et al., 2018). The thematic analysis of the focus groups shows the museum staff's interests could be categorized into three main areas: design (design for emotional experience and set emotional goals), understanding (understanding the role of emotions in visitor experience and learning from affective science), and measurements (measure emotions and methods of keeping measurement transparent to visitors) (May et al., 2018). To answer these questions, the team in the museum carried out a series of studies. This combined traditional data collection methods, such as survey and interview, while also trying to study emotion through EDA and eye-tracking technology. This measured emotions with mixed-methods and pointed out the challenges of each method. For instance, as summarized by May et al. (2018), eye-tracking data often requires manual analysis and EDA measures are difficult to interpret without using other methods and the data collected is influenced by other factors.

Hoare's (2018) study in the historic Tredegar House also combined surveys with physiological measurements of EDA and heart activity, in order to understand the affective experience of visiting the site. This study compares emotion words reported by visitors with physiological responses at that time. Ideally, this comparison could reveal the relationship of subjectively reported response and bodily response (Hoare, 2018), however, it may also have concerns of reliability. As can be seen in studies discussed in Section 7.2, to identify discrete emotions through EDA or heart activity are much more likely to be achieved in an environment with less external factors. Therefore, comparing the emotion words labelled by participants with physiological data collected in the study site is questionable to some extent.

These limitations of using EDA in both May's (2018) and Hoare's (2018) research are partially because of the difference between controlled environment and the real-world museum environment. However, it is also limited because of the research design. In these two studies, participants wear EDA devices while walking and exploring the museum space, talking with their companions and giving verbal comments. Although, this may be more similar to the natural way of visiting a museum, it is not a suitable design for collecting electrodermal data, as movement, talking and other external factors may all result in the change of EDA.

Canning's (2018) research applies mixed methods of questionnaire, interviews and physiological measurements in the form of heart rate variables. This research investigates the importance of affective experience in free-choice learning environments such as museums. However, the research found little evidence of affective response by measurement heart rate.

Despite the fact there are limitations to these studies, they are one of the first attempts of using physiological measurements in museums, and show the potential and practicality of measuring physiological response in museum environments.

Drawing from studies of measuring physiological measurements in a laboratory setting, as well as the research in the cultural heritage setting in recent years, there are certain requirements for choosing suitable tools:

a. Direct

   Direct measures, or remote measures, is the first decision that needs to be made. Direct measures refer to measurements that directly attach sensors or electrodes to participants, while remote measures refer to collected photographs or videos of participants and analysis of the images collected. In this study, in both the first and second round of observation, remote measures were carried out via video recordings. However, these observations recorded the occurrence of certain behaviours rather than analysing discrete emotions through body gestures; also, the ratings of valence, from displeasure to pleasure and arousal, from nonarousal to arousal, are based on the observer's subjective judgement instead of applying componential coding systems of facial expression or analysing specific facial muscle movements. This is largely due to the fact that identifying specific emotions from facial or body expression need a clear image of participants' face and ideally from multiple angles (e.g. front and side view close-up image). However, it is unlikely to be achieved in the digitally created environment in museums (for instance, the Venus Simulator, the Sir Patrick Moore Planetarium and the Space Oddities Gallery) due to their particular layout and lighting. Also because of the natural way of visiting and interacting with the in-gallery technology that involves bodily movements (e.g. lower head to read content on a screen, crouch down to talk with children), instead of facing one single direction as in a laboratory. Therefore, to measure emotions by tracking facial muscle movements through remote measurements of recordings is not suitable for this study, and direct measures using sensors or electrodes was considered a possibility.

b. Comfort

The physiological measures should be comfortable for visitors. Firstly, these measurements should not cause any uncomfortable feelings physically (e.g. fear or pain) for participants; the equipment used should be comfortable to wear. Secondly, it should be equipment or device that is less noticeable or visible for other visitors, which allows participants to feel comfortable to wander in museums or galleries and interact with the in-gallery technology without drawing other visitors' attention. Thus, measures that require a lot of sensors attached to participants' faces (e.g. facial EMG) or head (e.g. EEG) is not appropriate.

c. Wearable

The third requirements of the physiological methods is it should be wearable and portable. Because participants are expected to behave naturally and explore or interact with in-gallery digital technology, this would involve movement in the space and navigation of the gallery freely. Therefore, measurement needs a piece of equipment fixed place (for instance, the large equipment of fMRI) that is not in consideration for this research.

d. Affordable

It should be affordable equipment for the research, as well as for museums that attempt to try the physiological method.

Combining the four requirements, it is practically possible to measure activities of ANS, including heart rate, breath time, skin conductance etc. with existing sensors and equipment available on the market.

## 7.4 Measuring Skin Conductance

By reviewing the studies on emotions and emotional experience through measurements of behaviour, ANS and CNS, and combining the requirement of conducting physiological measurement in a non-laboratory setting (with a particular interest in museum space), the physiological measurement of ANS is considered to be the most appropriate method for this research.

As was touched upon in the section 7.2.1, there are three types of measures of the ANS for emotions: cardiovascular measures, respiratory measures and electrodermal measures. Among these measures, the response of EDA to the presentation of stimuli is most discernible compared to the respiratory and cardiovascular responses. For instance, when a stimulus is presented, SCL and the occurrence of skin conductance response (SCR) is easy to distinguish compared to the varying of heart rate and breath rate, which are much more difficult to distinguish. Additionally, the skin conductance is determined by the sweat level on the skin. Unlike other ANS (e.g. heart rate) that are controlled by both sympathetic and parasympathetic activity, the eccrine sweat glands are unambiguously controlled by the sympathetic, therefore, EDA is the direct representation of sympathetic activities (Dawson et al., 2007).

EDA measures include a variety of types of skin conductance measurements including SCL, change in SCL, frequency of nonspecific SCR, SCR amplitude, SCR latency etc. (Dawson et al., 2007). Among these measures, SCL and SCR are the two most often reported measurements (Kreibig, 2010).

SCL and SCR are actually two major components of skin conductance: tonic and phasic (Hardy et al., 2013). The tonic component referred to as SCL, is the slow variation of electrical conductivity of skin over time (Benedek and Kaernbach, 2010). The tonic SCL could vary widely for one subject in different psychological states and for different subjects' responses to the same stimulus or event; the general range for tonic SCL is between 2 μS to 20 μS (Dawson et al., 2007). The phasic SCR consists of a peak that forms by abrupt increase in the skin conductance after latency and the recovery time of slower decline of skin conductance back to the baseline (Benedek and Kaernbach, 2010).

Therefore, SCR is more important for research interested in measuring phasic skin conductance to specific external stimuli, which is particularly important EDA measures for identifying and extracting of physiological response for a short-term stimulus or event e.g. pictures, film clips, or musical excerpts. In contrast, SCL is more valuable for measuring skin conductance throughout a full experimental session (Christopoulos et al., 2019). Hence, in terms of measuring emotions, SCR could be applied to investigate discrete emotions, while SCL is more likely to be an indicator of arousal and provide a dimensional view of arousal, rather than identifying discrete emotions from the EDA at specific periods of time when a stimulus is presented. This research aimed to measure the skin conductance in the whole process of interacting with selected digital interactives, to see the change of arousal throughout the whole experience and identify key points in the experience where significant SCR is triggered. Therefore, in Cycle 3 the study collected the skin conduce signal for analysing both SCL and SCR.

Similar to other EDA, SCL is measured by passing a small current through a pair of electrodes attached on the skin's surface (Dawson et al., 2007). According to Ohm's law, the skin conductance (G) is equal to the current (I) passing through the skin divided by the voltage (V) applied between the two electrodes placed on the skin surface. This can be expressed as $G = I / V$. Therefore, if this small current remains constant, then, by measuring the change of voltage between the two electrodes attached, one can obtain the change of skin conductance. The skin conductance is expressed in unites of microSiemens (μS).

The two electrodes are placed on the skin to measure the voltage; the placement of electrodes is significant for the skin conductance signal collected. Several placements of electrodes are applied in different studies, as the eccrine sweat glands on the palmar and plantar surface are more responsive to psychological significance stimuli rather than thermal stimuli (Dawson et al., 2007). Commonly, for adult participants, the two electrodes are attached on the index finger and middle finger, but distal, medial or proximal phalanges are all acceptable placements. For children, because their fingers might be too small, it is also acceptable to place electrodes on the palm. As the electrodes are attached to the subjects' skin surface and the skin conductance is changed based on the moisture on the surface or skin, cleaning hands with an alcohol wipe or hand gel might change the resistance of the skin. Hence, before the measurement begins, subject should not have washed their hands with soap or cleaned hands with wipe, and the skin should be clean and dry.

### 7.4.1 Research design

Considering this link between physiological changes and emotions can perhaps allow us to explore the subjective personal feelings in a more objective way. This study measured the EDA of interacting with in-gallery digital technology. A device called 'Shimmer3 GSR+ Unit' was used in this study. Galvanic Skin Response (GSR), first proposed by Landis (1932), means the electrical resistance change of the skin, which is determined by the sweat level on the skin. The device is able to measure two types of physiological signals: EDA and photoplethysmography (PPG, detects the rate of blood flow that is controlled by the heart, it can be converted to an estimate of heart rate). The researcher chose the Shimmer product because it was recommended by Effie Lai-Chong Law (Professor in Human Computer Interaction, UoL), who is interested in measuring users' emotions in HCI and applying this GSR device in her research.

This piece of device (Figure 7.1) is very handy; the size of it is slightly larger than a USB stick and light in weight (28 grams). Also, it is the device that has been used in many effective computing, psychology and marketing research studies. Therefore, it is fair to say the device is safe and comfortable for participants. Unlike large wired units, GSR+ is a small wireless device for real-time data collection, display and storage. This portable feature is the key to use in visitor studies in museums. Thirdly, it is a considered an affordable option. The unit costs €428 and it contains an optical pulse sensing probe (to be attached to the finger), optical pulse sensors (to be attached on to the earlobe), a dock (to charge and configure the device), two GSR+ electrodes, two biophysical 9" leads and one wrist strap (all used for this study).


*Figure 7.1 The Shimmer3 GSR+ unit. Source: Photograph by the author.*

The software working alongside the Shimmer sensors is called Consensys, specially designed for configuring Shimmer devices, streaming real time data and managing the collected data. The software comes in two version, Consensys Pro and Consensys Basics. The basic one is free to use and able to stream live time data, collect and download data for a single device and basic data visualization. Consensys Pro has more advanced functions, including recording and plotting data for multiple devices, algorithms, and data descriptions etc., with a yearly licence (for one computer) of €199. Consensys Basic is more suitable for visitor research and museum staff who only need the basic functions, otherwise, Consensys Pro would be a better option for the ones needing advanced data analysis functions (e.g. algorithms PPG-to-HR).

The procedure to use Shimmer3 GSR+ Unit for data collection in Cycle 3 followed the same basic structure as other methods in Cycles 1 and 2. It started with recruiting participants by briefly introducing the research to visitors who attempted to interact with selected in-gallery digital technology. If they were interested, they were asked to read the information sheet and sign the consent form before participating in the research. Once they finished this step, the researcher then explained how the device worked. For the process of wearing the device, the researcher assisted in attaching two GSR+ sensing probes to participants' fingers (on the proximal phalanges of index finger and middle finger) on the nondominant hand. The finger cuffs were carefully adjusted to a modest level (too loose might lead to failure in data collection, too tight might cause discomfort for the participant). Next, was to attach the optical pulse sensor to the participants' earlobe (same side as the GSR sensors). Once all sensors were attached, the researcher helped to adjust the wrist strap on the participant's wrist (same side as the sensors). The Shimmer3 device was then placed on the wrist strap and then the connected jacks of two GSR+ sensors and the optical pulse sensor were attached to the device. Once these were done, the researcher turned on the device and participants were ready to explore the selected digital installations by themselves. After the measuring session, the researcher turned off the GSR device and detached the electrodes and took off the wrist strap. For hygiene consideration, antibacterial hand gel was provided for participants after the test, the sensors were cleaned with a disposable alcohol wipe after use and all items were stored in the GSR kit.

### 7.4.2 Ethics of physiological measurement

As a practice research towards an evaluative framework, this study highly respects participant privacy, psychological well-being and confidentiality. GSR measurements have rarely been used in visitor research, and because of their measure of physiological signal rather than verbal output or observational data, the researcher submitted a separated ethics application for physiological measurement in Cycle 3, and provided separated consent forms and information sheets for participants (Appendices 3.2 and 4.2).

Three points should be highlighted for physiological measurements in this study. Firstly, the data collected in this study is only for understanding sensory and emotional experience in museum visits, instead of for medical purpose or diagnosis. Secondly, the researcher paid attention to hygiene issues. Because the sensing probes attached to participants' fingers and earlobe, as well as the wrist strap, were not disposable and were re-used for many participants, they were cleaned using alcohol after each use and stored in the GSR kit. Thirdly, participants were informed that (even though the sensor is now more widely used and recognised) if a participant felt any discomfort, they were free to stop taking part in the study at any time. And, of course, they were free to withdraw from the process for any other reason at any time.

## 7.5 Data Analysis

Skin conductance signal can reveal emotional engagement by indicating emotional arousal. The change of skin conductance is linearly correlated with arousal (Lang, 1995). In this cycle, skin conductance of 17 participants (6 for Venus Simulator and the planetarium show, 5 for the interactive table) were collected with Shimmer3 (Figure 7.2). The device is able to display real-time data in the software Consensys when connected to a laptop or desktop through Bluetooth. Because the experiment was conducted in a museum, all data collected was stored on the device and uploaded to a computer when the researcher left the site. Participants experienced the digital installations by themselves; the researcher did not interrupt them during the process. In order to match up the starting point for each participant, participants for the planetarium and Venus were given a voice recorder; video recording was used instead for participants at the interactive table.

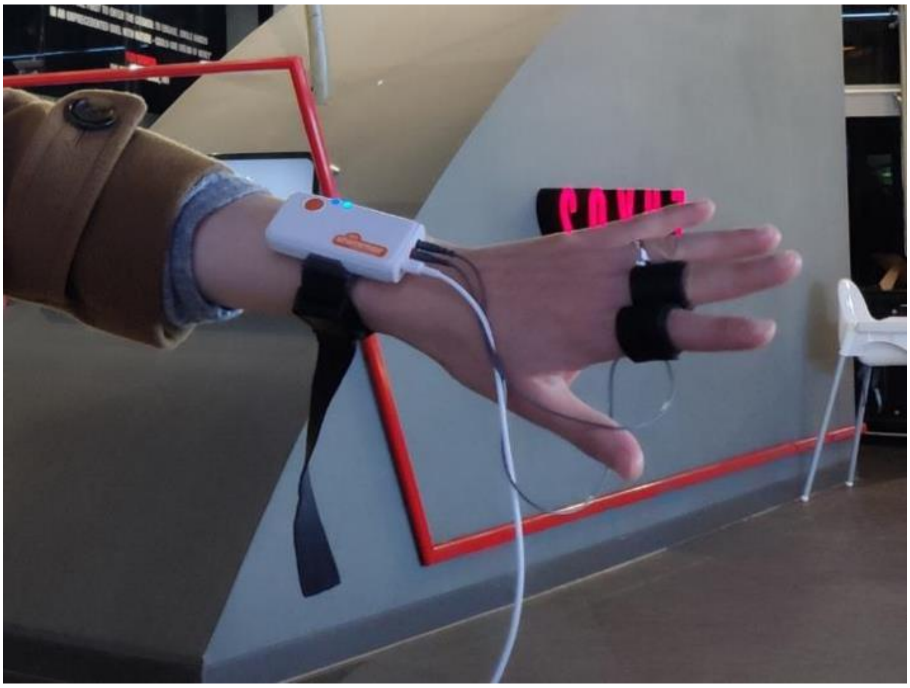


*Figure 7.2 A participant wearing Shimmer3 GSR+ device on her hand. Source: Photograph by the author.*

Before starting the analysis of the physiological data collected in this research, let us view a figure (Figure 7.3) from the study of Dawson and Nuechterlein (1984) as a demonstration of how to read SCR and SCL signals. In the beginning, there is 20 seconds of rest time, then arrows on the 20s, 35s and 50s show three times when a stimulus is presented. Several significant differences are shown in this graph. Firstly, for the tonic SCL, the upper tracing that starts at 10 μS remains in range between 10 μS to 11 μS and the lower tracing starts at 5 μS but decreases as the event goes on. Secondly, when the stimulus is presented, the phasic SCRs (small waves on the line) shown in the upper tracing are more frequent than the lower one. Thirdly, the upper tracing shows measurable SCRs when the stimulus is introduced. However, in the low tracing, in the three times of the presentation of repetitive stimulus, the SCR amplitude is lower and lower, and finally does not show a measurable SCR when the stimulus is presented the third time.

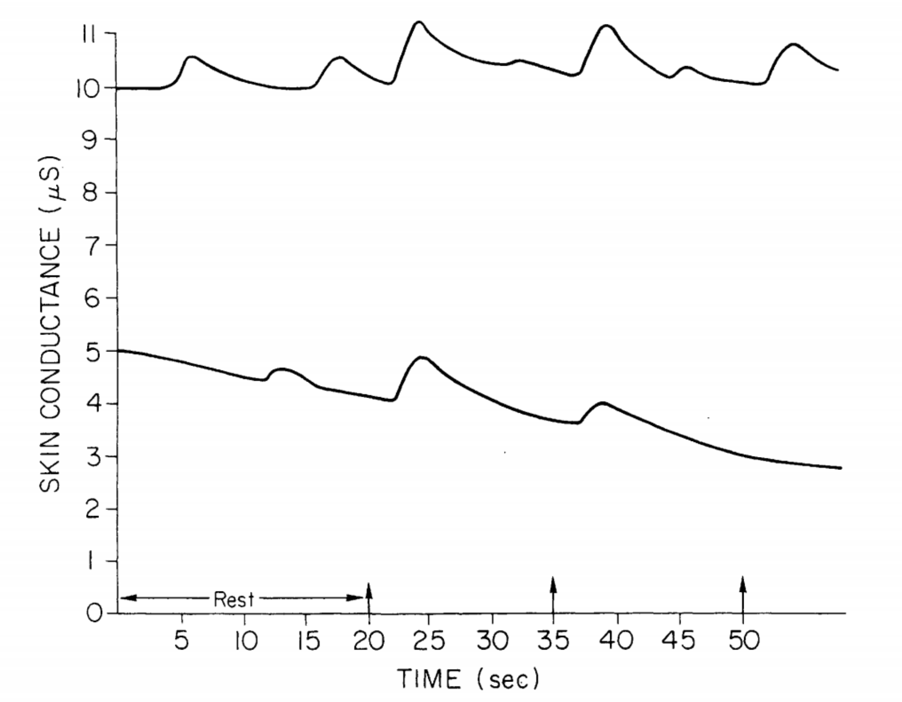



*Figure 7.3 Two hypothetical skin conductance recordings of 1 minute, including a rest period of 20 seconds and presentation of a mild innocuous stimulus for three times (Dawson and Nuechterlein, 1984: 205).*

### 7.5.1 Venus Simulator

Figure 7.4 below shows the skin conductance of 4 participants in the Venus Simulator. The change of skin conductance generally matched the development of the plot. The simulator experience last 5 minutes 3 seconds, and this figure also included 15 seconds before the start and 5 seconds after the end of the simulator experience. Therefore, the overall measurement consists of three phases, from 00:00 to 00:15 is a rest phase, 00:15 to 05:18 is the presentation of stimuli, and 05:18 to 05:23 is a short period of time after the stimulator experience.

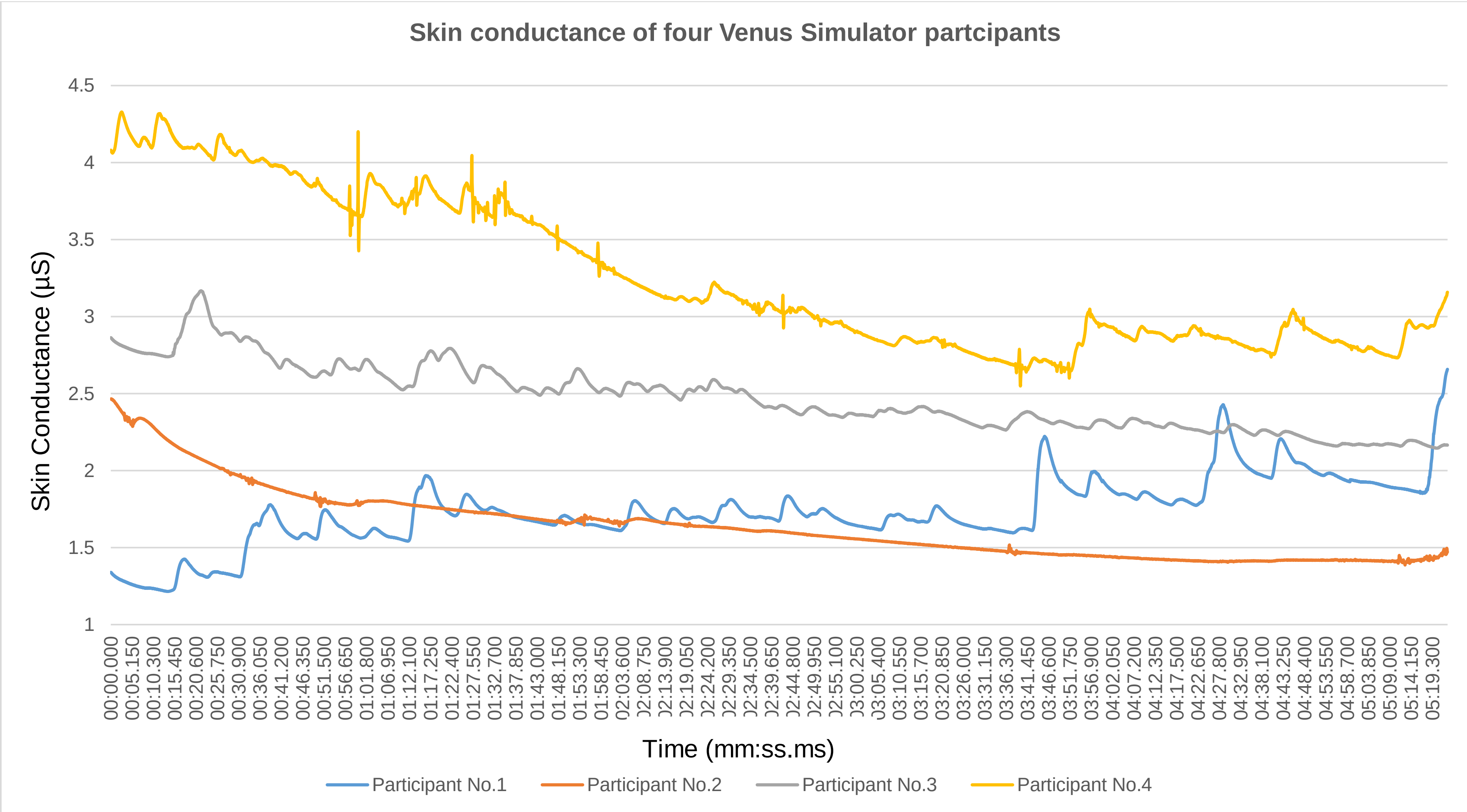



*Figure 7.4 Skin conductance recordings of four Venus Simulator visitors.*

The X axis is the time (mm:ss.ms), and Y axis is the skin conductance (µS). These four skin conductance recordings were selected from the measurements of six participants in the Venus Simulator, and each of the recordings are typical on their own. For instance, the SCL of participant No.2 is much more stable with very subtle changes during the whole measurement, compared to the recordings of the other three participants. This could be because participant No.2 had been in the simulator experience two times before, and this recording is the measurement of the third repetitive experience (the time gap between the second experience of the simulator ride and the measured experience is less than one minute). Therefore, almost no measurable SCR in this participant's recording was found, which is similar to the lower tracing in Figure 7.4, where measurable SCR is absent in the third time presentation of a repetitive stimulus. In contrast to the stable reading of participant No.2, the skin conductance recorded for participant No.4 has a lot of sharp fluctuations which are considered because of the movement of the measured site (participant's nondominant hand). Thus, a low pass filter of 2 Hz was applied to remove the high frequency noise which might be due to the movement or other noise components (Figure 7.5). Moreover, as a decreasing trend of the skin conductance signal of participants No.2, No. 3 and No.4, the recordings of participants show the opposite trend and increased for 1 µS.

The lowest tracing of participant No.1 started below 2 µS, and the highest tracing of the participant No.4 started above 4 µS. Although the figure shows the tonic SCL varies between the four participants, the four various tracings show SCRs to stimuli during the same time of the Venus experience. To be more specific, the three sets of data labelled on Figure 7.5 show similar SCRs between different participants at the same time.

The first example is at 01:23. At this point, the skin conductance of participants No.1 and No.4 started to increase for about four seconds. In the actual experience of the Venus Simulator, this period is where visitors saw a bright flashing plasma streak began to engulf the screen (projections on the curved wall in the front of the 'observation deck') and the screen became gradually engulfed in glowing plasma; they heard the sound of the burning fill the deck which made it difficult to hear the on-board communication and the sound of metal buckling and instruments rattling; and felt the floor which was shaking violently.

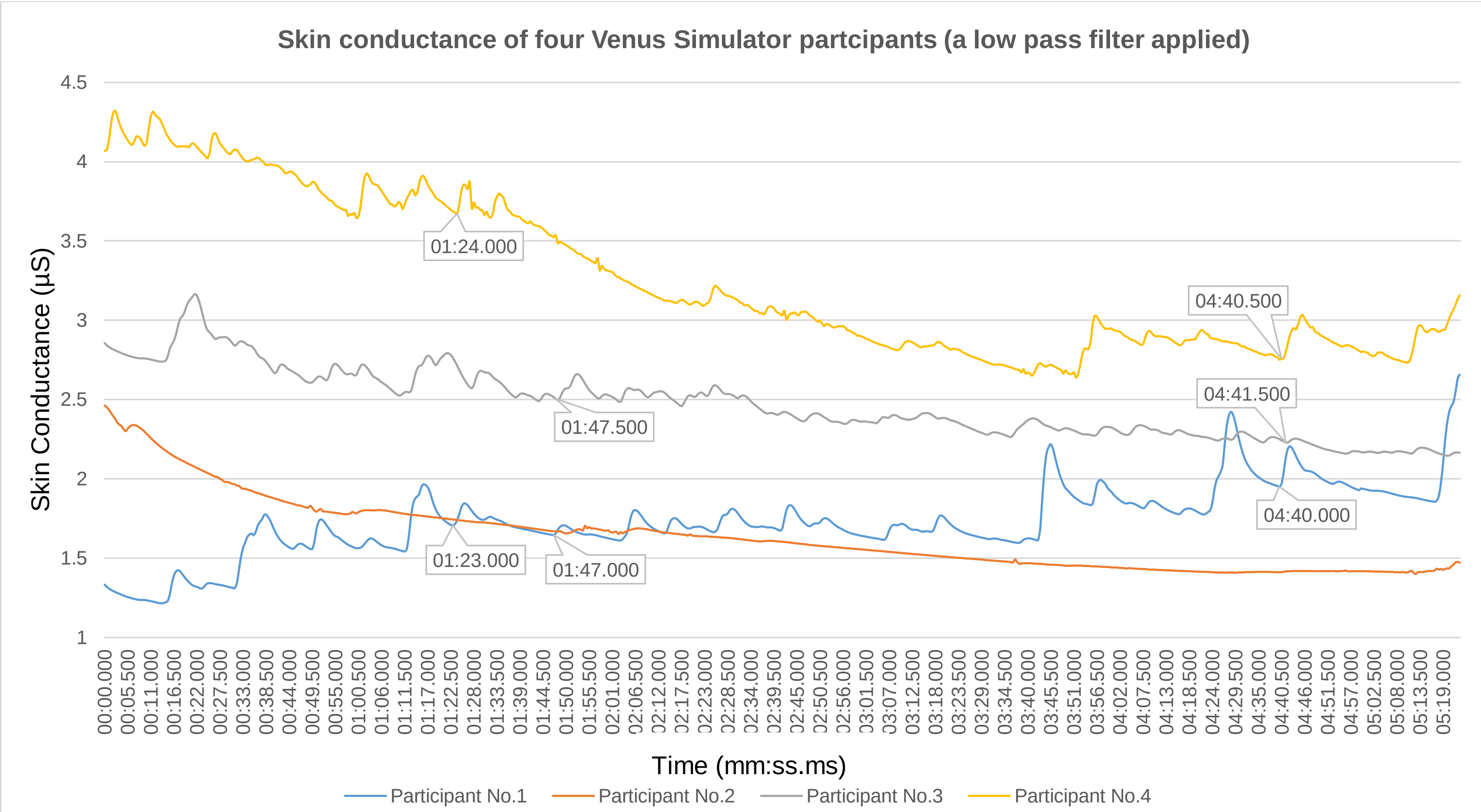



*Figure 7.5 Skin conductance recordings of four Venus Simulator visitors with a low pass filter of 2 Hz applied.*

The second example is the increasing of skin conductance signal of participants No.1 and No.3 which started at 01:47. In this period, visitors saw CO2 snow falling outside, and it collects and blows away like dry ice. As described by Franco (a Portuguese pilot on the airship) ‘Oh, wow! CO2 snow! Now that’s something you don’t see every day.’

The third is the measurable SCRs beginning around 04:40, at the time, the skin conductance of participants No.1, No.3 and No.4 experienced a similar rise. During that time, participants saw two huge legs appearing to the sides of the landing module that stretched out, the lander continued to slow down as the airship neared the ground. Then, the thrusters exerted maximum speed and the airship came to a stead hover just meters above the ground and slowly lowered down. During this landing stage, visitors on the ‘deck’ felt slight vibrations and a strong vibration of landing at the end. In these three examples, common changes in the skin conductance recordings were found during key scenes and moments in the digital interactive.

### 7.5.2 Planetarium show

The total length of the skin conductance measures for the planetarium show ‘We Are Stars!’ is 26 minutes and 18 seconds, as shown in Figure 7.6. Before the start, participants were already seated and they had been told to keep the hand that wore the device on the seat armrest during the entire experience. The skin conductance recoding shown below included one minute before the start of the show (00:00 to 01:00); during this time, a short announcement was given by the space crew. The actual planetarium show is 25 minutes and 3 seconds long (01:00 to 26:03) and 15 seconds after the end of the show finishes (26:03 to 26:18) was also included in the figures. Five participants’ EDA of watching the show were collected; this figure included valid recording of four participants.

In the first 1 minute and 10 seconds of the figure, two different patterns are shown on the figure. More specifically, from 00:00 to 01:10 the skin conductance of participants No.2 and No.4 drop slowly, while participants No.1 and No.3 show a great deal of fluctuation, especially in participant No.1. This might be largely due to the influence of other components. Although the actual content of the show was the same for all participants, there were other variables. For instance, the space crew might give the announcements differently at different shows: some of them might give the announcements in very engaging way, such as asking the visitors to make sure the safety belt was securely fastened and visitors laugh when they find out there is no safely belt, while there are other space crew who give more general safety announcements. Also, the audience who sit around the participants was also different; the voice recordings of each participant show their viewing experience varies a lot. For example, in the voice recordings of participants No.2 and No.4 there is much lower background noise than for participant No.1, where a lot of laugher and talking were heard. The style of announcement, background noise and many other components are all external stimuli for participants and might result in changes in skin conductance. The slow decrease of SCL in participants No.2 and No.4 is very typical of recordings where there is less influence from other noise. When visitors first entered the planetarium and were seated, they normally felt excited because of the huge dome above the room that is a brand-new experience for most of them, then when they were seated for a while and waiting for the show start, they might become less excited. Therefore, in the first minutes in the figure, a slow decrease was found for two of the participants.

Although the SCL data of the four participants seems very different, similarly SCRs can be found at specific points: stimuli such as vivid 3D visual effects, with spectacular scenery of the universe or engaging narratives, might be the reason of the change of skin conductance at these moments. Take the recordings of participants No.2 and No.4 for example, the show started at 01:00, after three seconds, the skin conductance of these two participants went up rapidly. Similarly, these two recordings show SCRs started at the same point of time (around 06:52). This time point is where the 'master' (a cartoon character in the show) told the youngsters to hold on tight, as they were traveling to the very beginning of time via a time machine. The visual image changed quickly from the coloured current scene (in the Time Tent) to the flash back in time (before the earth was formed, before the start is first shone) in black and white scenes.

Towards the end, the montage summarising the journey of life goes through reverse chronological order, from humans and other living creatures to dinosaurs, to the birth of the Earth, to the Big Bang and to protons and electrons, and increases of skin conductance were found in participants. More specifically, we could see a rise of skin conductance starting approximately at 25:00 for participants No.3 and No.4, and about 20 seconds later, readings of the other two participants show an increasing trend as well. From 25:00 to the end of the show is the climax of this full-dome planetarium experience. It takes the audience on a review of the whole story, followed by the exciting and passionate narrative of Andy Serkis, while the last minute of the show answers the question of what we are made of:

> “We’ve discovered that we are made of atoms and these atoms are on a journey as old as the universe. Before they became part of you, they were in animals, plants and in the air; they were once in dinosaurs, in primitive fish and made up the very first cells. And cells assembled form molecules containing atoms that first arrived on earth as comets and asteroids all within the clouds of giant nebulae containing complex atoms, delivered by exploding stars. Atoms that had been fused by gravity deep in the core of the stars, stars that were formed from giant clouds of hydrogen, the same hydrogen that was the first relationship between a proton and an electron. But it all started when energy came together to form matter after the universe expanded from a single tiny point…”

In the last 15 seconds, recordings of all four participants increase sharply, as is it the period when the show finished, and the lights were turned on and they prepare to make their way out.

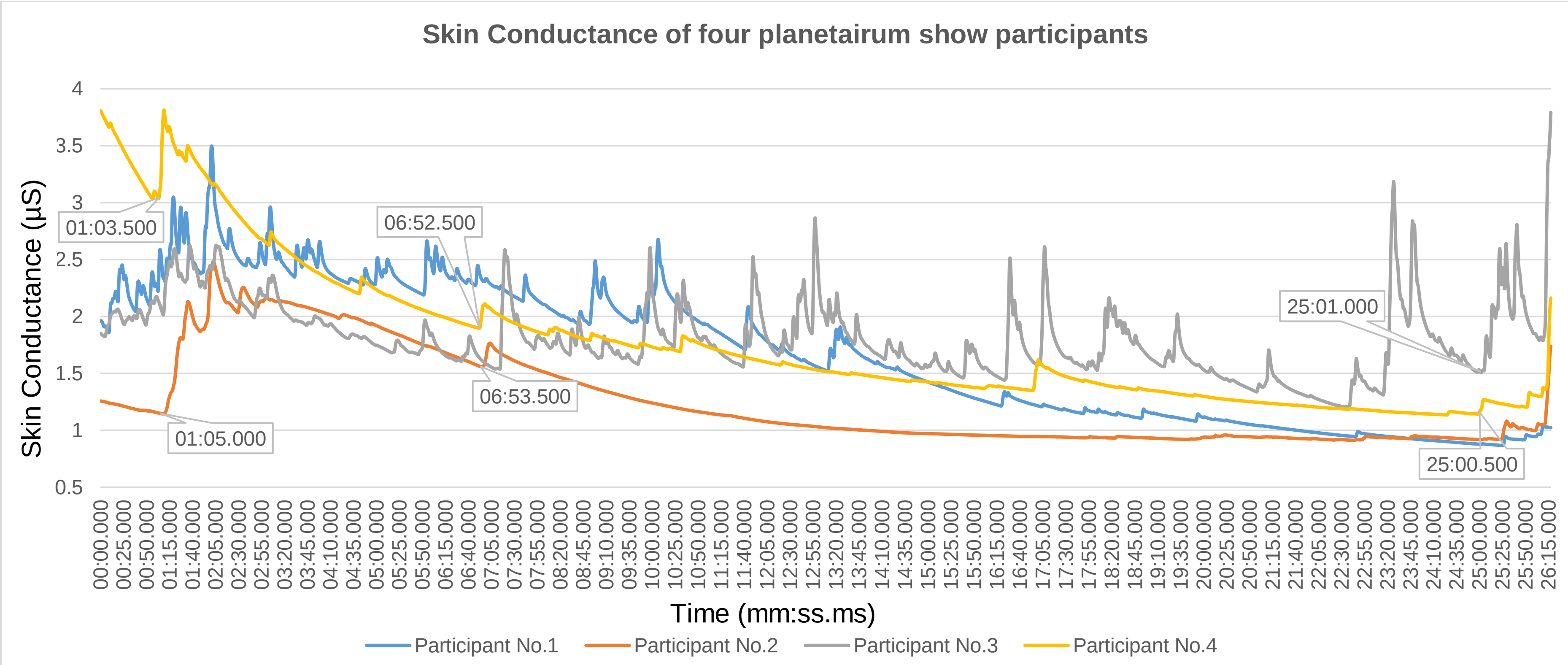



*Figure 7.6 Skin conductance recordings of four planetarium shows viewers with a low pass filter of 2 Hz applied.*

### 7.5.3 Interactive table

As mentioned, a voice recorder was used to assist in data collection and match the timeline for each participant in the planetarium and the simulator. However, the experience with the interactive table is unlike the other two in-gallery technologies that have a start and end point and have the same content for all visitors. Users spend various amounts of time with the table and are free to choose the content they want to view. Thus, a video recording was used to record participants' interactions with the table. Moreover, as users spent various lengths of time on the table it required us to analyse it differently. Instead of analysing skin conductance signal of all participants in a line graph, each skin conductance recoding needed to be understood based on each individual's journey with the table.

Five visitors took part in the trial of using GSR+ in the Space Oddities gallery. Participants spent from 2 minutes 29 seconds to 3 minutes 35 seconds with the table. The data collected for the five participants shows very similar patterns when comparing the skin conductance to the interaction with the table. This part uses the data collected of one participant as an example. Figure 7.7 is the data collected from one of the participants, who spent 3 minutes and 26 seconds using the interactive table. This experience generally consisted of two parts: links (navigate from homepage to sub-page and selecting content to read) and content (reading the content selected which consisted of images and text).

The figure highlights four periods in the experience, from 00:57 to 01:07, 01:38 to 01:52, 02:29 to 02:45 and 02:47 to 03:05. In the video, at 00:57, 01:38, 02:29 and 02:47 the participant started reading a new page (the page of 'Alien bacteria', 'Sokol suit', 'Space toilet' and 'How it works' respectively), and at 00:57, 01:07, 02:45 and 03:05 are the points where the participant finished reading the selected page. In the skin conductance recording, SCRs were found as shown in the figure. These four short periods of time all show a clear increase of skin conductance when the participant started to read content on a new page and reached the lowest point when the participant touched 'Back' when finished reading that page.

The skin conductance signal collected for the other four participants shows SCRs as the example pointed out in Figure 7.7. The recordings of skin conductance reasonably fit the activity during that period, and show that the EDA measures can reflect on the activities of using the interactive table. Significantly, despite external influences (such as noise in the gallery) compared to the controlled environment in laboratories, the physiological measurements of skin conductance could be seen to reflect visitor experience with in-gallery interactives in the museum environment.

After the trial in Cycle 3, some practical points need to be acknowledged when using the device to collect skin conductance signal:

a. Participants should keep the hand that is wearing the device as motionless as possible during the data collection, as movement could cause changes in the skin conductance. For example, in this study, for the planetarium, participants were asked to put their hand wearing the device on the seat armrest; for the Venus Simulator, they were encouraged to choose a comfortable position and remain still; for the interactive table, participants could explore the content with the dominant hand freely but were asked to rest the non-dominant hand with the device on the edge of the table.
b. Make sure participants do not speak during the process, as speaking may influence the skin conductance as well. Therefore, in the participant recruitment stage, it is better to recruit individual visitors, not groups or families.
c. To collect skin conductance, the data collection device is normally set at a comparatively low frequency. Most studies collected EDA signal in frequencies below 30 Hz, the manual of the GSR+ device suggests a set frequency of around 15 Hz. Therefore, in the trial, the frequency has been set to 20 Hz. The device used in this research was also able to collect PPG data, which could be converted to estimate heart rate (using PPG to HR algorithm in the software); the device should be set to high frequency for this (higher than 128 Hz).

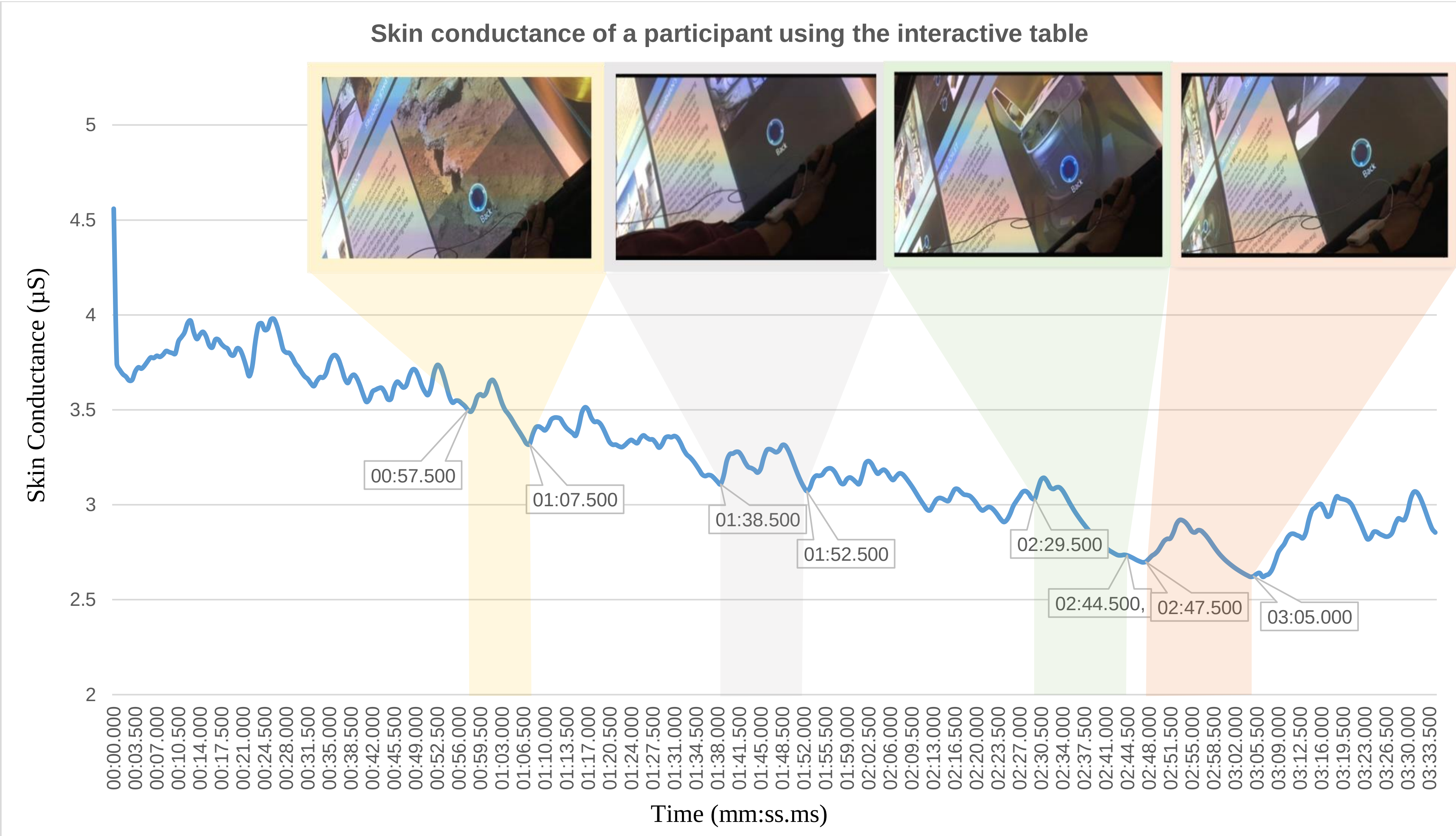



*Figure 7.7 Skin conductance recording of an interactive table user (a low pass filter of 2 Hz applied).*

## 7.6 Limitations

In Cycle 2, although some partial real-time data was collected, it was not possible to fully capture the visitor experience in real time. Also, in both Cycles 1 and 2, all methods were filtered either by visitors themselves (in interviews, questionnaires and think-aloud) or the researcher (in observations), raising questions of reliability. Neuroscience has proved there are obvious signs of physiological responses to emotional changes (Purves et al., 2012). The increase or decrease of physiological activity, such as heart rate, facial muscle movements, sweat and gastrointestinal motility can indicate various emotions (Purves et al., 2012). Therefore, this last design cycle went beyond traditional ways of evaluation and tried to measure visitors' sensory and emotional experience using physiological measurements.

After analysing studies of various types of physiological measurements and the characteristics of each of the measurements, the study measured EDA, as the skin conductance is a general and direct indicator of arousal. In this first attempt of measuring EDA in museum space, the results have shown the response of participants' skin conductance to the three formats of in-gallery digital technology. Individuals' difference of tonic SCL could be seen in the experience of interacting with the same technology, and the similarities of SCRs for external stimuli presented at certain periods of time during the activity could also be identified. Although it is a new evaluation tool for both the NSC and participants, the NSC highly supported this physiological measurement in the exhibition space. This measurement did not have any additional requirements than the traditional evaluation tools; the participants were comfortable to explore the interactive with the GSR device and other visitors' experiences were not influenced. The trial conducted in the NSC has shown it is applicable of measuring EDA using the GSR devices in museums. More significantly, it collected concurrent, non-verbal and non-filtered responses that indicate the arousal in visitors' experience of interacting with in-gallery digital technology.

However, there are also limitations in the measures of EDA in this research. Because the trial was conducted in a public space instead of a carefully controlled environment, the recordings collected may have larger measuring errors compared to the studies conducted in laboratory settings. However, it is still acceptable in the context of this study, as the purpose of the measurement is to see a general response and trend of EDA rather than extract and identify specific emotions. Secondly, the measurements of skin conductance are very sensitive to movement. Although participants were asked to keep as motionless as possible, noise caused by movement were found in some skin conductance recordings. The third limitation of this measurement is that it is hard to tell if the emotions are positive or negative by measuring EDA alone. The skin conductance could only indicate the arousal, however, as we know, emotions such as happiness and anger are high in arousal levels. To measure emotions in terms of both the arousal and valence, we would need to combine the EDA with other evaluation tools, for instance, observation or self-reporting methods.

By considering the outcome of the two former cycles, this chapter has shown the findings of using a GSR device to measure EDA, which is an indicator of arousal. This final iteration of experimentation attempted to include the measurements of the physiological output system, which is separate from the language and behaviour systems. The results of this cycle show the potential of using physiological measurements in museum settings.

# Chapter 8  Mapping and Synthesizing the Evaluative Design

## 8.1 Summarizing the Evaluative Cycles

In the case study at the National Space Centre, three interactives were selected that typified the key characteristics of multi-sensory, immersive and multi-user – all of which are new and emerging in in-gallery digital technologies (as identified in Chapter 3). Chapters 5 to 7 described the process of designing, testing and analysing evaluative methods in three iterative cycles. This section now summarizes the process of each evaluative design cycle.

### 8.1.1 Summarizing Cycle 1

Prior to conducting the first evaluative cycle, the study began with a three-day pilot in the institution. The pilot study was a preparation for data collection in Cycle 1. It helped to establish the level of support needed from museum staff for participant recruitment and where was the best place to distribute questionnaires, conduct interviews and place the cameras. Additionally, some practical issues were identified in the pilot study. For instance, it revealed the poor performance of the video camera in low light conditions, as well as helped to sort out the equipment needed and to figure out the time required for data collection in Cycle 1.

In Cycle 1, three classic evaluation methods in museum studies were tested. These three tools were: questionnaires, interviews and observations, as reviewed in Chapter 4. These methods are frequently used in the research of evaluating educational value and usability of in-gallery technology. Therefore, Cycle 1 aimed to test the effectiveness of measuring sensory and emotional experience with technology using the three common tools.

One-page questionnaires with single-choice (questions of demographic information and previous visiting experience), multi-choice (questions of senses and emotions) and open-ended questions (additional comments) were used in Cycle 1. The PAD Sematic Differential Scale, a model designed by Mehrabian and Russell (1974) was applied in the questionnaire. A multi-choice question designed with a list of words in the PAD scale helped to measure visitors' emotions while interacting with in-gallery technology and supported visitors to give emotional feedback from three dimensions: pleasure, arousal and dominance. A second multi-choice question was aimed at collecting physical feelings, with choices reflecting on the features of the interactives. The main strength of the first version of questionnaire was it demonstrated the variety of emotions visitor could have with in-gallery technology.

The short semi-structured interviews generated word clouds that showed a visual presentation of key feelings shared by visitors. The impressive, comfortable, enjoyable, exciting and a little bit sleepy experience of the planetarium show; an interesting, curious, immersive and different experience with vibrations in the Venus Simulator; and an informative, satisfied, relaxed and curious experience with the interactive table. The interviews conducted when participants finished the activity also showed detailed descriptions of bodily feelings of interacting with technology, as well as the feeling of physically being inside the exhibition space. Additionally, feedback of other aspects (e.g. other suggestions for the NSC) were also shown in the interview responses.

Direct observation in the Space Oddities and remote observation via video recording in the Venus Simulator showed the verbal and gestural communication between visitors and non-verbal interactions between visitors and technology. The length of time visitors spent with the interactives were recorded and the arousal and valence of each observed visitor interacting with in-gallery technology were rated using a 5-point Likert scale. With observational data, the research further distinguished differences of interaction frequencies between groups with children and adult groups.

### 8.1.2 Summarizing Cycle 2

With the inspiring idea of 'remembering self' and 'experiencing self', Cycle 2 aimed to improve the methods applied in the former cycle and to hear 'moment-based' sensory and emotional responses. In Cycle 2, the second version of questionnaires and observation were applied and a new tool 'think-aloud' (which is commonly used in studies of HCI) was tested.

The second version of questionnaires simplified demographic questions and removed questions of previous visiting experience in the 'Who are you' section; and further highlighted and enhanced the section of 'What you thought of the exhibit'. In order to help participants to separate the two sets of questions, the layout of the questionnaires clearly divided main questions into two parts: body (for sensory and physical feelings) and mind (emotional feelings). In the ‘body’ part, the questions were designed to follow the structure of SEEP, a sensory elicitation protocol developed in tourism studies and originally used to collect visitors’ sensory impression of tourist attractions and cities. These series of open-ended questions were applied to encourage visitors to recall sensory feelings. In the ‘mind’ part, the PAD scale was continually used, but instead of asking about the overall emotional experience, this part asked questions of emotional response before, during and after the activity separately. This improved design of the questionnaire offered opportunities to collect both sensory and emotional responses in more detail. Moreover, the new visualization of an ‘emotional wheel’ presented ‘high resolution’ images of the emotional landscape, showed a change of emotional responses in the three stages of the experience and the different emotional patterns in the three formats of interactives.

Direct observation in the Space Oddities was replaced by indirect observation via camera in Cycle 2. The fundamental improvement of this tool is the time-based observation analysis. In addition to counting the frequency of verbal and non-verbal interactions occurring in the video footage, in the second trial, the occurrence of verbal communications, intra-group gestural interactions and interactions with the exhibit were coded based on the time (for the simulator) or content (for the table) of the interactives. Furthermore, specific overt acts of interaction between visitors and technology were identified in the recordings.

The third method tested in Cycle 2 was ‘think-aloud’, which was able to collect feedback concurrently, as the replacement of the interviews which were conducted retrospectively in Cycle 1. An instruction sheet was provided to get participants briefed on the task and prepared to verbalize their thoughts of how they felt in the experience of interacting with in-gallery technology. Because this method required participants to speak to a clip-on microphone during the activity, it did not apply in the planetarium, as this test would influence other visitors’ planetarium viewing experience. Yet, tests conducted in the other two digital environments have shown the potential of CTA in collecting real-time feedback.

### 8.1.3 Summarizing Cycle 3

To this point in the evaluative design process, four methods have applied in the first two design cycles. Among these methods, questionnaires, interviews and think-aloud are measures of verbal feedback that are self-reported by visitors, while observation measures visitors' behavioural and facial expression and it is rated and recorded by the observer. Drawing upon the results and outcomes from the first two design cycles and inspired by the model of three data systems of emotion (language, behaviour and physiology) identified by Bradley and Lang (2002), Cycle 3 focused on measuring feelings from the third system, the physiological response.

Physiological responses are rarely investigated in visitor studies, therefore, prior to conducting measurements at the NSC, the study reviewed research that applied various types of physiological measurements, including measures of ANS, CNS and muscle movements. Combining the features of each physiological measurement with the requirements of conducting data collection in a museum environment, the study demonstrated the reasons for measuring EDA.

In Cycle 3, the device Shimmer GSR+ was used to measure EDA. A total of 13 valid recordings of skin conductance were collected from the three interactives. The skin conductance signal from different participants showed SCRs at the same time points in the Venus Simulator, and shared and common responses at certain periods were also found among the planetarium show participants. For the interactive table, data analysis showed a close link to individuals' activities and the SCRs. Cycle 3 was a first attempt of measuring EDA collected emotional responses from the physiological output system in this study and provided opportunity to see the non-verbal response of the 'experiencing self'.

## 8.2 Mapping the Evaluative Cycles

Having summarised the three Cycles, we can now begin to consider them together, as a single exercise, and start to synthesis the findings of this whole approach. A first useful step is to begin to map the various methods across the three interactive spaces and cycles.

*Table 8.1. Evaluative tools applied in the three cycles.*

| | | Planetarium Show | Venus Simulator | Interactive Table |
|---|---|---|---|---|
| *Cycle 1* | Questionnaires | ○ | ○ | ○ |
| | Interviews | ○ | ○ | ○ |
| | Observation | | ○ | ○ |
| *Cycle 2* | Questionnaires [v.2] | ○ | ○ | ○ |
| | Think-aloud | | ○ | ○ |
| | Observation [v.2] | ○ | ○ | ○ |
| *Cycle 3* | EDA measures | ○ | ○ | ○ |

### 8.2.1 An evolving set of tools and techniques

Each tool was targeted to different aspects of the experience with in-gallery digital technology. This research noticed, questionnaires, interviews and 'think-aloud' were designed to collect both sensory and emotional feedback; observations were designed to fit the purpose of understanding interactions during the experience and rating the valence and arousal of participants; and EDA measures were specifically targeted on the arousal level. To meet the requirements of measuring the targeted aspects of the visiting experience, different frameworks, models and scales were applied. For instance, questionnaires were designed with SEEP and PAD scales and observational guidelines were developed to code various types of interactions.

In these five methods, some tools were used individually, yet, think-aloud and EDA measures conducted in this study were tested in conjunction with other techniques; for example, two follow-up questions were asked in addition to think-aloud, and audio/video recordings were collected with physiological measurement. These additional methods were applied to collect feedback of the overall experience and support information. Furthermore, some additional materials were prepared in advance of the data collection. For instance, instruction sheets were provided for think-aloud participants to be briefed, to prepare and guide them regarding how to verbalize their thoughts. Likewise, observation sheets and observation guidelines were designed in advance to support the data collection and analysis.

In the data collection stage, time spent on each method varied a great deal. The total time spent on collection feedback using the questionnaires was about two weeks during each cycle, while observational data collection in one cycle only took two to three days. The difference is due to the characteristics of each method, but also influenced by the time of data collection (between term time and off-term time, as well as between weekdays and weekends). The time spent on each participant in data collection varied too. This is largely related to the length of each experience. For example, the length of the planetarium show is fixed, consequently, the EDA measures of the planetarium show would be around 30 minutes; while the time spent on the interactive table depends on individuals' preferences.

During most of the data collection, the researcher approached participants by herself. One exception was the questionnaires and interviews conducted with the planetarium show audiences, where the staff at the NSC (space crew) provided strong support in participant recruitment by introducing the research and encouraging participation during the show announcements. The place of data collection was different too, depending on the interactives and tools. Some data was collected inside the gallery or exhibit space, e.g. in observations, EDA measures and think-aloud; some were collected in the entrance or exit area of the exhibition, such as questionnaires of the simulator and the planetarium; but there was also data collection conducted in the museum café, e.g. interviews for the planetarium show.

In the data analysis stage, various types of software were used. These included commonly used Microsoft Office software, such as Excel and Word; statistical analysis software (SPSS Statistics); programming software RStudio, which is a development environment for the programming language R for statistical computing and graphics; as well as ConsensysPRO, the software which works alongside the GSR+ device. A wide range of data analysis techniques were applied, e.g. statistical analysis, thematic content analysis, behavioural coding, in the different methods and for analysing experience with different interactives. The analysed data was presented in the format of texts or graphs. The data visualizations used in this study mainly included word cloud, temporal visualization, and multidimensional visualization e.g. pie chart, bar chart, polar chart and bubble chart. These different design approaches, data collection methods and data analysis processes can be summarised as follows:

*Table 8.2 Design approaches, data collection methods and data analysis processes of each method.*

| | | Questionnaire | Interview | Think-Aloud | Observation | EDA |
|---|---|---|---|---|---|---|
| | | *Open responses and closed responses questionnaires* | *Semi-structured interviews* | *Concurrent think-aloud* | *Structured, non-participant observation* | |
| **Design** | Targets | Sensory experience, emotional experience, demographic information | Sensory experience, emotional experience | Sensory experience and emotional experience | Interactions, valence and arousal | Arousal |
| | Supporting tools | - | - | Follow-up questions | - | Video or audio recordings |
| | Format | Single page, paper-based | 7 interview questions | | | |
| | Additional materials | | | Instruction Sheet | Observation sheet, Notice, observation guidelines | Physiological measurement information sheet |
| **Collection** | Approaching Participant | Researcher and the Space crew | Researcher and the Space crew | Researcher | | Researcher |
| | Time spent | 16 days in Cycle 1, 14 days in Cycle 2 | 6 days | 4 days | 3 days in Cycle 1, 2 days in Cycle 2 | 4 days |
| | Time for each participant | One to five minutes to fill | Two to five minutes to answer interview questions | Depending on the length participants spent with the interactives | Depending on the length participants spent with the interactives | Depending on the length participants spent with the interactives |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Location | Outside or inside the gallery/space | Outside the gallery/space | Inside the gallery/space | Inside the gallery/space | Inside the gallery/space |
| | Equipment | Paper, pen, clipboards | Voice recorder | Voice recorder, clip-on microphone | Camera | Voice recorder, camera, GSR device |
| **Analysis** | Data | 151 questionnaires in Cycle 1 (about 50 for each interactive), 125 questionnaires in Cycle 2 (about 40 for each interactive) | 18 one-on-one interviews (6 for each interactive) | 10 think-aloud recordings for two in-gallery technologies (5 for each interactive) | Observed 120 visitors in Cycle 1 (60 for each interactive), behavioural coded 20 visitors in Cycle 2 (10 for each interactive) | 13 skin conductance recordings (4 to 5 recordings for each interactive) |
| | Tools | SPSS, R | Word, R | Word, Excel | Excel, SPSS | Excel, ConsensysPRO |
| | Techniques | Descriptive statistical analysis | Transcribing interview recordings, thematic content analysis | Transcribing think-aloud recordings, narrative analysis, thematic content analysis | Coding behaviours follow the observation guidelines, rating arousal and valence | Identifying measurable SCRs, matching physiological responses with contents |
| | Visualizations | Pie chart, bar chart, polar chart | Text, word cloud | Text | Time-based temporal visualization, bubble chart | Line graph |

### 8.2.2 An evolving set of roles and requirements

Starting to synthesise these findings, and beginning to map these different designs, methods and processes on to each other (across the three cycles), we can perhaps begin to identify the characteristics of a practical and effective evaluative design framework. Alongside these processes, another aspect of this synthesis (and this potential framework) would be the experience and requirements of the researchers and participants themselves. In other words, just as the tools and techniques changed and evolved across the three cycles, so also did the activities and expectations of the people involved in these techniques. These tools proposed different requirements for visitors who participated in the research, the researcher who conducted the research, and the institution where the fieldwork took place.

For participants, the questionnaire, interview and think-aloud methods all have special language related requirements for participants in order to collect valid data. More specifically, as the questionnaire applied the PAD, which is a sematic differentiate scale consisting of a list of words, it was essential for participants to understand the differences in these words (e.g. the difference between bipolar pairs, 'influenced' and 'influential' and meanings of less frequently used words such as 'melancholic', 'frenzied' and 'autonomous'). Because it was a paper questionnaire with open-ended questions, it required participants to be comfortable with handwriting. As for using interviews and the think-aloud method, which needed participants to give oral feedback, these techniques required participants to be able to describe their opinions and thoughts. Also, some tools needed additional time to get participants briefed and prepared before starting data collection, while some needed time after the activity, and the observations did not require additional time for visitors at all. Furthermore, some methods might influence the participants' experience with the selected digital technology. For example, think-aloud required participants to verbalize their thoughts while interacting with the technology, which could distract participants from their using/viewing experience; EDA measures required participants to wear sensors, keeping the non-dominant hand (the hand wearing the device) as motionless as possible and could not speak during the test; these requirements might influence their experience as well.

For the researcher, skill, data collection time, and data analysis time varied for each technique. Analysis and the visualized data collected had demands on the researcher's skill; for example, several advanced software programs were used in this research. Except for software skills, some tools also had requirement for communicational skills, such as how to approach visitors, how to prompt participants in interviews, etc. Time requirements of each tools were also crucial. In this study, a comparatively short time required for observational data collection was accompanied by a long time for behavioural coding; while questionnaires required the researcher to spend a long time in the NSC for data collection, but moderate time was spent on analysing questionnaires.

For the institution, evaluating sensations and emotions required different types and levels of support. To be more specific, collecting questionnaires in the planetarium shows required help from the space crew; observations needed support from technicians to place the camera and staff to place the notice in the observed areas; and the staff at the ticket desk helped to inform visitors when there was research taking place in the galleries.

Additional to these requirements for the institution, the research and participants, there was also the varied cost for each method in this study. These differences were largely because of equipment and device needed for conducting data collection. For example, conducting indirect observation needed a camera, and recording in low light environments like in the planetarium involved higher requirements for the equipment; measuring skin conductance needed a GSR device which was comparatively expensive; while the cost for paper questionnaires was very affordable.

Table 8.3 below indicates the roles and requirements from the visitors who participated in the research, the researcher who conducted the research, and the institution where the fieldwork took place.

*Table 8.3 Roles and requirements for participants, the researcher, the institution and cost of methods.*

| | | Questionnaire | Interview | Think-Aloud | Observation | EDA |
|---|---|---|---|---|---|---|
| **Participants** | Language | Text reading, Handwriting | Speaking | Speaking | No extra language requirements | No extra language requirements |
| | Time | Time needed after the activity | Time needed after the activity | Preparation time needed before the activity | No extra time needed | Preparation time needed before the activity |
| | Affect | Does not affect experience of the activity | Does not affect experience of the activity | Affected the experience during the activity | Does not affect experience of the activity | Affected the experience during the activity |
| **Researcher** | Skill | Moderate | Moderate | Moderate | High | High |
| | Time (data collection) | Long | Moderate | Moderate | Comparatively short | Moderate |
| | Time (data analyses) | Moderate | Long | Long | Very long | Long |
| **Institution** | Support | High | Moderate | Moderate | Very High | Moderate |
| | Affect | Does not affect normal | | | | |
| **Cost** | | Low | Moderate | Moderate | High | High |

### 8.2.3 Characteristics of the evaluative methods

Viewing the methods from different dimensions could reveal different characteristics of them. For instance, from the dimension of data collection time, these tools could be divided into two types: non-current data collection tools and concurrent data collection tools. Questionnaires and interviews were conducted when visitors finished their experience with selected interactives and these methods of collection give feedback retrospectively, therefore the feedback collected is memory-based and is given by the 'remembering self'. To the contrary, think-aloud and EDA measures are methods that are able to collect data concurrently while the participants are interacting with the technology, and these responses are momentary-based and are given by the 'experiencing self'. Although in observations, visitors' interactions and behaviours were coded later on, when the actual experiences were finished, observational recordings show the feedback of 'experiencing self'. Therefore, observation is considered as a concurrent evaluative tool.

The second dimension is the formats of the responses, including verbal response and non-verbal response. More specifically, the feedback collected by questionnaires, interviews and think-aloud are verbal based, therefore, it may have specific language requirements for participants. On the other hand, observations coded participants' behaviour and interactions and EDA measures recorded the physiological responses of skin conductance instead of verbal expression. Therefore, these non-verbal based data collection tools do not have language related requirement for participants.

The third dimension is the subjectivity of the methods. Interviews, questionnaires and think-aloud are methods that were self-reported by the participants, making them the feedback of the individuals' subjective experiences. Observations always come with concerns of observer bias, but to avoid this bias normally two observers cooperate and code recordings together. Yet, in this project that solution was not applicable, observational recordings were rated and coded by the author. In either case, observations are based on observers' subjective judgment. Thus, these four methods are filtered by the participant or the researcher. EDA measures, on the contrary, are non-filtered measurements that reflect participants' arousal. This is because the data collected is a direct measurement of skin conductance, which is not influenced by individuals' consciousness. In other words, EDA measures and other physiological measurements enable us to measure the subjective experience in a more objective way. Table 8.4 below summarises these key features of the evaluative tools.

*Table 8.4 Key features of the evaluative tools.*

| **Questionnaire** | **Interview** | **Think-Aloud** | **Observation** | **EDA** |
| --- | --- | --- | --- | --- |
| Non-current | | Concurrent | | |
| Verbal | | | Non-verbal | |
| Filtered | | | | Non-filtered |

## 8.3 Identifying New Principles

The previous section summarized the process of iterative design cycles, with questionnaires and observations applied in Cycles 1 and 2, interviews used in Cycle 1 but replaced by think-aloud in Cycle 2, and physiological measurements that were tested in Cycle 3. It then concluded key elements of method design, data collection and data analysis. Next, it discussed the requirements of using each tool, including the language ability and time availability for participants, skills, data collection and analysis workload for the researcher, support needed from the institution, as well as the cost involved of using each evaluation tool. The last part of the previous section pointed out differences of these tool from three dimensions: verbal and non-verbal, non-current and concurrent, filtered and non-filtered measurements. These discussions and tables helped to map the interactive design cycles.

In light of these discussions and summaries, the following section now aims to propose core principles of evaluating sensory and emotional experience of interacting with in-gallery digital technology. The discussion here starts with defining what these principles are, then explains why these principles are crucial by drawing upon examples from the evaluative design cycles, and implications for measuring senses and emotions in museums are discussed at the end. The core principles are: *differentiate*; *expand*; *combine*; *extend*; *contextualise;* and *scale*.

### 8.3.1 Differentiate

The evaluative methods for measuring sensations and emotions might not be the same, so it is necessary to be prepared to use different methods for each. An effective evaluation tool should be designed with consideration to this differentiation of emotional and sensory experience. They are two different parts of 'feeling' and 'experience'.

Sensations are bodily and physical feelings. As discussed in Chapter 2, the understanding of senses could be the classic view of the five senses (touch, sight, sound, smell and taste), or it could be more a complex combination of exteroceptive senses and interoceptive senses. Measuring sensory experience is measuring how visitors' bodies feel. Emotions, on the other hand, are mental feelings. The understanding of emotions could be in the form of discreet emotions, such as happy, anger, fear; but also, someone's emotions could be expressed in a dimensional view, from negative to positive, and from non-aroused to aroused. Some believe emotions are universal and shared across cultures, while others hold a constructional view and think emotions are shaped by culture and history. Although understanding of emotions varies, evaluating emotional experience with in-gallery technology is measuring how someone mentally feels.

Differentiating emotions and sensations in the design of evaluative tools is important, as it could help and support participants to answer questions more specifically. For instance, in the improved version of the questionnaires, questions targeted on sensory experience and emotional experience were split into two sections and highlighted with two colours. In this way, it might be easier for visitors to notice the purpose of the two sets of questions.

Differentiating the effectiveness of evaluative tools when measuring bodily and mental feelings is even more important. This study noticed all the five methods tested are workable for measuring emotions, however, only self-reported tools were able to feedback sensory experience. For example, the observations in Cycle 2 coded visitors' interaction with their companions and technology, by analysing their verbal interaction within the group, behaviour such as laughing could indicate positive response of their experience, and their facial expression could help to rate their arousal and valence. However, it is difficult to reveal individuals' bodily feelings of the experience by observing them. Unlike observation, self-reported methods such as interviews are more effective if collecting sensory feedback. For example, in the Cycle 1 interview transcripts, visitors shared feedback of how they felt about the lighting, brightness, sound volume, comfort level, etc.

*Sensations and emotions are two separate parts of the experience with in-gallery technology. Thus, this difference should be pointed out when measuring them and the methods used to evaluate them should also be differentiated.*

### 8.3.2 Expand

We can assume a visitor will have multiple diverse emotions and sensations throughout the experience with any in-gallery technology. Visitors will have more than one type of emotion and sensory feeling at a time, and visitors' emotions and sensations change over time during the experience, therefore, we need methods that are able to gather multiple emotional and sensory experiences with in-gallery digital technology.

The new and emerging types of interactives empower museums to communicate with visitors through multiple sensory channels and engage multiple senses simultaneously. The mixture of the visual, auditory and the sense of vibration in the Venus Simulator, the touch and sight of the interactive table experience, and the bodily feelings of physically being inside the full-dome planetarium are experiences that combine multiple sensations. Thus, the methods used to evaluate them need be able to reflect the diversity of sensations. In the feedback collected in the think-aloud, for example, the diversity of the sensory experience is clear. Like that seen in the transcripts of Participant D (Appendix 6), who verbalized their thoughts : 'the light is a bit scary', 'the extension of the screen is good', 'feel like you are in the rocket', 'feel you are turning with it', 'feel you are moving', 'feel your body is travelling, even though you are standing on a flat floor'.

It is equally important for the evaluative frameworks to gather the multiple emotions visitors have. As shown in responses collected with the PAD scale, where participants chose words across three dimensions of emotions to describe their experience. The emotions selected were not only restricted in the arousal and pleasure categories, but the words from the dominance category such as 'awed', 'guided' and 'in control' were chosen by many, and all of the 35 words in the scale were selected by at least one participant. And surprisingly, as shown in Table 5.4, many participants selected bipolar emotions. The fact that words chosen across the three dimensions, 35 types of emotions and bipolar adjective words were selected demonstrates the diversity and complexity of emotions visitors could have during their experience. Additionally, visitors' emotions may change as their experience goes on. Still using 'think-aloud' Participant D as an example, the transcript shows a change of emotions from scary and suspense in the beginning, to tense and excitement, then to relieved by the end.

The types of sensations and emotions are diversified; the sensory and emotional experience could change in different stages of the experience. The mixed and changing feelings with interactives are shown in the methods tested. *The ability to collect the various and changing feelings is crucial for an evaluative framework of measuring sensations and emotions.*

### 8.3.3 Combine

Sensory and emotional are two parts of visiting experiences that need to be differentiated, consequently it is important to identify methods effective on measuring each part and combine mixed methods of data collection to evaluate them.

Emotions could be measured through language, behaviour and physiological responses, while the measurement of sensations is more likely to be conducted by using self-reported methods, as discussed in section 8.2.1. This is the first reason of why combining mixed tools is necessary for evaluating both sensations and emotions.

Secondly, it is because each method has its own strengths and weaknesses. For instance, measuring EDA with a GSR device allowed us to collect non-verbal and non-filtered, objective physiological responses of participants' experience; but skin conductance can only reflect a single dimension of emotion. Therefore, when Participant No.4 of the Venus Simulator showed the SCR at 4 minutes 40 seconds in the lading stage (see Figure 7.4), this could only indicate the rise of arousal, but this arousal could be the result of either negative or positive emotions. In the dimensional view, there were multiple dimensions of emotions, e.g. the most commonly used two dimensions are arousal and valence and three dimensions of arousal, pleasure and dominance. Therefore, to measure emotions from multi-dimensions, EDA measures need to be applied with other methods, such as combined with observation.

Third, combing mixed methods could improve reliability and validity. Interviews and think-aloud are self-reported by participants, therefore, these methods have reliability concerns because of the social desirability bias. Visitors might try to give the 'right' feedback or the response they think the researcher is expecting. Observations were coded and rated by the researcher, which may have concerns of observer bias. EAD, which measures physiological responses has issues of reliability and validity too. As demonstrated in Cycle 3, a low frequency filter of 2 Hz has been applied to remove noise in skin conductance signals, but there were also a lot of other external stimuli in the galleries that might influence the measurements of EDA. Combing different methods could decrease the influence of bias found in a single measurement tool.

Different methods are required to measure sensations and emotions and each method has its own strengths and shortcomings. *To measure sensory and emotional experience we need to be ready to combine mixed methods.*

### 8.3.4 Extend

The traditional evaluation tools have been used in many evaluation studies when measuring the educational value and usability aspects of interactives. For this new perspective of measuring emotional and sensory experience with in-gallery technology, it was clear that new elements and new tools of evaluation were needed.

Unlike the measurements of learning and usability that are classic perspectives of evaluation and been widely explored in various research in museum studies, the sensory and emotional aspects in experience with in-gallery technology is comparatively less explored. Therefore, to understand and measure these experiences we needed to learn from other disciplines. In this study, SEEP was applied in the questionnaire, as it was designed in sensory studies to measure visitors' sensory impression of tourism attractions, and PAD is emotional state model originally developed in psychology. Learning from other disciplines and adding new elements to the traditional visitor studies tool has shown new insights, such as more detailed and in-depth feedback on individual senses and the emotional patterns of each interactive presented in the 'emotional wheel'.

However, new elements added to the traditional evaluation tools may not be enough for an evaluative framework of measuring sensations and emotions. Because these classic methods normally collect data post hoc, the emotions and sensation could vary a lot while the experience takes place. This is important for the framework be able to reflect these changes of emotions and sensations and collect momentary based feedback from the 'remembering self'. This requirement suggested the framework should be creative and try out new tools and techniques. In this iterative process, the new technique of 'think-aloud' was applied in Cycle 2, which has been shown to gather concurrent feedback of how visitors respond to different scenes in the simulator experience and different content pages on the interactive table. A new measurement of physiological responses was tested in Cycle 3, which showed real-time responses of interacting with three formats of in-gallery technology. Despite the test being conducted in the museum space rather than the controlled laboratory setting, the EDA signals of participants showed a reasonable fit with the activities of using the table, key scenes and moments of the planetarium show and the Venus Simulator.

The traditional methods, such as questionnaires and interviews can still be effective by upgrading them with new models and elements. More importantly, to collect concurrent feedback, this framework should be ready to learn and explore the potential of more creative tools, such as 'think-aloud' and physiological measurements. *Measuring experience from the perspective of emotions and sensations means we need to be prepared to extend our traditional toolset*.

### 8.3.5 Contextualise

The choice of methods applied to evaluate sensory and emotional experiment with in-gallery digital technology should be contextualised based on the format and characteristics of the technology, and be adapted to visitors' expectation of the institution.

Different formats and characteristics of digital technology requires different methods to measure it. Firstly, the methods should always be designed based on the characteristics of each interactive. For instance, the sensory questions in the questionnaire need to be designed to reflect on the individual sensations that might be involved in this experience, such as the visual, auditory and the immersive feeling in the planetarium show viewing experience or the visual and touch in the interactive table experience. Similarly, the behaviour coding guidelines for the observation were also designed according to the interactions occurring in the experience. The guidelines of the interactive table, meanwhile, are mainly focused on the verbal and non-verbal interactions between visitors: context viewing, special interactions and gestural interactions between the user and the technology. While the guidelines of the Venus Simulator highlighted the direction visitors looked, to identify the elements (the curved and extended projection on the two sides of room, the lights on the top, the vibration coming from the bottom or the screen displays information of the airship on the back wall) of the installation which attracted visitors' attentions during their experience. Secondly, some characterises of technology decided what types of method were most suitable. Such as the cinema-like experience of the planetarium show suggested that using 'think-aloud' in this environment was not appropriate.

Visitors' expectation for participating in an evaluative research might vary depending on the atmosphere and environment of the museum. In this study, the iterative cycles were conducted in the NSC, a museum where visitors are more open-minded and expected to use and explore various types of interactives. Here, it is this expectation visitors have, and the lively, vibrant atmosphere of the instruction which contributed to encouraging visitors to try new devices and test new methods. For instance, the testing of 'think-aloud' methods and physiological measurements, which were new to participants. Although it has not been tested in any traditional history or art museum, it could be more challenging to use new tools in these environments. Therefore, museums should be prepared to use methods that are outside the usual gallery context.

*The choice methods of conducting an evaluation of sensory and emotional experience with museum interactives should be decided by the formats and characteristics of the interactive, and should be contextualized into the environment of the museum.*

### 8.3.6 Scale

It is important to acknowledge that the new methods of in-gallery technology evaluation may require new tools, new cost and new skills. When choosing the methods to evaluate visitors' experience, the capacity of the organization should be considered.

The methods have different requirements for equipment and staff. For example, the in-direct observations a camera (and higher requirements in low-light environment) was needed, the 'think-aloud' needed a clip-on microphone and a voice recorder, and the EDA measures needed a particular device (e.g. the Shimmer GSR+ device used in this research). Meanwhile, for museum staff, new methods might require new skills, such as new skills of data analysis and visualization. Consequently, the organization might need to provide training for staff, for instance, training of conducting behavioural observation, understanding physiological measurements, and using new software or devices. Therefore, finally (but importantly), *when using these mixed tools and methods to evaluate the sensation and emotion of in-gallery digital interactives museums need be prepared for the requirements of cost, staff and training resources*.

## 8.4 Towards the Evaluative Framework

As more multi-sensory, multi-user, immersive experiences with in-gallery digital technology appear, will our classic visitor studies toolset still be effective for measuring user experience in the new wave of in-gallery technology? Are the traditional evaluative models (built around learning and usability) still fit for purpose when understanding visitors' emotional and sensory responses? In order to address these questions, this iterative evaluation design tested the traditional methods and explored new methods with three formats of interactives and through three design cycles

This chapter first summarized the objectives, key ideas, outcomes and findings in each design cycles. Then, the chapter mapped the process of methods developed in the evaluative design cycles; described the design, data collection and data analysis process; analysed the requirements of each method, including requirements for museums, researcher and participants; and identified key characteristics of the evaluation methods. Drawing upon lessons learned from the classic triptych of observation, interviews, and questionnaires, combing the findings of testing the 'think-aloud' method and electrodermal measurements, the chapter further identified six principles of the framework, which are: differentiate, expand, combine, extend, contextualised and scale. In this last section of the chapter is presented the basis towards the new evaluative framework of measuring sensory and emotional experience with in-gallery technology. Table 8.5 highlights the six core principles of the new framework, as well as the value of five key methods for measuring sensory and emotional experience.

*Table 8.5 Basis of the new evaluative framework of measuring sensory and emotional experience with in-gallery technology.*

| Core Principles |
|---|
| <u>Differentiate</u><br>The evaluative methods for measuring sensations and emotions may not be the same; the methods suitable for measuring experience with different formats of technology may vary too. Be prepared to use different methods for each. |
| <u>Expand</u><br>Assume a visitor will have multiple diverse emotions and sensations throughout the experience of any in-gallery technology. Because visitors will have more than one type of emotion and sensory feeling at a time, also, visitors' emotions and sensations change over time during the experience. The methods should be able to reflect the change and diversity of emotions and sensations. |
| <u>Combine</u><br>Sensory and emotional experience require mix methods of data collection. Different methods are required to measure sensations and emotions and each method |

| Methods | Advantages | Limits |
|---|---|---|
| Questionnaire<br>*Verbal measurement* | • Measuring both emotional and sensory experience.<br>• Presenting multiple emotions across three dimensions of pleasure, arousal and dominance.<br>• Collecting sensory feedback from various perspectives.<br>• Suitable for measuring experience with different formats of in-gallery digital technology.<br>• Collect large amount of feedback efficiently in comparatively short time. | • May contain difficult or less familiar words for some participants.<br>• May be difficult to read for some participants.<br>• Some participants may feel uncomfortable with handwriting.<br>• Unable to measure real-time responses.<br>• Feedback may have reliability concerns, e.g. social desirability bias. |
| Interview<br>*Verbal measurement* | • Suitable for various digitally created environments.<br>• Measuring both emotional and sensory experience.<br>• Identifying key emotions and sensations during the experience.<br>• Suitable for measuring experience with different formats of in-gallery digital technology. | • Limited vocabulary of describing emotional experience.<br>• Unable to measure real-time responses.<br>• Feedback may have reliability concerns, e.g. social desirability bias. |
| Think-aloud | • Suitable for various digitally created environments.<br>• Measuring both emotional and sensory experience. | • Could be challenging for participants to manage two tasks: interacting and verbalizing at the same time. |

has its own strengths and shortcomings. Measuring sensory and emotional experience with interactives should be ready for combining mixed methods.

Extend

Traditional methods of questionnaires and interviews are not enough. To measure sensory and emotional experience might need to learn from other academic disciplines. Significantly, to measure concurrent and non-verbal feedback, museums should be prepared to use new methods and extend our traditional toolset.

Contextualized

Requirements for visitors and researchers vary across methods; visitors' expectation and atmosphere vary in different types and scales of museums too. The choice of evaluation methods should be contextualized.

Scale

Acknowledging that the new methods of in-gallery technology evaluation may require new tools, new cost and new skills.

| | | |
|---|---|---|
| *Verbal measurement* | • Detailed and in-depth feedback, how they feel emotionally and physically, and description of why.<br>• Collect real-time, momentary-based feedback reported by participants. | • Feedback may have reliability concerns, e.g. social desirability bias.<br>• Not suitable for using in environments where visitors are expected to keep quiet.<br>• Might distract participants from the interacting experience with technology. |
| Observation<br>*Behavioural measurements* | • Measuring emotional experience and interactions with visitor and in-gallery digital technology.<br>• Collect real-time responses of interacting with the technology.<br>• Keep track of time spent with interactives.<br>• No additional requirements for visitors. | • Not suitable for collecting sensory feedback.<br>• Observer rating may have reliability concerns of observer bias<br>• Could be difficult to conduct in low-light environment.<br>• Observational data analysis could be time-consuming. |
| Electrodermal Measures<br>*Physiological measurements* | • Indicate arousal by measuring skin conductance level and skin conductance responses.<br>• Collect real-time responses of electrodermal activities.<br>• Measuring physiological response which is not influenced by individuals' consciousness.<br>• Suitable for measuring experience with different formats of in-gallery digital technology. | • Only indicate one dimension of emotion experience.<br>• Not able to collect feedback of individual senses.<br>• Other component (e.g. noise, movement) may influence the response of skin conductance.<br>• May affect the natural way of interacting with technology (require participants to not speak and keep one hand motionless). |

# Chapter 9 Conclusions

This thesis has aimed to understand visitors' sensory and emotional experience of interacting with in-gallery digital technology, by proposing principles and guidelines of measuring visitors' experience from this new perspective and forming a basis of a new evaluative framework for museums. This attempt to develop a framework of evaluating emotions and sensations in museum visits would help us to meet the requirements of measuring the impact of new and immerging in-gallery digital technology, which provides a more multi-sensory, immersive, social and shared interacting experience. It provided practical evidence to demonstrate that using only the existing tools for evaluating in-gallery interactives would not be enough considering the change in academic, technological environment and professional priorities. Therefore, this research pointed out the need to apply new elements and use new evaluative methods of evaluating sensory and emotional experience, more importantly, it proposed six core principles for a new framework and a practical guide to using various evaluative methods.

These findings corroborate and add to the academic trends in humanities and social sciences of re-evaluating and re-understanding the senses and emotions, particularly by providing theoretical and practical instructions of evaluating these experiences with digital technology in museums. This research also contributes to our understanding of the changes in the technological environment within museums and the growing media complexity of that environment. Additionally, this study provided an original, in-depth case study of measuring visitors' experience of in-gallery digital technology within one distinct museum environment. Therefore, this thesis will be of import to museum evaluation practitioners, and visitor studies theorists, as well as digital heritage researchers.

## 9.1 Summary of the Thesis

The literature review chapters helped to identify the gap in the current research and the needs for evaluating experience with museum technology from a new perspective. Chapter 2 examined the 'sensory turn' in broad humanities and social science, as well as in museum studies, which aims to recover a comprehensive understanding of human body and sense, and the 'emotional turn' in museum studies and other related research areas, which specifically focus on investigating the role of emotion in museums' interpretation and narrative (Munro, 2014). This chapter first discussed the different understandings of senses, then it reviewed research in museum studies, addressing issues with sensory experience and sensory engagements of the well investigated senses of sight and touch, the less-explored senses of sound, smell and taste, and the embodied feelings of physically being inside an environment. The chapter then examined studies that explored emotional engagement in museums and cultural organisations, using the examples of emotional as a tool to assist in interpretation and support education.

Chapter 3, in turn, reviewed the technological developments and trends in museums. This chapter first examined five important technologies that are recently applied and popularized in museums to improve interactivity and enrich visiting experience. The chapter was particularly focused on the employment of in-gallery digital technology in museum and cultural institutions. Viewing various examples of new and recently installed in-gallery technologies in museums worldwide, the chapter identified key characteristics of the new wave of technology. The three main characteristics are the multi-sensory experience, to create digital experience by engaging senses through multiple sensory channels; shared and social experience, rather than using digital technology that is only able to provide an individual experience, there is a trend of using technology that could interact with multiple users; and immersive experience, where visitors can be free from external disruptions and immerse themselves in the environment using digital technology. Each characteristic was discussed with supporting examples from museums and exhibitions.

Starting with a brief review of the history of visitor research in museums, Chapter 4 particularly examined the evaluation studies of various types of technology in museums, e.g. mobile phone applications, VR and website. Viewing these studies, the chapter first identified the two classic perspectives of evaluating the experience with technology, which are the educational value and usability. Secondly, through these studies, the chapter discussed the methods and tools applied and identified the three classic evaluation methods to measuring experience with museum technology: questionnaire, interview and observation.

Chapter 2 pointed out the academic turn of researching sensations and emotions, Chapter 3 identified the multi-sensory, multi-user and immersive characteristics of in-gallery technology. There are the trends in academic studies, and on the other side, there are the more multi-sensory, immersive and interactive experience created by new technology. Inspired by the sensory and emotional turns and considering the technology and digital environment that have changed, a new question proposed how to measure visitors experience with the new generation of technology, and particularly, from the perspective of sensations and emotions. To address this question and to understand what new an evaluative landscape could look like, the research started with the triptych of the three traditional methods and tested these evaluation methods in three iterative design cycles.

In Chapters 5, 6, and 7, we looked in turn at the three iterative cycles of evaluative design. These developed, improved and explored a set of tools which were used. In Chapter 5 we saw how three common evaluation methods in museums studies could be designed to fit the purpose of measuring sensations and emotions. Observations kept track of time spent in each digital exhibit, recorded the frequencies of verbal and non-verbal intra-group interactions and interactions with technology and rated arousal and valence. Questionnaires combining multi-choice and open-ended questions collected an understanding of visitors' emotional response across three dimensions. Retrospective interviews collected feedback of overall experience and provided the chance to collect direct verbal responses of feelings and opinions. It showed how traditional evaluation tools that are usually used to measure learning outcomes and usability could be designed and applied to measure sensory and emotional experience. Even though there are advantages and the possibility of success in the way that these tools are used, it left limitations of reflecting on the change of experience in different stages of the activities. This point is particularly important, as sensory and emotional experience could change a lot over time, due to various reasons, such as visual and audio effects, contents, surroundings, etc.

Chapter 6 addressed those limitations by introducing the idea of 'two selves' (Kahneman, 2011) for method development. When it comes to the original evaluation methods, especially interviews and questionnaires, the first round of field research was not able to capture the change in visitors' experience over time, as these two sets of data were collected post hoc. Therefore, changes in Cycle 2, including key questions in the questionnaire, were made, taking into account visitor experience before, during and after the activity; observations were coded based on time and interviews were replaced by ‘think-aloud’ method. In the ‘think-aloud’ test, participants were asked to wear a clip-on microphone and in real-time verbalise their thoughts of how they felt during their experience. And again, the success of these new tools suddenly allowed us to see participant real-time responses of the experience with digital technology. For example, in the planetarium we were first time able to see the change of emotions from the first step inside the planetarium, during the planetarium show and when the show finished. In Venus, we heard the real-time verbal description of experience during the journey heading to Venus. Equally, in the Space Oddities gallery, we could see interactions among visitors and with the interactive table and coded these interactions based on time.

However, yet again, despite these important changes in the way we designed these tools, it still left challenges. In this case, the challenge to collect non-verbal and non-filtered responses. Chapter 7 confronted this by introducing a radically new approach, and went beyond traditional ways of evaluation and tried to measure visitors’ sensory and emotional experience using physiological measurements. Neuroscience studies have proved there are obvious signs of physiological responses to emotional changes (Purves et al., 2012). The increase or decrease of physiological activity, such as heart rate, facial muscle movements, sweat and gastrointestinal motility can indicate various emotions (Purves et al., 2012). Considering this link between physiological changes and emotions can perhaps allow us to explore the subjective personal feelings in a more objective way. Therefore, Cycle 3 measured the EDA with GSR device, and the result showed a reasonable fit of skin responses with the development of plot or content of the three digital installations.

Chapter 8 stood back and synthesized the evidence by mapping all of the cycles together, and was able to find the pattern across all the tools and design cycles. Through that, Chapter 8 identified a set of principles which could form the bases of the new framework. These principles emphasized the importance of combing, expending, extending, differentiating, contextualizing and scaling in measuring sensations and emotions. Additionally, the chapter summarized advantages and limitations of the five tested evaluation methods applied. The core principles and practices are presented here as the initial suggestions of an evaluative framework for measuring immersive, multisensory and shared experiences with museum interactives.

## 9.2 Discussion of Findings

Inspired by the sensory turn, the thesis is an intellectual exercise in researching in-gallery digital technology from a different perspective. The aim of the research is to form a basis of new evaluative framework to measure visitor's experience with digital interactives. Therefore, the thesis specifically addressed a series of questions: what does the turn to sensations and emotions mean for museums in terms of understanding visitor experience holistically? What are the trends and the characteristics of the new wave of technology come into museums and cultural institutions? How can we use classic evaluation methods (that were designed to fit the purpose of measuring educational value and usability of museum technology) to measure sensations and emotions? What are the new techniques, tools and methods we need to meet the requirements of measuring these? And more importantly, what could the basis of an evaluative framework of measuring emotional and sensory experience look like? This research makes original contribution in a number of ways on practical, conceptual and methodological level.

On a practical level, the research measured the impact of three in-gallery digital installations in the NSC. The Sir Patrick Moore Planetarium (the planetarium show 'We Are Stars!' in particular), the Venus Simulator and the interactive table in the Space Oddities gallery were selected as examples of immersive, multi-sensory and shared (multi-user) experience created by new in-gallery technology. For the NSC, it was the first time measuring visitors' sensory and emotional experience with digital exhibits, which helped the NSC understand more about its visitors' experience from a new perspective.

The findings in the three rounds of evaluative design showed visitors' emotional and sensory experience with these interactives using different methods, while also collecting suggestions for the NSC for future improvements. For the institution, this research has presented a comprehensive view of sensations and emotions visitors could have in this interactive experience with selected exhibits. More specifically, it gathered verbal responses from visitors, that described their physical experience and emotional feeling with the three exhibitions using interviews and the 'think-aloud' method; collected questionnaires which could be used for further quantitative analysis; coded visitors interactions in observations, which helped to identify the different types of interaction among different visiting groups; and identified key moments during the 'We Are Stars!' and the simulator experience where participants showed measurable SCRs at the same time. Additionally, the data collected in the study also identified areas which might need to be improved. For instance, interview participants pointed out that when they made their way out the aisle it was a little bit dark, so the NSC might need to consider adjusting the lighting in the exit area, for when some visitor still feel unsteady on their feet. Two participants took part in the 'think-aloud' test in the Venus Simulator and they were not clear what was going on in the simulator; this suggested some introduction should be provided for the simulator for those who have language barriers. Consequently, this thesis is now a piece of research to help the NSC, as well as to help the researcher who wanted to understand science centre interactivity, planetarium experience, and experience of a simulator.

At a conceptual level, the thesis identified the needs and importance of understanding impacts of digitally created environments in terms of sensory and emotionally engaging experience. This thesis is inspired by the academic turn of understanding the role of sense and sensory experience holistically, and as pointed out by Economou et al. (2018), the needs of understanding and creating emotionally engaging experience for visitors. Also, as the new and emerging formats of technology are able to create more complex, immersive and rich sensory experiences, these vary greatly with what we have previously had with in-gallery technology. Therefore, this thesis is triggered by the existing needs of understanding, measuring and analysing experience with new in-gallery technology. While acknowledging the value of analysing the learning outcomes and usability of technology, the thesis identified the gap in the literature where we lack frameworks to provide a coherent and comprehensive understanding of sensations and emotions with interactive technology in museums.

This project has also shown the value of using a new set of theoretical informants and theoretical foundations for digital heritage and museum studies research. This thesis has also shown the value of looking to marketing studies, sensory studies, media studies, psychology and so on. The results of applying models and methods learned from other research areas helped to measure these emotions and sensations. For instance, the PAD scale from psychology and marketing research helped visitors to feedback their experience from different dimensions and showed us the diversity of the emotional experience. The SEEP from tourism studies, meanwhile, demonstrated how to gather responses of individual senses by using an imaginative way to recall memories. Moreover, the 'think-aloud' method from HCI, presented the possibility of collecting real-time verbal feedback and allowed us to see the change of emotions and sensations. And, of course, the physiological measurements that are rarely applied in the visitor studies, have shown its potential of measuring physiological responses to indicate arousal. Therefore, this research showed what other places we could go for evaluative inspiration, which could give us a set of assumptions, terminology and ways of thinking which could inform our work.

On the methodological level, firstly, this thesis pointed out the limitations of existing traditional evaluation tools and showed the irreplaceable value of these tools in understanding and measuring visitors' experiences. In the first two design cycles, the study designed classic evaluation methods with new frameworks and models drawn from psychology and sensory studies. Testing these tools in the NSC with three different formats of digital interactives has demonstrated the value of classic evaluation tools when measuring sensory and emotional experience. The high response rate, the effective data collection and analysis process, and the ability to precisely feedback sensory and affective experience (including sensory experience through multiple sensory channel and emotions across three dimensions) by using a questionnaire. Interviews have the flexibility that allows participants to express their feelings with their own words, as well as the space for them to describe not only 'how' they feel, but more importantly 'why' they feel that way. Unlike the self-report methods of interview and questionnaire, observation could reveal the interactions between users and technology and interactions among visitors; it also collects real-time responses of interacting with in-gallery digital media through participants' verbal communications, facial and bodily expressions.

In addition to acknowledging the effectiveness of using classic visitor study tools, the research also pointed out the challenges for each method; for instance, the limitations of using verbal-based measurements, how time-consuming behavioural coding is, and concerns of social desirability bias and observer bias.

Except from limitations related to the individual method discussed in the summary sections of Chapter 5 to 7, crucially, there are also limitations in the set of methods. More specifically, re-thinking the triptych of the classic evaluative tools, the research noticed this set of tools lacked the ability to feedback the momentary-based experience and capture the change of emotional and sensory experience, especially in interviews and questionnaires. Although this could be improved by dividing the whole experience with in-gallery technology into 'before', 'during' and 'after' key stages (e.g. the improved version of the questionnaire used in Cycle 2), it still cannot be viewed as time-based measurements. The significant difference of the 'experiencing self' and 'remembering self' suggest the need to have a complete picture of the sensations and emotions, measuring the momentary-based and memory-based experience are equally important. To refine the evaluative framework with the aim of designing time-based measurements, the research introduced the 'think-aloud' method and designed the time-based analysis and visualization for video observation.

Reviewing the common evaluation tools together with CTA as a toolset, the major shortcoming is all data collected with these tools are either 'filtered' by participants or the observer, and only measure affect through two dimensions: behaviour and language. While there are three emotion output systems: overt act, language and physiology, as pointed out by Bradley and Lang (2002). These three systems are completely different, they share no common metric and vary greatly in sensitivity and reliability (Bradley and Lang, 2002). Therefore, in the last round of the evaluative design, the research turned to exploring the possibility of measuring physiological response. From the perspective of the development of the toolset, aside from adding the third dimension of measuring affective experience, physiometric methods are able to collect 'non-filtered' responses. This research measured participants' EDA, which is a direct indicator of affective arousal and it is out of the control of individuals' consciousness.

It is challenging to identify specific emotions through physiological responses in museums and other cultural heritage settings at the current stage. For this research, the inconclusive data is a direct result of measuring physiological response in the 'wild', with many uncontrollable external factors. This is also caused by the natural way of interacting with in-gallery interactives, which always includes movement. Limited by external factors and movements during the measurements, the form of understanding physiological data and data analysis should also fit the condition and purpose of applying physiometric measures in cultural heritage settings. As suggested by Hoare (2018), the understanding of bio-data in a cultural heritage setting should not be closed and conclusive, but as 'enabling generative and expansive forms' (Hoare, 2018, p.4) of understanding. In this experiment of using physiometric measures in the NSC, it is a practical exercise and critical thinking of measuring emotions from a new perspective and understanding the implications of doing so. The GSR signal collected shows the general trend of participants' affective arousal, which is concurrent and non-filtered feedback of affective experience of interacting with digital media. The shared 'highlight moments' in the experience may further inspire and contribute to the design of in-gallery interactives. Although physiological data has shown its potential for evaluation, it should be used in combination with other methods for a more complete and reliable understanding and interpretation of visitor's sensory and affective experience.

As stated in Chapter 1, this thesis is an attempt to research 'research methods' for measuring sensations and emotions in museums and other cultural heritage institutions. The overall approach of the evaluative design is not driven by an existing framework or hypothesis, but relied on the evidence collected and needs identified during the design process. This approach allowed the research to test, refine and improve methods through an iterative process. Testing various methods in three cycles, the thesis identified each method's requirements for the researcher, organization and participants. More importantly, it is this approach of evaluative design that supported the evolving of the framework: from the basic and common evaluation tools to a basic framework that is consistent with both traditional and new evaluation methods; and from a toolset with verbal-based, non-current and self-reported methods, towards a framework designed with considerations of non-verbal, concurrent and non-filtered elements.

Except for summarizing the advantages and limitations of each method (for details see Table 8.5) and identifying the two key ideas advancing the evaluative design, which was to measure through different output channels (language, behaviour and physiology) and to understand the importance of non-verbal, concurrent and non-filtered methods, the third methodological contribution of the thesis also includes the recommendations in Chapter 8 – the foundations and principles. The thesis proposed six core principles for the evaluative framework of measuring sensory and emotional experience:

- Differentiate. Be prepared to use different methods of measuring sensations and emotions.
- Expand. Be ready to expand the understanding and design method to reflect the change and diversity of emotions and sensations.
- Combine. Be ready to use mixed methods and measure sensations and emotions through different output systems.
- Extend. Be prepared to extend our traditional toolset and use new methods to collect real-time, non-verbal feedback.
- Contextualized. Be ready to situate and localize in the institutional context.
- Scale. To acknowledge the new methods may require new tools, new costs and new skills.

This research is an attempt to understand the sensory and emotional dimensions of experience with in-gallery digital technology. It is inspired by, and contributes to, the sensory turn and emotional turn in social science and humanities. The field research in the NSC has tested various evaluation tools with three new formats of in-gallery interactives, which could be viewed as practical examples for museums practitioners who are interested in this type of evaluation. The findings have shown the overall approach of evaluative design is appropriate and effective for this research. Through the iterative design process, the framework is able to effectively measure both emotional and sensory experience, and more importantly, it starts to show the change of experience over time and the multiple dimensions of emotional experience. Therefore, for a researcher who wants to develop a similar type of evaluation framework, evaluative design is a method that could be considered. It is an approach with flexibility that makes the improvements from cycle to cycle become possible. And without being driven by existing theoretical framework or hypothesis, this evidence-based practice could also contribute to the design and refinements of individual evaluation tools, as well as the evolution of the framework.

## 9.3 Limitations

This research has looked at the context within science centre and discovery centres only, using the main case study in the NSC. Therefore, there is a serious limitation that comes as a direct consequence of using one case study in one institution. The first concern is: would this research be different in an art museum, anthropology museum or ethnographic museum? Additionally, the NSC is a national museum, so would this research have been different in a local museum or community museum? Did the whole context of a science and interactive centre, as well as the context of a national cultural organization, in any way affect the experiment in terms of reasoning of what methods were possible, applicable, workable and permissible?

There are many elements which helped the research in this context. Firstly, the NSC is an institution that is very reflective on its interactivity, and comfortable with their interactivity being investigated and inspected. The permission from the organization was crucial for this research to test various methods. I had help from the space crews in the exhibition space, staff at the ticket desk, technicians and duty managers; this support and help allowed me to get a video camera out, stand in the gallery with questionnaire and clipboard, and ask visitors to wear microphones and GSR sensors.

Secondly, the organization's culture at the NSC supported the smooth execution of the research. The service design of the institution has many explainers and demonstrators in the exhibition space, and this created a framework that was very supportive for my research. There was signage, permissions, transactions, introductions, interpretations and guiders, but a service framework like the NSC is not in every museum, and this one actually provided hooks and platforms to be able to conduct my research.

Thirdly, the fact that the NSC has various types of interactives made the evaluative design and testing of methods a precondition of conducting the research, but on the other hand, this vibrant environment might influence visitors' attitudes of participating in this visitor research. The NSC uses various types of digital technology, including interactive kiosks, touchscreens, monitors, projections etc., in the exhibition space to tell the story of space history and astronomy. With a lot of digital elements in the galleries, it creates a vibrant and lively environment for visitors, and this might contribute to encouraging visitors to try new evaluation tools and test new methods.

This enthusiasm for research interactivity, the unique organizational culture and lively environment are important supporting elements in this research, however, this might not have been the case in other cultural organizations.

The second limitation is that the research also looked at the UK context. We need to always remind ourselves that, every study of technology has to be understood in a national and social context. And so the reciprocity of the technology-social relationship is important for this study as well. As demonstrated in the theory of social shaping of technology (SST), technological development is not a result that follows technical logic, by contrast, it is the consequence of social influence (MacKenzie and Wajcman, 1999). The central idea underlying the theory of SST is about choices, which exists in the process of design and innovation of technologies (Williams and Edge, 1996). Different choices made by individuals or groups of people in the process of developing a particular technology would lead to different outcomes in the end. In contrast with the long-standing traditional approach of 'technological determinism' (MacKenzie and Wajcman, 1999), which views technological changes as an independent factor which is away from the social influences, SST believes the social consequences of technological developments.

To acknowledge the relationship between technology and society is the foundation to carrying out related research. Baggesen's (2015) thesis is an example that considered the influence of social context on digital technology and localised in a national discourse. Given the influence of European, Australia and American museum theory and practice, her research conspicuously analysed digital museum discourse and mobile museology in the Danish context. Social and technology are two components that could not been seen as separate with each other, they are reciprocal and synergetic. My research considered emerging technology as a special group of technology that is newly employed, and views visitors and people as crucial parts of the social experience. Therefore, the development of in-gallery technology, trends and characteristic of it may differ in different cultural and national contexts. A question worth considering is if the study was conducted in other parts of the world, would it have the same results? If not, what would be different? In other cultural contexts or other parts of the world, are the trends toward sensations and emotions seen in academic research? Are these in-gallery technologies used in all parts of the world? Do those museums also have the technological turn? To answer the set of questions relating to the technology development and technological trend, which need to be contextualized in social and cultural background, the idea of this research needs to be tested in other cultural contexts as well.

As well as the need to be used in other types of museums and cultural organizations, and the need to be adapted to other cultural contexts, this research also needs to be tested with children. The evaluation methods in this research were only tested with adult visitors. Children are a large part of the NSC visitors, and in fact, although the research focused on adult visitors, children still influenced the data collection in many ways. For instance, in the observation, interactions within visiting groups were coded, this included verbal and non-verbal interactions between adult visitors and children; some 'think-aloud' participants interacted with selected digital installation with children, therefore, it included conversations with children; and some cases in the questionnaire, children might help other visitors in their group to fill in the feedback or read out the content for them. The requirements of evaluating children's experience with in-gallery technology and suitable methods for conducting visitor research with children vary a great deal. Thus, there is also a limitation that the research is not able to reflect children's experience with technology.

In addition to the broader limitations with the research methodology, there are shortcomings of the research budget and my own developing research skills. New methods, in particular, the physiological measurements applied require new devices. In this research, I used the device (Shimmer3 GSR+) recommended by specialists in human-computer interaction. Yet, if it is possible, the measurements would be more convincing if I could test different GSR products, for example Empatica E4 wristband and BioNomadix Transmitter. Also, I am a single researcher. If there were a team of researchers, maybe they could try out other evaluative tools, or collect larger sets of data with the five methods applied.

And I am limited by my skills as well. I am someone who started the research not knowing how to film visitors, how to do emotional surveys, how to use physiometric devices, or how to do coding. I have learnt a great deal about these techniques through this PhD project, as a researcher in-training and in the process of developing and improving skills, but this project was therefore limited by my capability. Perhaps there are some techniques that are more specialized, for example emotion capture though facial expression and emotion extraction from mixed measurements of physiological responses which might also be relevant to this research.

## 9.4 Future Research

There are various possible directions for this research. The most immediate possible step is to further analyse the existing data. For instance, for questionnaires collected, various statistical analysis could be conducted, such as to analyse the connection between previous visiting experience with overall rating of the exhibition and the variations of emotions selected among three types of visiting groups; in interview transcripts, a closer analysis of interview transcriptions could be done; in observational recording, movements within the space, bodily movements and gestures could be coded in more detail, and the content of verbal interaction could be transcribed.

In order to measure the less explored experience of sensations and emotion, the methods designed in the three cycles learned from psychology, HCI, tourism studies, and applied models and frameworks of PAD and SEEP. These findings from other studies empowered the classic evaluation tools to fit the purpose of measuring from a new perspective. However, these models were not designed specifically for museums and their visitors. Therefore, for future research, it is worth considering whether we really need, for example, all the words in the PAD scale or would it be more accessible for visitors to replace some words with frequently-used and familiar alternatives. Also, in this study, the SEEP was a protocol designed with open-ended questions. It collected detailed sensory responses, but it was more time-consuming for visitors to some extent. Therefore, if we could develop a scale or model that consists of a list of words or phrases specifically used to describe sensations involved in a museum visit, we could collect responses more efficiently.

The thesis presented a basis towards a new framework, but it is only a start to measuring digital experience in the discourse of sensory and emotional turn. Therefore, what we need to do is to take it further, to expand the list of methods in the toolkit, in addition to the methods tested, and it is worth exploring the possibilities of using other evaluative methods and their effectives of measuring visitor experience from the perspective of sensations and emotions. Additionally, to form a deeper understanding of the six principles: differentiate, expand, combine, extend, contextualise and scale in a wider context, in other cultural backgrounds or different museums environment. And ultimately, to design a framework specifically focusing on visitor's sensory and emotional experience with digital technology in museums.

As we look back on the rapid change in in-gallery technology, and look forward to new ways of understanding, measuring and evaluating visitor experience, this study aimed to offer a glimpse into the new approaches we may need to take. More significantly, by identifying core principles and providing a practical guide of using the evaluation methods, this study aimed to provide the basis for a new evaluative framework with digital technology in museums.

# Appendices

## Appendix 1: Questionnaires

### 1.1 Pilot Questionnaire (for the planetarium show)

## How Was That?

**Who Are You?**

1. Are you male or female? ☐M ☐F

2. Which age group do you fit into?
   ☐18-24 ☐25-34 ☐35-44 ☐45-54 ☐55+

3. Who are you visiting the museum with today?
   ☐By yourself ☐With family ☐With friend(s) ☐With children

4. Have you been to the National Space Centre before?
   ☐No, first time. ☐Yes.
   (How many times? ☐1-2 ☐3-5 ☐more than 6 times)

**What You Thought of the Show?**

5. Have you watched a 360-degree film before in your past visits to Nation Space Centre? ☐Yes ☐No

6. Have you watched a 360-degree film before in other museums or attractions? ☐Yes ☐No

7. What is your overall impression of this 360-degree film experience in the Sir Patrick Moore Planetarium?
   ☐Very Good ☐Good ☐Neutral ☐Bad ☐Very Bad

8. Which word(s) do you think can best describe your feelings of watching the show? (Please select one to three words below.)

| | | | |
|---|---|---|---|
| ☐Annoyed | ☐Pleased | ☐Unsatisfied | ☐Satisfied |
| ☐Despairing | ☐Hopeful | ☐Melancholic | ☐Contented |
| ☐Bored | ☐Relaxed | ☐Unhappy | ☐Happy |
| ☐Stimulated | ☐Calm | ☐Excited | ☐Sleepy |
| ☐Dull | ☐Aroused | ☐Unaroused | ☐Wide awake |
| ☐Jittery | ☐Sluggish | ☐Frenzied | |

9. What part of the show made the biggest impression on you?
   ☐the 360-degree fulldome screen ☐the sound effects
   ☐the narrative and story of the show 'We Are Stars!'
   ☐the atmosphere Other___________

Is there anything else you want to say about this experience?

______________________________________________

______________________________________________

### 1.2 Sample Cycle One Questionnaire (for the simulator)

# How Was That?

## Who Are You?

1. Are you male or female? ☐M ☐F

2. Which age group do you fit into?
   ☐18-24 ☐25-34 ☐35-44 ☐45-54 ☐55+

3. Who are you visiting the museum with today?
   ☐By yourself ☐With family (☐With children) ☐With friend(s)

4. Have you been to the National Space Centre before?
   ☐No, first time. ☐Yes.
   (How many times? ☐1-2 ☐3-5 ☐more than 6 times)

## What You Thought of the Exhibit?

To help you feel like you are flying a spacecraft, the 'Venus' simulator uses a large screen, surround sound and a vibrating floor.

5. Have you ever been experienced a multi-sensory exhibit before?
   ☐No ☐Yes
   (☐In National Space Centre ☐In other museums or attractions)

6. What is your overall impression of this multi-sensory experience in the Venus exhibit?
   ☐Very Good ☐Good ☐Neutral ☐Bad ☐Very Bad

7. Which word(s) do you think can best describe your feelings of this exhibit?

| | | | |
|---|---|---|---|
| ☐Annoyed | ☐Pleased | ☐Unsatisfied | ☐Satisfied |
| ☐Despairing | ☐Hopeful | ☐Melancholic | ☐Contented |
| ☐Bored | ☐Relaxed | ☐Unhappy | ☐Happy |
| ☐Stimulated | ☐Calm | ☐Excited | ☐Sleepy |
| ☐Wide awake | ☐Aroused | ☐Unaroused | ☐Dull |
| ☐Jittery | ☐Sluggish | ☐Frenzied | ☐Controlling |
| ☐Controlled | ☐Influenced | ☐Influential | ☐Submissive |
| ☐Dominant | ☐Guided | ☐Autonomous | ☐Cared for |
| ☐In control | ☐Awed | ☐Important | |

8. What part of the show made the biggest impression on you?
   ☐the visual effects ☐the sound effects
   ☐the physical feeling of 'landing'
   ☐the atmosphere Other___________

Is there anything else you want to say about this experience?

_______________________________________________

_______________________________________________

## 1.3 Sample Cycle Two Questionnaire (for the simulator)

### How Was That?

**Who Are You?**

Are you male or female? ☐ Male ☐ Female

Which age group do you fit into?

☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55+

Who are you visiting the National Space Centre with today?

☐ By yourself ☐ With children ☐ With adults

**What You Thought of the Exhibit?**

BODY

First, we would like to know about your **sensory and physical experience** of the Interactive Table. Tell us the three things that first come to mind about the physical sensation of being inside the Space Oddities exhibition.

1. ☐ 2. ☐ 3. ☐

When you first walked inside the exhibition, how did the environment make you feel?

☐

When you were interacting with the Table, what did you think of the visual experience?

☐

What did you think of the touch experience?

☐

MIND

Next, we would like to know more about your **feelings and emotions** of the Table. Look at the following words:

| | | | |
|---|---|---|---|
| 1. Annoyed | 2. Pleased | 3. Unsatisfied | 4. Satisfied |
| 5. Despairing | 6. Hopeful | 7. Melancholic | 8. Contented |
| 9. Bored | 10. Relaxed | 11. Unhappy | 12. Happy |
| 13. Stimulated | 14. Calm | 15. Excited | 16. Sleepy |
| 17. Wide awake | 18. Aroused | 19. Unaroused | 20. Dull |
| 21. Jittery | 22. Sluggish | 23. Frenzied | 24. Controlling |
| 25. Controlled | 26. Influenced | 27. Influential | 28. Submissive |
| 29. Dominant | 30. Guided | 31. Autonomous | 32. Cared for |
| 33. In control | 34. Awed | 35. Important | |

OK, choose <u>up to 5</u> words (in each case) that best describe how you were feeling

- <u>before</u> using the Table ☐ ☐ ☐ ☐ ☐
- <u>during</u> interacting with the Table ☐ ☐ ☐ ☐ ☐
- <u>after</u> using the Table ☐ ☐ ☐ ☐ ☐

# Appendix 2: Observation Record

## 2.1 Observation sheet of direct observation (for the interactive table) in Cycle One

### Observation Sheet

Date: 31 . 05.2017 Place: NSC. Interactive Table Observer: JINGYU PENG.

| | Gen-der | Age * | Visiting Group** | | | Time spent with the exhibition | | Time spent with the interactive | | Communication (V=Verbally; N=Nonverbally) | | | Pleasure | Arousal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M/F | A/B | I | AG | GwC | In | Out | Start | End | Participation | Content | Operation | Displeasure — Pleasure | Non-arousal — Arousal |
| 1 | M | A | | | √ | 44:05 | 47:28 | 47:17 | 47:28 | √ | √ | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 2 | M | B | √ | | | 59:57 | 02:13 | —:— | —:— | — | — | — | ~~1 2 3 4 5~~ | ~~1 2 3 4 5~~ |
| 3 | M | A | | | √ | 06:30 | 08:29 | 06:04 | 07:25 | V. NV | — | NV | 1 2 3 (4) 5 | 1 2 (3) 4 5 |
| 4 | M | B | | | √ | 15:19 | 17:59 | —:— | —:— | — | — | — | ~~1 2 3 4 5~~ | ~~1 2 3 4 5~~ |
| 5 | F | B | | | √ | 15:19 | 18:00 | 16:54 | 17:13 | √ | — | — | 1 2 3 (4) 5 | 1 2 (3) 4 5 |
| 6 | M | A | | | √ | 25:05 | 29:35 | 25:10 | 29:35 | | √ | V NV | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 7 | F | A | | | √ | 27:55 | 30:08 | —:— | —:— | — | — | — | ~~1 2 3 4 5~~ | ~~1 2 3 4 5~~ |
| 8 | F | A | | | √ | 29:09 | 35:51 | 29:15 | 31:42 | — | √ | — | 1 2 3 (4) 5 | 1 (2) 3 4 5 |
| 9 | M | A | | | √ | 29:09 | 35:51 | —:— | —:— | — | — | — | ~~1 2 3 4 5~~ | ~~1 2 3 4 5~~ |
| 10 | M | B | | | √ | 33:40 | 34:10 | 33:42 | 33:45 | — | — | — | 1 2 (3) 4 5 | (1) 2 3 4 5 |
| 11 | F | A | | | √ | 34:10 | 36:00 | 34:12 | 35:12 | — | √ | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 12 | F | A | | | √ | 35:10 | 37:52 | 36:55 | 37:38 | — | — | V. NV | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 13 | F | A | | √ | | 40:20 | 40:33 | —:— | —:— | — | — | — | ~~1 2 3 4 5~~ | ~~1 2 3 4 5~~ |
| 14 | F | A | | | √ | 43:17 | 43:58 | 43:20 | 43:47 | — | — | — | 1 2 (3) 4 5 | (1) 2 3 4 5 |
| 15 | F | A | | | √ | 44:46 | 46:14 | 44:56 | 45:30 | √ | — | — | 1 2 (3) 4 5 | (1) 2 3 4 5 |
| 16 | M | A | | | √ | 46:30 | 48:36 | 46:35 | 47:44 | √ | — | V. NV | 1 2 3 (4) 5 | 1 2 (3) 4 5 |
| 17 | F | A | | | √ | 47:00 | 49:36 | 48:00 | 49:03 | √ | — | V. NV | 1 2 (3) 4 5 | 1 2 (3) 4 5 |
| 18 | M | A | | | √ | 50:26 | 51:55 | 51:42 | 51:50 | | — | V | 1 2 3 (4) 5 | 1 (2) 3 4 5 |
| 19 | M | A | | | √ | 50:30 | 55:57 | 52:50 | 54:19 | V. NV | — | V. NV | 1 2 3 (4) 5 | 1 2 (3) 4 5 |
| 20 | F | A | | | √ | 57:35 | 02:42 | 59:58 | 02:05 | V. NV | √ | NV | 1 2 3 (4) 5 | 1 2 3 (4) 5 |

*Age: A=18-44, B=45+

** Visiting Group: I=Individual; AG=Adult group; GwC=Group with children.

# Observation Sheet

Date: 31.05.2017 Place: NSC. Interactive Table Observer: JINGYU.

| | Gender | Age * | Visiting Group** | | | Time spent with the exhibition | | Time spent with the interactive | | Communication (V=Verbally; N=Nonverbally) | | | Pleasure | | Arousal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M/F | A/B | I | AG | GwC | In | Out | Start | End | Participation | Content | Operation | Displeasure | Pleasure | Non-arousal | Arousal |
| 1 | F | A | | | ✓ | 58:47 | 59:30 | 58:50 | 58:55 | V | — | — | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 2 | M | A | | | ✓ | 01:44 | 03:58 | 01:52 | 03:56 | — | — | — | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 3 | M | A | | | ✓ | 01:55 | 04:52 | 03:29 | 04:46 | V. NV | — | V | 1 2 3 (4) 5 | | 1 2 (3) 4 5 | |
| 4 | F | A | ✓ | | | 05:10 | 07:45 | 05:15 | 07:42 | | — | — | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 5 | F | A | | | ✓ | 06:08 | 10:05 | 06:12 | 07:20 | V | — | V.NV | 1 2 3 (4) 5 | | 1 (2) 3 4 5 | |
| 6 | F | B | | | ✓ | 06:20 | 11:36 | 07:30 | 10:10 | — | V | V | 1 2 3 (4) 5 | | 1 (2) 3 4 5 | |
| 7 | M | B | ✓ | | | 10:40 | 17:20 | 11:50 | 14:45 | — | — | — | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 8 | F | A | | | ✓ | 13:25 | 15:21 | 13:40 | 14:56 | V | V | V.NV | 1 2 (3) 4 5 | | 1 2 (3) 4 5 | |
| 9 | F | A | | | ✓ | 15:40 | 16:45 | 15:45 | 15:55 | V. NV | — | — | 1 2 (3) 4 5 | | 1 2 (3) 4 5 | |
| 10 | F | B | | | ✓ | 57:00 | 59:14 | 57:15 | 59:10 | V | V | V | 1 2 3 (4) 5 | | 1 (2) 3 4 5 | |
| 11 | M | B | | | ✓ | 57:50 | 59:59 | 57:55 | 59:35 | — | V | V.NV | 1 2 (3) 4 5 | | 1 2 (3) 4 5 | |
| 12 | M | B | | | ✓ | 59:58 | 03:20 | 00:05 | 01:36 | — | V | | 1 2 (3) 4 5 | | 1 2 (3) 4 5 | |
| 13 | M | A | | ✓ | | 02:41 | 05:05 | —:— | —:— | — | — | — | ~~1 2 3 4 5~~ | | ~~1 2 3 4 5~~ | |
| 14 | F | A | | | ✓ | 07:08 | 15:10 | 07:15 | 15:08 | V.NV | V | V | 1 2 (3) 4 5 | | 1 2 (3) 4 5 | |
| 15 | M | A | | | ✓ | 10:25 | 17:17 | 12:56 | 13:30 | — | — | V. NV | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 16 | F | A | | | ✓ | 14:15 | 15:42 | 14:18 | 15:40 | — | V | — | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 17 | M | A | | | ✓ | 17:55 | 20:03 | 17:58 | 18:05 | V | — | V. NV | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 18 | F | B | | ✓ | | 18:05 | 20:45 | 18:48 | 19:50 | — | — | — | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |
| 19 | F | A | | | ✓ | 23:04 | 25:34 | 23:45 | 25:30 | V | V | V | 1 2 3 (4) 5 | | 1 2 (3) 4 5 | |
| 20 | M | A | | | ✓ | 25:49 | 27:03 | 25:53 | 27:00 | — | V.NV | — | 1 2 (3) 4 5 | | 1 (2) 3 4 5 | |

*Age: A=18-44, B=45+

** Visiting Group: I=Individual; AG=Adult group; GwC=Group with children.

## Observation Sheet

Date: 31.05.2017 Place: NSC Interactive Table Observer: Jingyu Peng

| | Gender | Age * | Visiting Group** | | | Time spent with the exhibition | | Time spent with the interactive | | Communication (V=Verbally; N=Nonverbally) | | | Pleasure | Arousal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M/F | A/B | I | AG | GwC | In | Out | Start | End | Participation | Content | Operation | Displeasure … Pleasure | Non-arousal … Arousal |
| 1 | M | A | | | ✓ | 28:55 | 32:25 | 28:58 | 29:33 | — | V | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 2 | F | A | | | | 28:56 | 32:04 | 29:04 | 30:58 | V | — | — | 1 2 3 (4) 5 | 1 2 3 (4) 5 |
| 3 | M | B | | | ✓ | 31:54 | 33:12 | 32:04 | 33:08 | — | — | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 4 | F | A | | | ✓ | 32:57 | 34:28 | 32:59 | 33:09 | — | — | V | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 5 | F | A | | | ✓ | 36:06 | 37:42 | 36:12 | 36:30 | — | — | — | 1 2 (3) 4 5 | (1) 2 3 4 5 |
| 6 | M | A | | | ✓ | 38:45 | 42:52 | 38:50 | 39:20 | NV | — | V | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 7 | F | A | | | ✓ | 38:45 | 42:19 | 40:20 | 40:45 | — | V | V·NV | 1 2 (3) 4 5 | 1 2 (3) 4 5 |
| 8 | F | B | V | | | 40:45 | 51:40 | 43:54 | 48:15 | — | — | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 9 | M | A | | V | | 43:08 | 46:25 | 43:58 | 44:50 | — | — | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 10 | F | A | | V | | 43:10 | 47:05 | 43:45 | 46:50 | V | — | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 11 | M | A | | | ✓ | 47:50 | 52:20 | 48:07 | 48:17 | — | — | NV | 1 2 (3) 4 5 | (1) 2 3 4 5 |
| 12 | F | A | | | ✓ | 51:10 | 51:40 | —:— | —:— | — | — | — | ~~1 2 3 4 5~~ | ~~1 2 3 4 5~~ |
| 13 | F | A | | | ✓ | 52:05 | 55:57 | 52:30 | 55:40 | V | V | — | 1 2 (3) 4 5 | 1 2 (3) 4 5 |
| 14 | F | A | | | ✓ | 54:00 | 20:05 | 06:01 | 13:44 | V | V | V | 1 2 (3) 4 5 | 1 2 (3) 4 5 |
| 15 | M | B | | | ✓ | 55:57 | 00:01 | 56:00 | 59:55 | — | — | NV | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 16 | F | B | | | ✓ | 55:57 | 00:35 | 56:02 | 00:30 | — | V | V·NV | 1 2 3 (4) 5 | 1 (2) 3 4 5 |
| 17 | M | A | ✓ | | | 00:00 | 02:20 | 00:05 | 00:57 | — | — | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 18 | M | B | | V | | 00:40 | 04:05 | 01:20 | 02:03 | — | V | — | 1 2 (3) 4 5 | 1 2 (3) 4 5 |
| 19 | F | A | | V | | 04:17 | 06:00 | 04:10 | 05:30 | — | V | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |
| 20 | M | A | | V | | 05:36 | 06:42 | 05:38 | 06:09 | — | — | — | 1 2 (3) 4 5 | 1 (2) 3 4 5 |

*Age: A=18-44, B=45+

** Visiting Group: I=Individual; AG=Adult group; GwC=Group with children.

## 2.2 Observation record of the Venus Simulator in Cycle Two

| | | Interaction With Visitors | | | | | | Interaction With The Digital Exhibit | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Verbal Interaction | | Non-verbal Interaction | | | | Viewing/Observing | | | | Spatial Interaction |
| | | Talking | Laughing | Eye Contact | Pointing | Taking Photo | Swaying | Sides | Top | Floor | Back | Walking |
| **Participant 1** | | | | | | | | | | | | |
| 00:00 | 07:00 | | | | | | | | | | | |
| 00:30 | 07:30 | | | | | | | | | | | |
| 01:00 | 08:00 | 10 | 2 | 3 | | | | | | | | |
| 01:30 | 08:30 | 10 | | 8 | | | | 2 | | | | |
| 02:00 | 09:00 | 12 | | 8 | | | | 1 | | | | |
| 02:30 | 09:30 | 15 | | 14 | | | | 2 | | | 1 | |
| 03:00 | 10:00 | 7 | | 10 | 3 | | 2 | | | | | 2 |
| 03:30 | 10:30 | 3 | | 2 | | | | | | | | 4 |
| 04:00 | 11:00 | 3 | | 3 | | | | | | | | |
| 04:30 | 11:30 | 2 | | 2 | | | | 1 | | | | |
| 05:00 | 12:00 | 1 | | 1 | | | | | | | | |
| 05:30 | 12:30 | | | | | | | | | | | |
| 06:00 | 13:00 | | | | | | | | | | | |
| **Participant 2** | | | | | | | | | | | | |
| 00:00 | 41:17 | | | | | | | | | | | |
| 00:30 | 41:47 | 2 | | | | | | | | | 2 | |
| 01:00 | 42:17 | | | | | | | 8 | 1 | 2 | 1 | 2 |
| 01:30 | 42:47 | | | | | | | 2 | 3 | 1 | | 1 |
| 02:00 | 43:17 | | | | | | | | 1 | | | |
| 02:30 | 43:47 | 1 | | | | | | 4 | | | | |
| 03:00 | 44:17 | | | | | | | | | | | |
| 03:30 | 44:47 | | | | | | | 2 | 1 | | | |
| 04:00 | 45:17 | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 04:30 | 45:47 | | | | | | | 3 | | | | |
| 05:00 | 46:17 | 1 | | | | | | 4 | 2 | 2 | 1 | |
| 05:30 | 46:47 | | | | | | | | | | | |
| 06:00 | 47:17 | | | | | | | | | | | |
| **Participant 3** | | | | | | | | | | | | |
| 00:00 | 08:16 | | | | | | | | | | | |
| 00:30 | 08:46 | | | | | | | | | | | |
| 01:00 | 09:16 | 2 | | 1 | | | | 2 | 1 | 1 | 2 | 1 |
| 01:30 | 09:46 | 3 | | | | | | 1 | | | | |
| 02:00 | 10:16 | | | | | | | 1 | | | 8 | |
| 02:30 | 10:46 | 3 | | | | | | | 1 | 1 | | |
| 03:00 | 11:16 | 3 | 2 | 3 | | | | | 1 | | | |
| 03:30 | 11:46 | 2 | | | | | | | | | | |
| 04:00 | 12:16 | 4 | | | | | | | | | | |
| 04:30 | 12:46 | 2 | 2 | 1 | | | 1 | | | | | |
| 05:00 | 13:16 | 4 | | 1 | | | | 1 | 1 | | 2 | |
| 05:30 | 13:46 | | | | | | | | | | | |
| 06:00 | 14:16 | | | | | | | | | | | |
| **Participant 4** | | | | | | | | | | | | |
| 00:00 | 08:16 | | | | | | | | | | | |
| 00:30 | 08:46 | | | | | | | | | | | |
| 01:00 | 09:16 | 2 | | | 1 | | | 5 | 1 | 3 | 5 | 1 |
| 01:30 | 09:46 | | | | | | | | 3 | | 8 | |
| 02:00 | 10:16 | | | | | | | | | | | |
| 02:30 | 10:46 | | | | | | | 1 | | | | |
| 03:00 | 11:16 | 4 | | 2 | 2 | | | | 1 | | | |
| 03:30 | 11:46 | | | | | | | | | | | |
| 04:00 | 12:16 | | | | | | | | | | | |
| 04:30 | 12:46 | | | | | | 1 | 1 | | | | |
| 05:00 | 13:16 | 3 | | 2 | | | | 1 | 1 | | 2 | |
| 05:30 | 13:46 | | | | | | | | | | | |
| 06:00 | 14:16 | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Participant 5** | | | | | | | | | | | | |
| 00:00 | 31:17 | | | | | | | | | | | |
| 00:30 | 31:47 | 2 | | | 1 | | | | 2 | 1 | | 1 |
| 01:00 | 32:17 | 4 | | 2 | 1 | | | | | | 2 | |
| 01:30 | 32:47 | 2 | | 2 | | | 3 | 1 | | | | |
| 02:00 | 33:17 | | | | | | | 1 | 3 | | | |
| 02:30 | 33:47 | | | | | | | | | | | |
| 03:00 | 34:17 | | | | | | | | | | | |
| 03:30 | 34:47 | 1 | | 1 | | | | 1 | | | | |
| 04:00 | 35:17 | | | | | | | | | | | |
| 04:30 | 35:47 | 4 | | 2 | 3 | | | | | | | |
| 05:00 | 36:17 | 4 | | 2 | | | | 6 | | | 1 | 2 |
| 05:30 | 36:47 | 2 | | 1 | | 1 | | | | | | |
| 06:00 | 37:17 | | | | | | | | | | | |
| **Participant 6** | | | | | | | | | | | | |
| 00:00 | 31:17 | | | | | | | | | | | |
| 00:30 | 31:47 | | | | | | | | | | | |
| 01:00 | 32:17 | 1 | | | | | | | 1 | 3 | | |
| 01:30 | 32:47 | 2 | | 1 | | | | | | | 2 | |
| 02:00 | 33:17 | 5 | | 2 | 5 | | | 3 | 2 | | 3 | |
| 02:30 | 33:47 | | | | | | | | | | | |
| 03:00 | 34:17 | 2 | | | | | | | | | | |
| 03:30 | 34:47 | 7 | | | 4 | | | | | | | |
| 04:00 | 35:17 | | | | | | | | 1 | | | |
| 04:30 | 35:47 | 5 | | | 2 | | | | | | | |
| 05:00 | 36:17 | 5 | | | 1 | | | 5 | | | | |
| 05:30 | 36:47 | 3 | | 1 | | 1 | | | | | | 3 |
| 06:00 | 37:17 | | | | | | | | | | | |
| **Participant 7** | | | | | | | | | | | | |
| 00:00 | 22:10 | | | | | | | | | | | |
| 00:30 | 22:40 | 3 | | 1 | | | | | 1 | 2 | 9 | 5 |
| 01:00 | 23:10 | | | | | | | 3 | | | 1 | 2 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01:30 | 23:40 | 1 | | | | | | | | | 5 | 3 |
| 02:00 | 24:10 | | | | | | | | | | 10 | |
| 02:30 | 24:40 | 3 | | 3 | | | | | | | | |
| 03:00 | 25:10 | | | | | | | | | | | |
| 03:30 | 25:40 | | | | | | | | | | | |
| 04:00 | 26:10 | | | | | | | | | | | |
| 04:30 | 26:40 | | | | | | | | | | | |
| 05:00 | 27:10 | | | | | | | | | | | |
| 05:30 | 27:40 | | | | | | | | | | | |
| 06:00 | 28:10 | | | | | | | | | | | |
| **Participant 8** | | | | | | | | | | | | |
| 00:00 | 22:10 | | | | | | | | | | | |
| 00:30 | 22:40 | | | | | | | | | | | |
| 01:00 | 23:10 | | | | | | | | | | | |
| 01:30 | 23:40 | | | | | | | | | | | |
| 02:00 | 24:10 | 1 | | 1 | | | | 3 | 2 | 1 | 5 | |
| 02:30 | 24:40 | | | | | | | 4 | | | | 3 |
| 03:00 | 25:10 | | | | | | | | | | | |
| 03:30 | 25:40 | 3 | | 2 | | | | | | | | |
| 04:00 | 26:10 | | | | | | | | | | | |
| 04:30 | 26:40 | 2 | | 1 | | | | | | | | |
| 05:00 | 27:10 | | | | | | | | | | 8 | 1 |
| 05:30 | 27:40 | | | | | | | | | | 10 | |
| 06:00 | 28:10 | | | | | | | | | | | |
| **Participant 9** | | | | | | | | | | | | |
| 00:00 | 27:46 | | | | | | | | | | | |
| 00:30 | 28:16 | 3 | | | | | | | | | | |
| 01:00 | 28:46 | 5 | 3 | 2 | | | | 2 | 2 | | 1 | |
| 01:30 | 29:16 | 4 | 1 | | | | | 1 | 1 | | | |
| 02:00 | 29:46 | 6 | | 4 | | | | 1 | 1 | | | |
| 02:30 | 30:16 | 7 | | | | | | 1 | | | | |
| 03:00 | 30:46 | 4 | | 3 | | | | 1 | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03:30 | 31:16 | 4 | | 2 | | | | | 1 | | | |
| 04:00 | 31:46 | | | | | | | 2 | 1 | | | |
| 04:30 | 32:16 | | | 1 | | | | | | | | |
| 05:00 | 32:46 | 3 | | 1 | | | | 1 | | | | |
| 05:30 | 33:16 | | | | | | | 2 | 3 | | | |
| 06:00 | 33:46 | 3 | | | | | | 1 | | | | |
| **Participant 10** | | | | | | | | | | | | |
| 00:00 | 02:45 | | | | | | | | | | | |
| 00:30 | 03:15 | | | | | | | | | | | |
| 01:00 | 03:45 | | | | | | | 2 | 1 | | 2 | 1 |
| 01:30 | 04:15 | 2 | | | | | | | | | | |
| 02:00 | 04:45 | 3 | | 1 | | | | 3 | | | | |
| 02:30 | 05:15 | | | | | | | 2 | | 1 | | |
| 03:00 | 05:45 | 4 | | 1 | 1 | | | | | | 1 | |
| 03:30 | 06:15 | 1 | | | | | | | | | | 2 |
| 04:00 | 06:45 | | | | | | | 2 | | 2 | | |
| 04:30 | 07:15 | 1 | | | | | 3 | | | | | |
| 05:00 | 07:45 | 5 | | 1 | | | | | | | | |
| 05:30 | 08:15 | 2 | 1 | | | | | | | | 2 | 1 |
| 06:00 | 08:45 | | | | | | | | | | | |

# Appendix 3: Informed Consent Form

## 3.1 Cycle One and Cycle Two

How Did That Interactive Make You Feel?
Towards a framework for evaluating the emotional and sensory experience of next generation in-gallery technology.

**Informed Consent Form**

(to be completed after the Participant Information Sheet has been read)

| | |
|---|---|
| The purpose and details of this study have been explained to me. I understand that this is designed to further academic development and that all procedures have been approved by the University of Leicester Ethics Approvals committee. | Yes ☐ No ☐ |
| I have read and understood the Information Sheet and this consent form. | Yes ☐ No ☐ |
| I have had an opportunity to ask questions about my participation. | Yes ☐ No ☐ |
| I understand that I am under no obligation to take part in this study. | Yes ☐ No ☐ |
| I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing. | Yes ☐ No ☐ |
| I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others. | Yes ☐ No ☐ |
| I agree to participate in this study, which will comply at all times with the Data Protection Act (1988) in the UK. | Yes ☐ No ☐ |

You Name ______________________________

Your signature ______________________________

Signature of Investigator ______________________________

Date ______________________________

### 3.2 Cycle Three

How Did That Interactive Make You Feel?
Towards a framework for evaluating the emotional and sensory experience of next generation in-gallery technology.

**Informed Consent Form**

If you are willing to participate in the project as described in the Information Sheet, please respond to the following items and sign your name below.

| **I am aware and,** | **Yes** | **No** |
|---|---|---|
| I have read the Research Project Information Sheet and General Data Protection Regulation information in the leaflet. | ☐ | ☐ |
| I understand that this is designed to further academic development and that all procedures have been approved by the University of Leicester Ethics Approvals Committee. | ☐ | ☐ |
| I have had an opportunity to ask questions about my participation. | ☐ | ☐ |
| I am happy to participate in this study, including interacting with the selected exhibition and wearing the sensors. | ☐ | ☐ |
| I am happy that my physiological data will be published anonymously in an aggregated form as findings of the research project | ☐ | ☐ |
| I am happy that my verbal comments will be published anonymously as findings of the research project | ☐ | ☐ |
| I know that I am free to stop taking part in this research at any time, for any reason, if I no longer want to. | ☐ | ☐ |

Signature:

______________________________

Printed name:

______________________________

Date:

______________________________

Please note, that even after signing this, you still have the right to withdraw your participation in the research project at any time and without giving any reasons. You may also ask for information you supply to be removed from the study, where this information can be clearly identified as having been supplied by you.

# Appendix 4: Participant Information Sheet

## 4.1 Cycle One and Two

How Did That Interactive Make You Feel?
Towards a framework for evaluating the emotional and sensory experience of next generation in-gallery technology.

## Participant Information Sheet

Investigator: Jingyu Peng (jp431@le.ac.uk)
Supervisor: Dr Ross Parry (rdp5@le.ac.uk)
Department: School of Museum Studies, University of Leicester, Leicester, Leicestershire, LE1 7RF.

### What is the purpose of the study?

This research aims to provide insights into how the public interact with the latest technologies on offer in museums. Specifically, this work is investigating the effect of emerging digital media on human sensations and emotions, in exhibition settings. In practice, this means attempting to measure how in-gallery technologies engage different physical senses and influence visitors emotionally**.**

### Who is doing this research and why?

The research will be conducted by the investigator (named Jingyu Peng) under the supervision of Dr Ross Parry. The project is being undertaken by the researcher as a part of her PhD at the University of Leicester. The contact details are listed at the top of this information sheet.

### There are only three criteria needed to participate in this study:

1. That you are a visitor to the National Space Centre in Leicester
2. That you Took part in one of the selected interactives (the 360-degree film 'We are stars!', the Venus or the interactive table) in the NSC.
3. That you are an adult, aged 18 years or over. (If you are accompanying a child, our research will only be concerning you as an adult visitor.)

### There are three things that we will ask you to do to facilitate this study:

1. Your behaviour might be **observed** in the selected area via a camera. You are free to choose whether to be observed or not. There will be a notice in the gallery to inform you which area is being observed.
2. You will be invited to fill in a **questionnaire**. The questionnaire is one page with some questions regarding your experience of watching the show.
3. You will be asked to take part in an **interview**. The interview was developed to ask you a few questions regarding your experience. The interview will be recorded by a voice recorder.

It is our hope that this information can help us to understand emotional and sensory experience with in-gallery technology and to improve the methods of measuring visitors' experience.

Thank you for considering this invitation to take part. We value your opinion.

### Once I take part, can I change my mind?

You are free to choose whether you want to take part in the observation, interview and/or questionnaire. If you have changed your mind at any time, before, during or after the interview or observation please just contact the researcher.

You can withdraw at any time, for any reason, and you will not be asked to explain your reasons for withdrawing.

### How long will it take?

1. The questionnaire will take approximately 1 minute to fill.
2. The interview will take approximately 3 minutes to complete.

### Will my taking part in this study be kept confidential?

The study has been approved by the University Research Ethics Committee at Leicester.

All data in this doctoral research study is treated as confidential, according to the Data Protection Act in the UK (1988). What this means is that information that you give will be assigned a code that is only know to the researcher and will not be realised to any third parties. It will be stored on a security-code encrypted laptop for fieldwork and transferred to a computer at the University of Leicester where it will be securely kept for a period not exceeding 5 years. Aspects of that data and a summary of research findings will be published in a doctoral thesis at the University of Leicester, and may subsequently appear in published papers. A report on the main findings will also be provided to the National Space Centre to help to enhance its visitor experiences of emerging technologies. At no time will you be personally identified unless you expressly agree to do so. All interviews will be de-identified and anonymous, with general remarks paraphrased.

### I have some more questions; who should I contact?

If you have any queries or concerns about the conduct of this study, please contact Jingyu Peng (PhD Researcher) by email: jp431@le.ac.uk

If you want to know more about the research, please visit
http://www2.le.ac.uk/departments/museumstudies/PhD-Students/CurrentPhDStudents/JingyuPeng

How Did That Interactive Make You Feel?
Towards a framework for evaluating the emotional and sensory experience of next generation in-gallery technology.

## Participant Information Sheet

Investigator: Jingyu Peng (jp431@le.ac.uk)
Supervisor: Prof. Ross Parry (rdp5@le.ac.uk)
Department: School of Museum Studies, University of Leicester, Leicester, Leicestershire, LE1 7RF.

### What is the purpose of the study?

This research aims to provide insights into how the public interact with the latest technologies on offer in museums. Specifically, this work is investigating the effect of emerging digital media on human sensations and emotions, in exhibition settings. In practice, this means attempting to measure how in-gallery technologies engage different physical senses and influence visitors emotionally.

### Who is doing this research and why?

The research will be conducted by the investigator (Jingyu Peng) under the supervision of Prof. Ross Parry. The project is being undertaken by the researcher as a part of her PhD at the University of Leicester. The contact details are listed at the top of this information sheet.

### There are only three criteria needed to participate in this study:

1. That you are a visitor to the National Space Centre in Leicester
2. That you took part in one of the selected interactives (the 360-degree film 'We are stars!', the Venus Simulator or the Interactive Table) in the NSC.
3. That you are an adult, aged 18 years or over. (If you are accompanying a child, our research will only be concerning you as an adult visitor.)

### What we will ask you to do to facilitate this study:

Two types of measures will be taken: skin conductance and heart rate with a device called Shimmer3. These devices are customer grade which means they will be comfortable, and widely used for research and business purposes. Two reusable electrodes will attach to two fingers of one hand, and one ear clip. During this process, you are asked to remain motionless as much as possible. Additionally, we will ask you a few follow-up questions about your experience.

It is our hope that this information can help us to understand emotional and sensory experience with in-gallery technology and to improve the methods of measuring visitors' experience.

Thank you for considering this invitation to take part. We value your opinion.

### Once I take part, can I change my mind?

You can withdraw at any time, for any reason, and you will not be asked to explain your reasons for withdrawing.

## Will my taking part in this study be kept confidential?

All data in this doctoral research study is treated as confidential, according to the EU General Data Protection Regulation (GDPR). What this means is that information that you give will be assigned a code that is only know to the researcher and will not be realised to any third parties. It will be stored on a security-code encrypted laptop for fieldwork and transferred to a computer at the University of Leicester where it will be securely kept for no longer than is absolutely necessary. Aspects of that data and a summary of research findings will be published in a doctoral thesis at the University of Leicester and may subsequently appear in published papers. A report on the main findings will also be provided to the National Space Centre to help to enhance its visitor experiences of emerging technologies. At no time will you be personally identified unless you expressly agree to do so.

The study has been approved by the University Research Ethics Committee at Leicester.

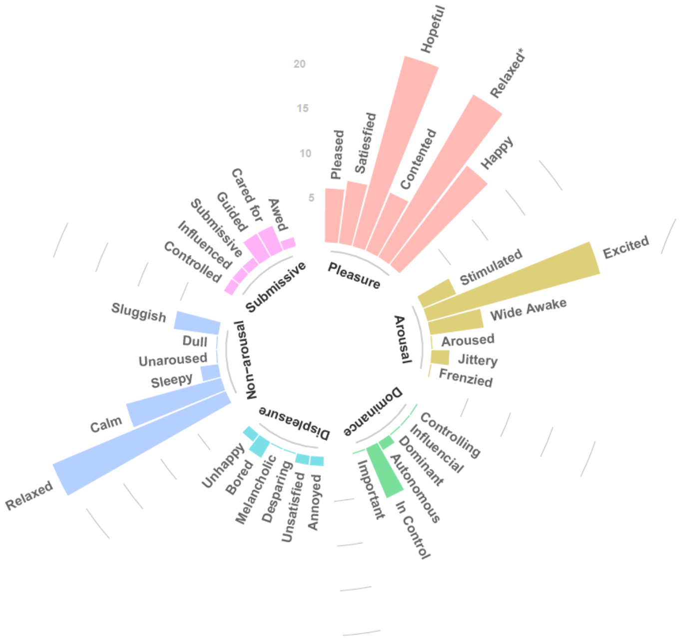
## I have some more questions; who should I contact?

If you have any queries or concerns about the conduct of this study, please contact Jingyu Peng (PhD Researcher) by email: jp431@le.ac.uk

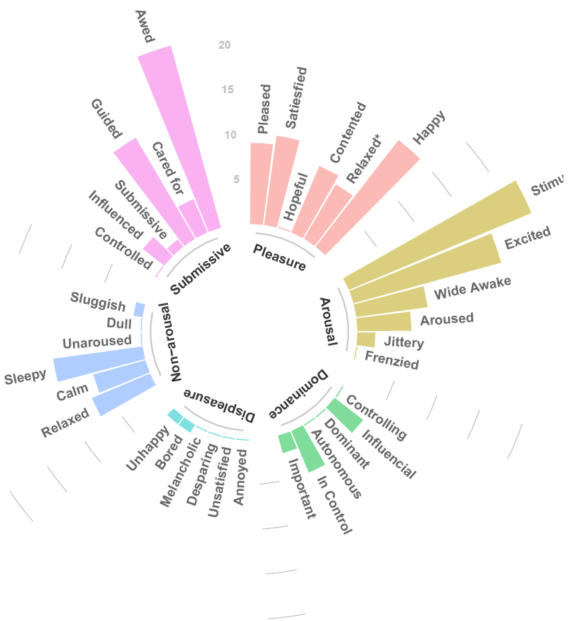
If you want to know more about the research, please visit http://www2.le.ac.uk/departments/museumstudies/PhD-Students/CurrentPhDStudents/JingyuPeng

# Appendix 5: Polar Charts Show before, during and after the Activity.

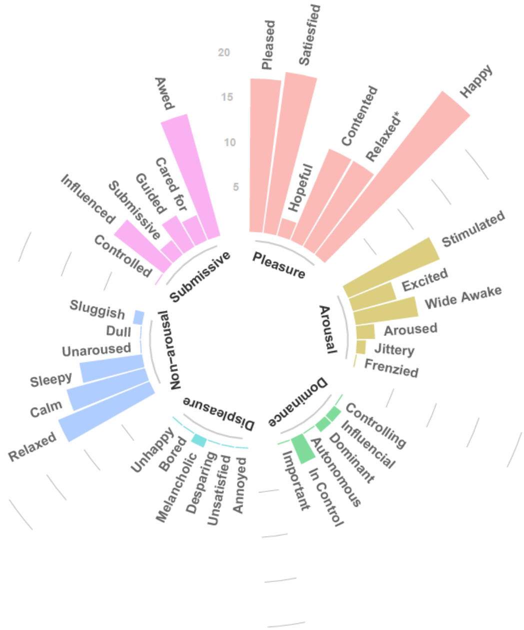
## 5.1 Planetarium show




Before

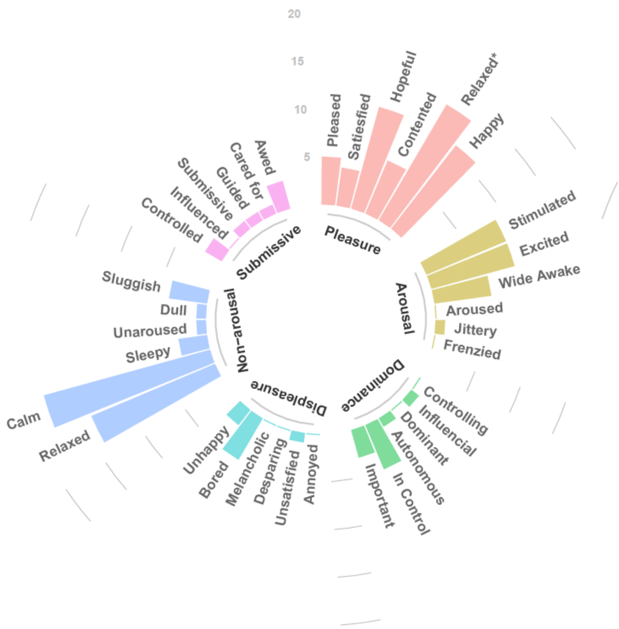



During

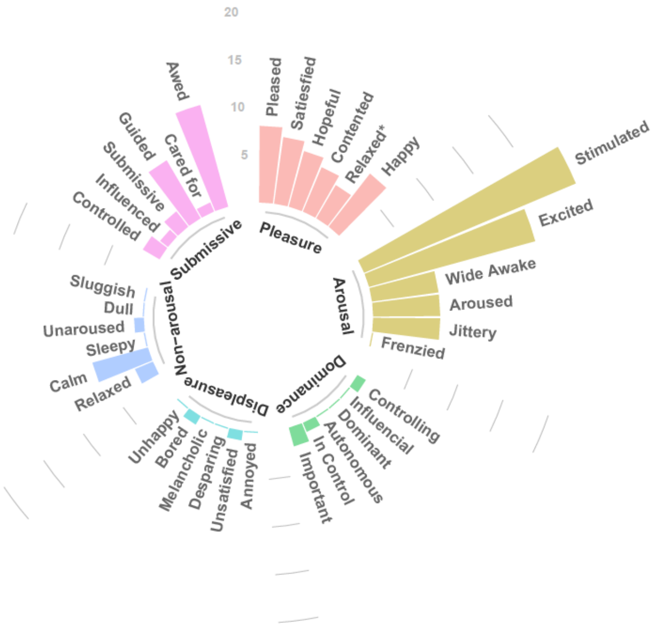



After

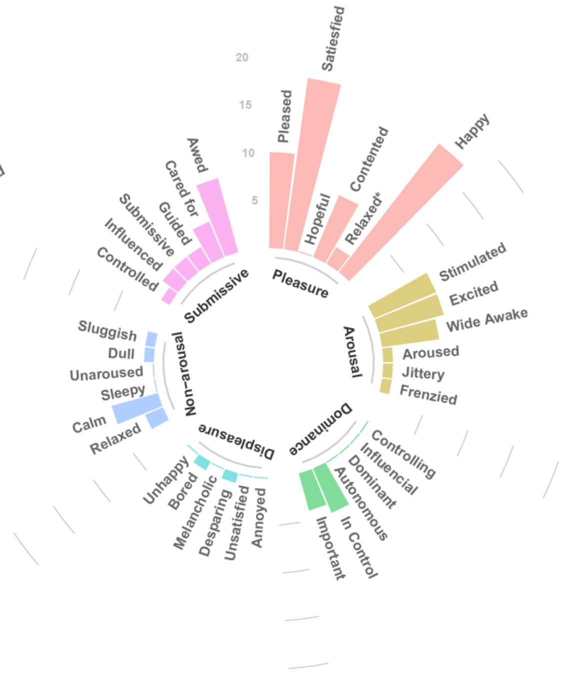
## 5.2 Venus simulator




Before

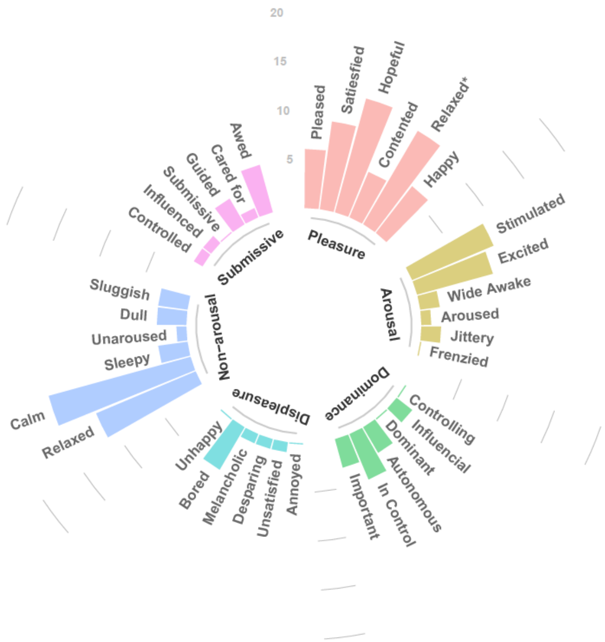



During



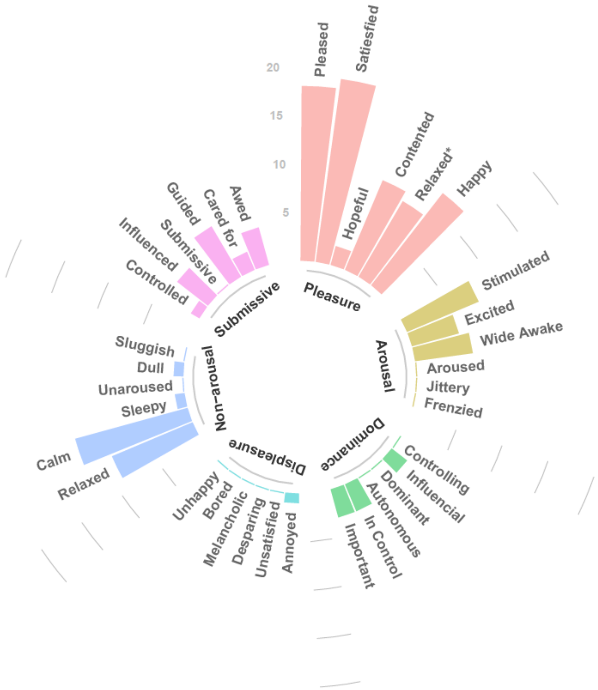

After

## 5.3 Interactive table




Before


During




After

## Appendix 6: ‘Think-aloud’ Participant D Transcript.

| | | |
|---|---|---|
| 1 | ‘Scary, the light is a bit scary.’ | 00:00 |
| 2 | ‘Suspense.’ | 00:24 |
| 3 | ‘A little bit tense.’ | 00:45 |
| | Separation in 2, 1. | 00:48 |
| 4 | ‘I think the extension of the screen is good, with the vibration as well.’ | 01:10 |
| 5 | ‘Feeling the moment.’ | 01:35 |
| 6 | ‘They really want to make you feel this experience as real.’ | 02:02 |
| 7 | ‘A little bit of fear.’ | 02:25 |
| 8 | ‘Oh, no.’ | 03:13 |
| 9 | ‘I feel like really tense, what’s gonna happen?’ | 03:28 |
| 10 | ‘They are like fixing something.’ | 03:40 |
| 11 | ‘Oh, no.’ | 03:45 |
| 12 | ‘Oh no, it feels like you are in the rocket, isn’t it?’ | 04:10 |
| 13 | ‘You actually feel you are turning with it.’ | 04:15 |
| 14 | ‘It feels like you are moving.’ | 04:18 |
| 15 | ‘It is real, yeah.’ | 04:28 |
| 16 | ‘Wow, wow.’ | 04:37 |
| 17 | ‘It does feel your body are traveling, even though you are standing on flat floor.’ | 04:44 |
| 18 | ‘Relieved.’ | 05:15 |
| 19 | ‘We are not burned.’ | 05:20 |

# References


Ackerman, D. (1991) *A natural history of the senses.* New York: Vintage Books.

Agarwal, A. and Meyer, A. (2009) 'Beyond usability: evaluating emotional response as an integral part of the user experience', *CHI'09 Extended Abstracts on Human Factors in Computing Systems*, pp. 2919-2930.

Allen, N.B., de L. Horne, D.J and Trinder, J. (1996) 'Sociotropy, Autonomy, and Dysphoric Emotional Responses to Specific Classes of Stress', *Journal of Abnormal Psychology,* 105(1), pp. 25-33.

Ambrose, T. and Paine, C. (2012) *Museum basics.* London: Routledge.

Amedi, A., Zohary, E., Hendler, T., Peled, S. and Malach, R. (2001) 'Visuo-haptic object-related activation in the ventral visual pathway', *Nature Neuroscience,* 4(3), pp. 324-330.

Anderson, B. (2006) Becoming and being hopeful: Towards a theory of affect. *Environment & Planning D: Society and Space*, 24, pp.733-52.

Anderson, M. (1997) 'Introduction' in K. Jones-Garmil (ed.) *The wired museum: emerging technology and changing paradigms,* Washington, DC: American Association of Museums.

Angeli, D.D. and O'Neil, E. (2015) 'A smartphone headset for augmented-reality experiences in museums', *MW2015: Museums and the Web 2015*.

App, B., McIntosh, D.N., Reed, C.L. and Hertenstein, M. J. (2011) 'Nonverbal Channel Use in Communication of Emotion', *Emotion,* 11(3), pp. 603-617.

Arnott, S.R. and Alain, C. (2014) 'A Brain Guide to Sound Galleries', in Levent, N. and Pascual-Leone, Á (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 85-108.

Bacci, F. and Pavani, F. (2014) "First Hand," not "First Eye" Knowledge: Bodily Experience in Museums', in Levent, N. and Pascual-Leone, A. (eds.) *The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space.* Lanham: Rowman & Littlefield Publishers, pp. 17-28.

Bachorowski, J. (1999) 'Vocal Expression and Perception of Emotion', *Current Directions in Psychological Science,* 8(2), pp. 53-57.

Baggesen, R.H. (2015) *Mobile museology: An exploration of fashionable museums, mobilisation, and trans-museal mediation.* University of Copenhagen, Royal School of Library and Information Science. Available at: http://static-curis.ku.dk/portal/files/144743950/Ph.d._2015_Baggesen.pdf (Accessed: 1 October 2019).

Bakeman, R. and Gottman, J.M. (2006) *Observing interaction: An introduction to sequential analysis.* Cambridge: Cambridge Univ. Press.

Barbas, M., Loureiro, A., Messias, I. and Pacheco, N. (2015) ‘Visualyzart Project – The Role in Education’, *Procedia - Social and Behavioral Sciences,* 191, pp. 2829-2834.

Benedek, M. and Kaernbach, C. (2010) ‘A continuous measure of phasic electrodermal activity’, *Journal of Neuroscience Methods,* 190(1), pp. 80-91.

Benko, H., Wilson, A. and Balakrishnan, R. (2008) ‘Sphere: Multi-Touch Interactions on a Spherical Display’, ACM, pp. 77-86.

Berntson, G.G. and Cacioppo, J.T. (2000) ‘From homeostasis to allodynamic regulation’, J. Cacioppo, L. Tassinary, & G. Berntson (eds.), *Handbook of Psychophysiology*. Cambridge: Cambridge University Press, pp. 401-426

Bitgood, S. (2011) *Social design in museums.* Edinburgh: Museumsetc.

Black, G. (2005) *The engaging museum: Developing museums for visitor involvement.* London: Routledge Ltd.

Blechert, J., Lajtman, M., Michael, T., Margraf, J. and Wilhelm, F.H. (2006) ‘Identifying anxiety states using broad sampling and advanced processing of peripheral physiological information’, *Biomedical sciences instrumentation,* 42, pp. 136-141.

Borun, M. and Korn, R. (1999) *Introduction to museum evaluation.* Washington, DC: American Assoc. of Museums.

Boucsein, W. (2012) *Electrodermal activity.* New York: Springer.

Bowen, J.L. (2014) ‘Emotion in Organizations: Resources for Business Educators’, *Journal of Management Education,* 38(1), pp. 114-142.

Boyer, D. and Marcus, J. (2011) ‘Implementing Mobile Augmented Reality Applications for Cultural Institutions’, *Museums and the Web 2011,* Archives & Museum Informatics: Toronto.

Bradley, M. and Lang, P. (1994) ‘Measuring emotion: The self-assessment manikin and the semantic differential’, *Journal of Behavior Therapy and Experimental Psychiatry,* 25(1), pp. 49-59.

Bradley, M. and Lang, P. (2002) ‘Measuring emotion: Behaviour, feelings and physiology’, in Lane, R. D. and Nadel, L. (eds.) *Cognitive Neuroscience of Emotion.* Oxford University Press, pp. 242-276.

Brown, T.M. and Fee, E. (2002) ‘Walter Bradford Cannon’, *American Journal of Public Health,* 92(10), pp. 1594-1595.

Bull, M., Gilroy, P., Howes, D. and Kahn, D. (2006) ‘Introducing Sensory Studies’, *The Senses and Society,* 1(1), pp. 5-7.

Campbell, S. (2006) *Our Faithfulness to the Past: Reconstructing Memory Value.* Philosophical Psychology, 19 (3), 361-380.

Canadian Heritage Information Network (2014a) *CHIN's TechWatch: Spring 2014*. Available at: https://app.pch.gc.ca/sgc-cms/nouvelles-news/anglais-english/?p=8113 (Accessed: 3 January 2019)

Canadian Heritage Information Network (2014b) *CHIN's TechWatch: Summer 2014*. Available at: https://app.pch.gc.ca/sgc-cms/nouvelles-news/anglais-english/?p=8487 (Accessed: 3 January 2019)

Canadian Heritage Information Network (2015) *CHIN's TechWatch: Winter 2015*. Available at: https://app.pch.gc.ca/sgc-cms/nouvelles-news/anglais-english/?p=8871 (Accessed: 3 January 2019)

Candlin, F. (2010) *Art, museums and touch.* Manchester: Manchester University Press.

Canning, E. (2018) 'Evaluating and documenting affect in the art museum', *2018 3rd Digital Heritage International Congress (DigitalHERITAGE) held jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018)*, San Francisco, CA, USA, 2018, pp. 1-4, doi: 10.1109/DigitalHeritage.2018.8810096.

Carreras, C. and Rius, J. (2011) 'Evaluation of ICT Applications in the New Lleida Museum, Spain', *Visitor Studies*, 14(2), pp. 219-232.

Casile, A. and Ticini, L.F. (2014) 'The Role of Sensory and Motor systems in Art Appreciation and Implications for Exhibition Design', in Levent, N. and Pascual-Leone Alvaro (eds.) *The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space.* Lanham: Rowman & Littlefield Publishers, pp. 131-149.

Center for the Future of Museums (2012) *TrendsWatch 2012: Museums and the Pulse of the Future*. American Alliance of Museums. Available at: https://www.aam-us.org/wp-content/uploads/2017/12/2012_trendswatch.pdf (Accessed: 3 January 2019)

Center for the Future of Museums (2013) *TrendsWatch 2013: Back to the Future*. American Alliance of Museums. Available at: https://www.aam-us.org/wp-content/uploads/2017/12/2013_trendswatch.pdf (Accessed: 3 January 2019)

Center for the Future of Museums (2014) *TrendsWatch 2014*. American Alliance of Museums. Available at: https://www.aam-us.org/wp-content/uploads/2017/12/2014_trendswatch.pdf (Accessed: 3 January 2019)

Center for the Future of Museums (2015) *TrendsWatch 2015*. American Alliance of Museums. Available at: https://www.aam-us.org/wp-content/uploads/2018/04/2015_trendswatch_pdf_fnl_3EAAFDB042FEF931B479B9566.pdf (Accessed: 3 January 2019)

Chalupa, L.M. and Werner, J.S. (2003) *The visual neurosciences.* Cambridge, Mass.; London: MIT.

Chan, S. (2014) 'Too busy to blog: a short round up of 2014', Available at: http://www.freshandnew.org/ (Accessed: 1 September 2016)

Chan, S. and Cope, A. (2015) ‘Strategies against Architecture: Interactive Media and Transformative Technology at the Cooper Hewitt, Smithsonian Design Museum’, *Curator: The Museum Journal,* 58(3), pp. 352-368.

Chatterjee, H.J. (2008) *Touch in museums.* New York: Berg.

Chatterjee, H. and Noble, G. (2009) 'Object Therapy: A Student-selected Component Exploring the Potential of Museum Object Handling as an Enrichment Activity for Patients in Hospital', *Global journal of health science,* 1(2).

Chatterjee, H., Vreeland, S. and Noble, G. (2009) 'Museopathy: Exploring the Healing Potential of Handling Museum Objects', *Museum & Society.*

Ching, K.W. and Singh, M.M. (2016) ‘Wearable Technology Devices Security and Privacy Vulnerability Analysis’, *International Journal of Network Security & Its Applications,* 8(3), pp. 19-30.

Christopoulos, G.I., Uy, M.A. and Yap, W.J. (2019) ‘The Body and the Brain: Measuring Skin Conductance Responses to Understand the Emotional Experience’, *Organizational Research Methods,* 22(1), pp. 394-420.

Classen, C. (2005a) ‘McLuhan in the rainforest: The sensory world of oral cultures’, in Howes, D. (ed.) *Empire of the senses: the sensual culture reader.* Oxford and New York: Berg, pp. 147-163.

Classen, C. (2005b) *The book of touch.* Oxford: Berg.

Classen, C. (2007) ‘Museum Manners: The Sensory Life of the Early Museum’, *Journal of Social History,* 40(4), pp. 895-914.

Classen, C. (2012) *The Deepest Sense: A Cultural History of Touch.* Baltimore: University of Illinois Press.

Classen, C. and Howes, D. (2006) ‘The Museum as Sensescape: Western Sensibilities and Indigenous Artifacts’, in Edwards, E., Gosden, C. and Phillips, R.B. (eds.) *Sensible Objects: Colonialism, Museums and Material Culture.* Oxford, England: Berg, pp. 199-222.

Cluett, S. (2014) ‘Ephemeral, Immersive, Invasive: Sound as Curatorial Theme, 1966-2013’, in Levent, N. and Pascual-Leone, Á (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 109-118.

Connor, S. (2005) ‘Michel Serres’ Five Senses’, in Howes, D. (ed.) *Empire of the senses: the sensual culture reader.* Oxford: Berg.

Cooke, L. (2010) ‘Assessing Concurrent Think-Aloud Protocol as a Usability Test Method: A Technical Communication Approach’, *IEEE Transactions on Professional Communication,* 53(3), pp. 202-215.

Crang, M. and Tolia-Kelly, D.P. (2010) ‘Nation, Race, and Affect: Senses and Sensibilities at National Heritage Sites’, *Environment and Planning A,* 42(10), pp. 2315-2331.

Cunliffe, D., Kritou, E. and Tudhope, D. (2001) 'Usability Evaluation for Museum Web Sites', *Museum Management and Curatorship,* 19(3), pp. 229-252.

Damala, A., Ruthven, I. and Hornecker, E. (2019) 'The MUSETECH Model', *Journal on Computing and Cultural Heritage (JOCCH),* 12(1), pp. 1-22.

Damala, A., Vaart, M., Clarke, L., Hornecker, E., Avram, G., Kockelkorn, H. and Ruthven, I. (2016) 'Evaluating tangible and multisensory museum visiting experiences: Lessons learned from the meSch project', *Museums and the Web 2016,* Museums and the Web, LLC.

Darwin, C. (1890) *The expression of the emotions in man and animals.* London: John Murray.

Dawson, M.E. and Nuechterlein, K.H. (1984) 'Psychophysiological Dysfunctions in the Developmental Course of Schizophrenic Disorders', *Schizophrenia bulletin,* 10(2), pp. 204-232.

Dawson, M.E., Schell, A.M. and Filion, D. L. (2007) 'The Electrodermal System', in Cacioppo, J.T., Tassinary, L.G. and Berntson, G. (eds.) *Handbook of Psychophysiology.* 3rd edn. Cambridge: Cambridge University Press, pp. 159-181.

de Rojas, C. and Camarero, C. (2008) 'Visitors' experience, mood and satisfaction in a heritage context: Evidence from an interpretation center', *Tourism Management,* 29(3), pp. 525-537.

Desmet, P. (2000) 'Emotion through expression; designing mobile telephones with an emotional fit.', in Harada, A. (ed.) *Report of modeling the evaluation structure of KANSEI,* 3, pp. 103-110.

Desmet, P. (2005) 'Measuring Emotion: Development and Application of an Instrument to Measure Emotional Responses to Products', in Blythe, M., Monk, A. F., Overbeeke, K. and Wright, P. (eds.), *Funology: from Usability to Enjoyment.* Dordrecht: Kluwer

Diest, I., Winters, W., Devriese, S., Vercamst, E., Han, J. N., Woestijne, K.P. and Bergh, O. (2001) 'Hyperventilation beyond fight/flight: Respiratory responses during emotional imagery', *Psychophysiology,* 38(6), pp. 961-968.

Dodd, J.A., Hopes, D., Tseliou, M.A. and Jones, C. (2015) *Talking Statues: The User Experience,* Research Centre for Museums and Galleries.

Drobnick, J. (2005) 'Volatile Effects: Olfactory Dimensions of Art and Architecture', in Howes, D. (ed.) *Empire of the senses: the sensual culture reader.* Oxford: Berg.

Drobnick, J. (2014) 'The museum as smellscape', in Levent, N. and Pascual-Leone, A. (eds.) *The multisensory museum: Cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield Publishers, pp. 177–196.

Drotner, K., Dziekan, V., Parry, R. and Schrøder, K.C. (2019) *The Routledge handbook of museums, media and communication.* London; New York: Routledge, Taylor & Francis Group.

Dudley, S. (2009) *Museum Materialities: Objects, Engagements, Interpretations.* London: London: Routledge.

Economou, M. (1998) 'The Evaluation of Museum Multimedia Applications: Lessons from Research', *Museum Management and Curatorship,* 17(2), pp. 173-187.

Economou, M. and Pujol Tost, L. (2007) 'Educational tool or expensive toy? Evaluating VR evaluation and its relevance for virtual heritage', in Kalay, Y., Kvan, T. and Affleck, J. (eds.) *New Heritage: New Media and Cultural Heritage.* Routledge, pp. 242-260.

Economou, M., Young, H. and Sosnowska, E. (2018) 'Evaluating emotional engagement in digital stories for interpreting the past. The case of the Hunterian Museum's Antonine Wall EMOTIVE experiences', *3rd Digital Heritage International Congress*, San Francisco, USA.

Ekman, P. (1994a) 'Strong Evidence for Universals in Facial Expressions', *Psychological Bulletin,* 115(2), pp. 268-287.

Ekman, P. (1994b) *The nature of emotion.* New York: Oxford Univ. Press.

Ekman, P. and Friesen, W.V. (1971) 'Constants across cultures in the face and emotion', *Journal of Personality and Social Psychology,* 17(2), pp. 124-129.

Ekman, P. and Friesen, W.V. (1975) *Unmasking the face.* Englewood Cliffs, NJ: Prentice-Hall.

Ekman, P. and Friesen, W.V. (1978) *Facial action coding system.* Palo Alto, Calif: Consulting Psychologists Press.

Ericsson, K.A. and Simon, H.A. (1993) *Protocol analysis: Verbal data reports as data*. Cambridge, Mass.: MIT Press.

Falk, J.H. and Dierking, L.D. (1992) *The museum experience.* Washington, D.C.: Whalesback Books.

Falk, J.H. and Dierking, L.D. (2008) 'Enhance visitor interaction and learning with mobile technologies', in Tallon, L. and Walker, K. (eds.) *Digital technologies and the museum experience.* Lanham, Md.: AltaMira Press.

Falk, J.H., Scott, C., Dierking, L., Rennie, L. and Jones, M.C. (2004) 'Interactives and Visitor Learning', *Curator: The Museum Journal,* 47(2), pp. 171-198.

Forte, M., Pescarin, S. and Pujol Tost, L. (2006) 'VR applications, new devices and museums: public's feedback and learning. A preliminary report', *Proceedings of the 7th international symposium on virtual reality, archaeology and cultural heritage, VAST,* pp. 64-69.

Foster, H. (2008) *Evaluation toolkit for museum practitioners,* The East of England Museum Hub.

Freedberg, D. and Gallese, V. (2007) 'Motion, emotion and empathy in esthetic experience', *Trends in Cognitive Sciences,* 11(5), pp. 197-203.

Gallegos, D. and Mchoul, A. (2006) 'It's not about good taste. It's about tastes good', *The Senses & Society,* 1(2), pp. 165-181.

Gilman, B.I. (1916) ‘Museum Fatigue’, *The Scientific Monthly,* 2(1), pp. 62-74.

Gregory, K. and Witcomb, A. (2007) ‘Beyond nostalgia: The role of affect in generating historical understanding at heritage sites’, in Knell, S., MacLeod, S. and Watson, S. (eds.) *Museum revolutions: how museums change and are changed*, pp. 263-275.

Gretzel, U. and Fesenmaier, D. (2010) ‘Capturing sensory experiences through semi-structured elicitation questions’, in Morgan, M., Lugosi, P. and Ritchie, J.R.B. (eds.) *The Tourism and Leisure Experience: Consumer and Managerial Perspectives.* Bristol: Bristol: Channel View Publications, pp. 137-159.

Grunert, S.C. and Grunert, K.G. (1995) ‘Measuring subjective meaning structures by the laddering method: Theoretical considerations and methodological problems’, *International Journal of Research in Marketing,* 12(3), pp. 209-225.

Guthrie, G. (2010) *Basic Research Methods: An Entry to Social Science Research.* India: Sage Publications India.

Haapalainen, R. (March 1999) ‘Revising the Finnish National Gallery’s web pages’, *Museums and the Web 1999*.

Haden, R. (2011) ‘Lionizing Taste: Toward an Ecology of Contemporary Connoisseurship’, in Srong, J. (ed) *Educated Tastes: Food.* University of Nebraska Press, pp. 239-290.

Hannu, K and Pallab, P (2000) ‘A Comparison of Concurrent and Retrospective Verbal Protocol Analysis’, *The American Journal of Psychology,* 113(3), pp. 387-404.

Hardy, M., Wiebe, E.N., Grafsgaard, J.F., Boyer, K.E. and Lester, J.C. (2013) ‘Physiological Responses to Events during Training’, *Proceedings of the Human Factors and Ergonomics Society Annual Meeting,* 57(1), pp. 2101-2105.

Hauser, W., Noschka-Roos, A., Reussner, E. and Zahn, C. (2009) ‘Design-Based Research on Digital Media in a Museum Environment’, *Visitor Studies,* 12(2), pp. 182-198.

Hawkes, C.H. and Doty, R.L. (2009) *The neurology of olfaction.* Cambridge: Cambridge University Press.

Heath, C. and vom Lehn, D. (2004) ‘Configuring Reception’, *Theory, Culture & Society,* 21(6), pp. 43-65.

Hein, G.E. (1998) *Learning in the museum.* London: Routledge.

Hertzum, M., Hansen, K.D. and Andersen, H.H.K. (2009) ‘Scrutinising usability evaluation: does thinking aloud affect behaviour and mental workload?’, *Behaviour & Information Technology,* 28(2), pp. 165-181.

Hoare, J. (2018) 'Heart on Your Sleeve? Emotion, Wearable Technology and Digital Heritage', *2018 3rd Digital Heritage International Congress (DigitalHERITAGE) held jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018),* San Francisco, CA, USA, 2018, pp. 1-4, doi: 10.1109/DigitalHeritage.2018.8810130.

Holbrook, M.B. and Batra, R. (1987) 'Toward a Standardized Emotional Profile (SEP) Useful in measuring responses to the nonverbal components of advertising', in Hecker, S. and Stewart, D.W. (eds.) *Nonverbal Communications in Advertising,* pp. 95-109.

Hooper-Greenhill, E. (1994) *Museums and Their Visitors.* London: Routledge.

Hornecker, E. and Stifter, M. (2006) 'Learning from interactive museum installations about interaction design for public settings', *Proceedings of the 18th Australia conference on Computer-Human Interaction: Design: Activities, Artefacts and Environments* ACM, pp. 135.

Howes, D. (1991) *The varieties of sensory experience: a sourcebook in the anthropology of the senses.* Toronto; Buffalo: University of Toronto Press.

Howes, D. (2005) *Empire of the senses: the sensual culture reader.* Oxford: Berg.

Howes, D. (2014) 'Introduction to Sensory Museology', *The Senses and Society,* 9(3), pp. 259-267.

Izard, C.E. (1971) *The face of emotion.* New York: Appleton-Century-Crofts.

Izard, C.E. (1977) *Human emotions.* New York: Plenum Press.

Jenke, R., Peer, A. and Buss, M. (2014) 'Feature extraction and selection for emotion recognition from EEG', *IEEE Transactions on Affective Computing,* 5(3), pp. 327-339.

Jermyn, H. (2001) *The Arts and Social Exclusion: a review prepared for the Arts Council of England*, London: Arts Council of England.

Johnson, L., Adams, B.S., Estrada, V., and Freeman, A. (2015). *NMC Horizon Report: 2015 Museum Edition*. Austin, Texas: The New Media Consortium.

Johnson, L., Adams, B.S., Freeman, A., (2013). *The NMC Horizon Report: 2013 Museum Edition*. Austin, Texas: The New Media Consortium.

Johnson, L., Adams, S., and Witchey, H. (2011). *The NMC Horizon Report: 2011 Museum Edition*. Austin, Texas: The New Media Consortium.

Johnson, L.C. and Lubin, A. (1966) 'Spontaneous electrodermal activity during waking and sleeping', *Psychophysiology,* 3(1), pp. 8-17.

Johnstone, T. and Scherer, K.R. (2000) 'Vocal Communication of Emotion', in Lewis, M. and Haviland, J. (eds.) *The handbook of emotion.* New York: Guilford Press, pp. 220-235.

Kahneman, D. (2011) *Thinking, fast and slow.* London: Penguin.

Keir Winesmith and Suse Anderson (2020) *The Digital Future of Museums.* Milton: Taylor and Francis.

Kidd, J., Ntalla, I. & Lyons, W. (2011) 'Multi-touch interfaces in museum space: reporting preliminary findings on the nature of interaction', in Ciolfi, L., Scott, K., and Barbieri, S. (eds.) *Re-thinking Technology in Museums 2011*.

Kleinberg-Levin, D.M. (1993) *Modernity and the hegemony of vision.* Berkeley, Calif.; London: University of California Press.

Koelsch, S., Fritz, T., v. Cramon, D.Y., Müller, K. and Friederici, A.D. (2006) 'Investigating emotion with music: An fMRI study', *Human Brain Mapping,* 27(3), pp. 239-250.

Korsmeyer, C. (1999) *Making sense of taste.* Ithaca: Cornell Univ. Press.

Kozhevnikov, M., Hegarty, M. and Mayer, R.E. (2002) 'Revising the Visualizer-Verbalizer Dimension: Evidence for Two Types of Visualizers', *Cognition and Instruction,* 20(1), pp. 47-77.

Kreibig, S.D. (2010) 'Autonomic nervous system activity in emotion: A review', *Biological Psychology,* 84(3), pp. 394-421.

Kring, A.M. and Gordon, A.H. (1998) 'Sex Differences in Emotion', *Journal of Personality and Social Psychology,* 74(3), pp. 686-703.

Lacey, S. and Sathian, K. (2014) 'Please DO Touch the Exhibits! Interactions between Visual Imagery and Haptic Perception', in Levent, N. and Pascual-Leone, Á. (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 3-16.

Lacey, S., Lin, J. and Sathian, K. (2011) 'Object and spatial imagery dimensions in visuo-haptic representations', *Experimental Brain Research,* 213(2), pp. 267-273.

Landis, C. (1932) 'Electrical phenomena of the skin', *Psychological bulletin,* 29(10), pp. 693-752.

Lang, P.J. (1995) 'The emotion probe: Studies of motivation and attention', *American Psychologist,* 50(5), pp. 372.

Smith, L., Campbell, G. and Wetherell, M. (2018) *Emotion, Affective Practices, and the Past in the Present.* Milton: Taylor and Francis.

Levent, N. and McRainey, D.L. (2014) 'Touch and Narrative in Art and History Museums', in Levent, N. and Pascual-Leone, Á (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 61-83.

Levent, N. and Pascual-Leone, Á (2014) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield.

Lin, Y., Wang, C., Jung, T., Wu, T., Jeng, S., Duann, J. and Chen, J. (2010) 'EEG-Based Emotion Recognition in Music Listening', *IEEE Transactions on Biomedical Engineering,* 57(7), pp. 1798-1806.

Livingstone, M.S. (1988) 'Art, Illusion and the Visual System', *Scientific American,* 258(1), pp. 78-85.

Logan, W. and Reeves, K. (2008) *Places of Pain and Shame: Dealing with 'Difficult Heritage'.* Taylor and Francis.

Loomis, R.J. (1987) *Museum visitor evaluation.* Nashville, Tenn: American Association for State and Local History.

Loureiro, B. and Rodrigues, R. (2011) 'Multi-touch as a Natural User Interface for elders: A survey', *6th Iberian Conference on Information Systems and Technologies (CISTI 2011)*, pp.1-6.

MacKenzie, D.A. and Wajcman, J. (1999) *The social shaping of technology.* Buckingham; Philadelphia: Open University Press.

Maeda, F., Kleiner-Fisman, G. and Pascual-Leone, A. (2002) 'Motor Facilitation While Observing Hand Actions: Specificity of the Effect and Role of Observer's Orientation', *Journal of Neurophysiology,* 87(3), pp. 1329-1335.

Malach, R., Reppas, J.B., Benson, R.R., Kwong, K.K., Jiang, H., Kennedy, W.A., Ledden, P.J., Brady, T.J., Rosen, B.R. and Tootell, R.B. (1995) 'Object-Related Activity Revealed by Functional Magnetic Resonance Imaging in Human Occipital Cortex', *Proceedings of the National Academy of Sciences of the United States of America,* 92(18), pp. 8135-8139.

Mann, S. (1997) 'Wearable computing: a first step toward personal imaging', *Computer,* 30(2), pp. 25-32.

Mason, J. (2002) *Qualitative researching.* 2nd ed. London: Sage.

Mausfeld R. (2013) 'The Biological Function of Sensory Systems', in Galizia C., Lledo PM. (eds.) *Neurosciences*. Berlin, Heidelberg: Springer Spektrum, pp. 239-252.

Mauss, I.B. and Robinson, M.D. (2009) 'Measures of emotion: A review', *Cognition & Emotion*, 23(2), pp. 209-237.

Mauss, M. (1973) 'Techniques of the body', *Economy and Society,* 2(1), pp. 70-88.

May, S., Todd, K. & Paneto, S. (2018) 'Measuring and Designing for a Range of Meaningful Emotions in an Informal Learning Environment', *2018 3rd Digital Heritage International Congress (DigitalHERITAGE) held jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018)*, San Francisco, CA, USA, 2018, pp. 1-8, doi: 10.1109/DigitalHeritage.2018.8810104.

McGee, C. and Rosenberg, F. (2014) 'Art Making as Multisensory Engagement: Case Studies from The Museum of Modern Art', in Levent, N. and Pascual-Leone, Á. (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 29-44.

McGilchrist, I. (2009) *The Master and His Emissary: The Divided Brain and the Making of the Western World.* Yale University Press.

Mehrabian, A. and Russell, J.A. (1974) *An approach to environmental psychology.* MIT Press.

Melton, A.W. (1988) *Experimental studies of the education of children in a museum of science.* Washington, D.C.: American Association of Museums.

Menlove, B. (2013) ‘A Custom Fit: Personalizing Experiences Using Technology’, *Dimensions* (May/June), pp. 41.

Mihalache, I.D. (2014) ‘Taste-full Museums: Educating the Senses One Plate at a Time’, in Levent, N. and Pascual-Leone, Á (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 197-213.

Miles, R.S. (1988) *The design of educational exhibits.* London: Unwin Hyman.

Modlin, E.A., Alderman, D.H. and Gentry, G.W. (2011) ‘Tour Guides as Creators of Empathy: The Role of Affective Inequality in Marginalizing the Enslaved at Plantation House Museums’, *Tourist Studies,* 11(1), pp. 3-19.

Montagu, A. (1986) *Touching: The Human Significance of the Skin.* New York: Harper & Row.

Montoya, P., Campos, J.J. and Schandry, R. (2005) ‘See red? Turn pale? Unveiling Emotions through Cardiovascular and Hemodynamic Changes’, *The Spanish journal of psychology,* 8(1), pp. 79-85.

Morse, N. (2019). The Social Role of Museums: from Social Inclusion to Health and Wellbeing, in M. O'Neill and G. Hooper (eds.) *Connecting Museums,* London: Routledge, pp.45-68.

Morse, N. (2020) *The Museum as a Space of Social Care.* Routledge.

Munro, E. (2014) ‘Doing emotion work in museums: reconceptualising the role of community engagement practitioners’, *Museum & Society,* 12(1), pp. 44-60.

Neely, L. and Rozner, E. (2015) ‘Museum3D: Experiments in engaging audiences using 3D’, *MW2015: Museums and the Web 2015.*

Neely, L. and Langer, M. (2013) ‘Please Feel the Museum: The Emergence of 3D Printing and Scanning’, in Proctor, N. and Cherry, R. (eds.) *Museums and the Web 2013.* Silver Spring, MD: Museums and the Web.

Nelson, G.A. and Cohn, S. (2015) ‘Data Collection Methods for Evaluating Museum Programs and Exhibitions’, *Journal of Museum Education,* 40(1), pp. 27-36.

Newman, A., F. McLean and G. Urquhart (2005) .Museums and the active citizen: Tackling the problems of social exclusion., *Citizenship Studies* 9 (1), pp. 41-57.

Nielsen, J. (1993) *Usability engineering.* Cambridge, MA: Academic Press.

Nielsen, J. (1994) ‘Estimating the number of subjects needed for a thinking aloud test’, *International Journal of Human - Computer Studies,* 41(3), pp. 385-397.

Ochsner, K.N., Bunge, S.A., Gross, J.J. and Gabrieli, J.D.E. (2002) ‘Rethinking feelings: An fMRI study of the cognitive regulation of emotion’, *Journal of Cognitive Neuroscience,* 14(8), pp. 1215-1229.

Öhman, A., Hamm, A. and Hugdahl, K. (2000) 'Cognition and the autonomic nervous system: Orienting, anticipation, and conditioning', in Anonymous New York, NY, US: Cambridge University Press, pp. 533-575.

Pallasmaa, J. (2014) 'Museum as an Embodied Experience', in Levent, N. and Pascual-Leone, Á (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 239-250.

Pallesen, K.J., Brattico, E., Bailey, C., Korvenoja, A., Koivisto, J., Gjedde, A. and Carlson, S. (2005) 'Emotion Processing of Major, Minor, and Dissonant Chords: A Functional Magnetic Resonance Imaging Study', *Annals of the New York Academy of Sciences*, 1060(1), pp. 450-453.

Pamphilon, B. (1999) 'The Zoom Model: A Dynamic Framework for the Analysis of Life Histories', *Qualitative Inquiry,* 5(3), pp. 393-410.

Panksepp, J. (1998) *Affective neuroscience the foundations of human and animal emotions.* New York: Oxford University Press.

Panksepp, J. and Biven, L. (2012) *The archaeology of mind.* New York: Norton.

Newman, A., F. McLean and G. Urquhart (2005) .Museums and the active citizen: Tackling the problems of social exclusion., *Citizenship Studies* 9 (1), pp. 41-57.

Parry, R. (2013) 'The end of the beginning: normativity in the Postdigital Museum', *Museum Worlds,* 1(1), pp. 24-39.

Pascual-Leone, A. and Hamilton, R. (2001) 'The metamodal organization of the brain', *Progress in brain research,* 134, pp. 427-445.

Pascual-Leone, A., Amedi, A., Fregni, F. and Merabet, L.B. (2005) 'The plastic human brain cortex', *Annual Review of Neuroscience,* 28, pp. 377.

Peissig, J.J. and Tarr, M.J. (2007) 'Visual Object Recognition: Do We Know More Now Than We Did 20 Years Ago?', *Annual review of psychology,* 58(1), pp. 75-96.

Petrantonakis, P.C. and Hadjileontiadis, L.J. (2010) 'Emotion recognition from EEG using higher order crossings', *IEEE Transactions on Information Technology in Biomedicine,* 14(2), pp. 186-197.

Plomp, R. (2013) *The intelligent ear: on the nature of sound perception.* Hove: Psychology Press.

Pujol Tost, L. and Economou, M. (2007) 'Exploring the suitability of virtual reality interactivity for exhibitions through an integrated evaluation: the case of the Ename Museum', *Museology,* 4, pp. 81-97.

Pujol Tost, L. and Economou, M. (2009) 'Worth a Thousand Words? The Usefulness of Immersive Virtual Reality for Learning in Cultural Heritage Settings', *International Journal of Architectural Computing,* 7(1), pp. 157-176.

Purves, D., Augustine, G.J., Fitzpatrick, D., Hall, W.C., LaMantia, A. and White, L.E. (2012) *Neuroscience.* Sunderland, Mass.: Sinauer Associates.

Pye, E. (2008) *The Power of Touch: Handling Objects in Museum and Heritage Context.* Milton: Routledge.

Rees Leahy, H. (2009) 'Watch your step: embodiment and encounter at Tate Modern', in Dudley, S. (ed.) *Museum Materialities: Objects, Engagements, Interpretations.* London: London: Routledge, pp. 162-174.

Rees Leahy, H. (2012) *Museum bodies: the politics and practices of visiting and viewing.* Farnham: Ashgate.

Reynolds, T.J. and Gutman, J. (2000) 'Laddering theory, method, analysis, and interpretation', in Reynolds, T.J. and Olson, J.C. (eds.) *Understanding consumer decision making: The means-end approach to marketing and advertising strategy.* Mahwah, N.J.: Psychology Press, pp. 25-62.

Robins, K. (1996a) *Into the image: culture and politics in the field of vision.* London: Routledge.

Robins, K. (1996b) 'Cyberspace and the worlds we live in', in Featherstone, M, and Burrows, R (eds), *Cyberspace/Cyberbodies/Cyberpunk: Cultures of Technological Embodiment*. London: SAGE, pp. 135-156.

Rodéhn, C. (2018) 'Emotions in the Museum of Medicine. An investigation of how museum educators employ emotions and what these emotions do', *International Journal of Heritage Studies,* pp. 1-13.

Roes, I., Stash, N., Wang, Y. and Aroyo, L.M. (2009) 'A personalized walk through the museum: the CHIP interactive tour guide', *Conference on Human Factors in Computing Systems Proceedings*, pp. 3317-3322

Rozin, P. (1982) "Taste-smell confusions' and the duality of the olfactory sense', *Perception & Psychophysics,* 31(4), pp. 397-401.

Rubin, H.J. and Rubin, I. (2012) *Qualitative interviewing: The art of hearing data.* Thousand Oaks, Calif.: SAGE.

Russo, J.E., Johnson, E.J. and Stephens, D.L. (1989) 'The Validity of Verbal Protocols', *Memory & Cognition,* 17(6), pp. 759-769.

Scerbo, M.W., Freeman, F.G., DiNocero, F., Mikulka, P.J., Parasuraman, R. and Prinzel, L.J., III (2001) *The efficacy of psychophysiological measures for implementing adaptive technology*. Available at: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20010067614.pdf (Accessed: 1 September 2017)

Schorch, P. (2014) 'Cultural feelings and the making of meaning', *International Journal of Heritage Studies,* 20(1), pp. 22-35.

Scott, S., Hinton-Smith, T., Härmä, V. and Broome, K. (2013) 'Goffman in the Gallery: Interactive Art and Visitor Shyness', *Symbolic Interaction,* 36(4), pp. 417-438.

Screven, C.G. (1993) 'United States: a science in the making', *Museum International,* 45(2), pp. 6-12.

Serrell, B. (1997) 'Paying Attention: The Duration and Allocation of Visitors' Time in Museum Exhibitions', *Curator: The Museum Journal,* 40(2), pp. 108-125.

Singleton, R. and Straits, B.C. (1999) *Approaches to social research*. 3rd ed. New York: Oxford: Oxford University Press.

Sola, T. (1997) *Essays on museums and their theory: towards a cybernetic museum*, Helsinki: Finnish Museums Association.

Sokhadze, E. (2007) 'Effects of Music on the Recovery of Autonomic and Electrocortical Activity After Stress Induced by Aversive Visual Stimuli', *Applied Psychophysiology and Biofeedback*, 32(1), pp. 31-50.

Sorabji, R. (1971) 'Aristotle on Demarcating the Five Senses', *The Philosophical Review,* 80(1), pp. 55-79.

Stearns, P.N. and Stearns, C.Z. (1985) 'Emotionology: Clarifying the History of Emotions and Emotional Standards', *The American Historical Review,* 90(4), pp. 813-836.

Stemmler, G., Heldmann, M., Pauls, C.A. and Scherer, T. (2001) 'Constraints for emotion specificity in fear and anger: The context counts', *Psychophysiology,* 38(2), pp. 275-291.

Stevenson, R.J. (2009) 'Phenomenal and access consciousness in olfaction', *Consciousness and Cognition,* 18(4), pp. 1004-1017.

Stevenson, R.J. (2014) 'The Forgotten Sense: Using Olfaction in a Museum Context: A Neuroscience Perspective', in Levent, N. and Pascual-Leone, Á (eds.) *Multisensory museum: cross-disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 151-166.

Stimler, N. and Andrew, G.A. (2014) 'Making New Art Inspired by the Met's Collections with Google Glass', Available at: https://www.metmuseum.org/blogs/digital-underground/2014/making-new-art. (Accessed: 1September 2016)

Stogner, M.B. (2011) 'The Immersive Cultural Museum Experience – Creating Context and Story with New Media Technology', *The International Journal of the Inclusive Museum,* 3(3), pp. 117-130.

Stoica, A., Fiotakis, G., Simarro Cabrera, J., Muñoz Frutos, H., Avouris, N. and Dimitriadis, Y. (2005) 'Usability evaluation of handheld devices: A case study for a museum application', *Proceedings PCI 2005.*

Suh, J., Ahn, J., Kim, H. & Kim, J. 'Evaluation of an interactive multimedia exhibit in the National Museum of Korean Contemporary History, South Korea', *NODEM 2014,* pp. 275.

Sutherland, I.E. (1968) 'A head-mounted three dimensional display', *fall joint computer conference*.

Sylaiou, S., Economou, M., Karoulis, A. and White, M. (2008) 'The evaluation of ARCO: A lesson in curatorial competence and intuition with new technology', *Computers in Entertainment,* 6(2), 23. (doi:10.1145/1371216.1371226)

Tarlow, S. (2012) 'The Archaeology of Emotion and Affect', *Annual Review of Anthropology,* 41, pp. 169-185.

Tarr, M. (2015) 'Location, location, location! The proliferation of indoor positioning and what it means and doesn't mean for museums', *MW2015: Museums and the Web*.

Thomas, S. and Mintz, A. (1998) The virtual and the real: media in the museum, Washington, DC: America Association of Museums.

Tolia-Kelly, D. (2010) *Landscape, race and memory: material ecologies of citizenship.* Farnham: Ashgate.

Turner, J.H. and Stets, J.E. (2006) 'Sociological Theories of Human Emotions', *Annual Review of Sociology,* 32(1), pp. 25-52.

Tyson, A.M. (2008) 'Crafting emotional comfort: interpreting the painful past at living history museums in the new economy', *Museum & Society,* 6(3), pp. 246-262.

Uchida, M. and Peng, J. (2019) 'Feeling the Exhibition: Design for an Immersive and Sensory Exhibition Experience', in Drotner, K., Dziekan, V., Parry, R. and Schrøder, K.C. (eds.) *The Routledge handbook of museums, media and communication.* London; New York: Routledge, Taylor & Francis Group, pp. 306-314.

van den Haak, M., De Jong, M. and Jan Schellens, P. (2003) 'Retrospective vs. concurrent think-aloud protocols: Testing the usability of an online library catalogue', *Behaviour & Information Technology,* 22(5), pp. 339-351.

Van Diest, I., Winters, W., Devriese, S., Vercamst, E., Han, J.N., Van De Woestijne, Karel P and Van Den Bergh, O. (2001) 'Hyperventilation beyond fight/flight: Respiratory responses during emotional imagery', *Psychophysiology,* 38(6), pp. 961-968.

Vavoula, G. and Sharples, M. (2009) 'Meeting the Challenges in Evaluating Mobile Learning: A 3-Level Evaluation Framework', *International Journal of Mobile and Blended Learning (IJMBL),* 1(2), pp. 54-75.

Vavoula, G., Sharples, M., Rudman, P., Meek, J. and Lonsdale, P. (2009) 'Myartspace: Design and evaluation of support for learning with multimedia phones between classrooms and museums', *Computers & Education,* 53(2), pp. 286-299.

Virzi, R.A. (1992) 'Refining the Test Phase of Usability Evaluation: How Many Subjects Is Enough?', *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 34(4), pp. 457-468.

Visser, J. and Richardson, J. (2013) *Digital engagement in culture, heritage and the arts*. Available at: https://digitalengagementframework.com/digenfra3/wp-content/uploads/2016/02/Digital_engagement_in_culture_heritage_and_the_arts.pdf (Accessed: 2 October 2019)

Vlemincx, E., Van Diest, I., De Peuter, S., Bresseleers, J., Bogaerts, K., Fannes, S., Li, W. and Van Den Bergh, O. (2009) 'Why do you sigh? Sigh rate during induced stress and relief', *Psychophysiology,* 46(5), pp. 1005-1013.

Voegelin, S. (2014) 'Soundwalking the Museum: A Sonic Journey through the Visual Display', in Levent, N. and Pascual-Leone, Á (eds.) *Multisensory museum: cross-*

*disciplinary perspectives on touch, sound, smell, memory, and space.* Lanham: Rowman & Littlefield, pp. 119-130.

Waldstein, S.R., Kop, W.J., Schmidt, L.A., Haufler, A.J., Krantz, D.S. and Fox, N.A. (2000) 'Frontal electrocortical and cardiovascular reactivity during happiness and anger', *Biological Psychology,* 55(1), pp. 3-23.

Waston, S. (2015) 'Emotions in the History Museum', in Witcomb, A. and Message, K. (eds.) *The International Handbooks of Museum Studies.* John Wiley & Sons, Ltd, pp. 283-301.

Watson, S. (2016) 'Why do Emotions Matter in Museums and heritage sites?', in van Boxtel, C. (ed.) *Sensitive Pasts: Questioning Heritage in Education.* New York: Berghahn Publishers.

Watson, S. (2018) 'Emotional engagement in heritage sites and museums: Ghosts of the past and imagination in the present', in Watson, S., Barnes, A. and Bunning, K. (eds.) *A Museum Studies Approach to Heritage.* London: Routledge, pp. 441-456.

Westerink, J.H., Van Den Broek, E.L., Schut, M.H., Van Herk, J., and Tuinenbreijer, K. (2008). 'Computing emotion awareness through galvanic skin response and facial electromyography', in Westerink, J., Ouwerkerk, M., Overbeek, T. and Pasveer W.F. (eds.) *Probing experience*. Springer, Dordrecht, pp. 149-162.

Whitehead, A.E., Taylor, J.A. and Polman, R.C.J. (2015) 'Examination of the suitability of collecting in event cognitive processes using Think Aloud protocol in golf', *Frontiers in psychology,* 6, 1083.

Williams, L., Das, P., Liddell, B., Olivieri, G., Peduto, A., Brammer, M. and Gordon, E. (2005) 'BOLD, sweat and fears: fMRI and skin conductance distinguish facial fear signals', *NeuroReport,* 16(1), pp. 49-52.

Williams, R. and Edge, D. (1996) 'The social shaping of technology', *Research Policy,* 25(6), pp. 865-899.

Witcomb, A. (2013) 'Understanding the role of affect in producing a critical pedagogy for history museums', *Museum Management and Curatorship,* 28(3), pp. 255-271.

Yee-King, M., Confalonieri, R., Jonge, D.D., Hazelden, K., Sierra, C., d'Inverno, M., Amgoud, L., and Osman, N. (2013). Multiuser museum interactives for shared cultural experiences: an agent-based approach. *AAMAS*.

Yin, R.K. (2014) *Case study research: Design and methods.* 5th ed. Los Angeles: SAGE.

Zaltman, G. (2003) *How customers think.* Boston, Mass: Harvard Business School Press.

Zeki, S. (1999) *Inner vision: An exploration of art and the brain.* Oxford: Oxford University Press.