ENHANCING THE MUSEUM EXPERIENCE FOR VISUALLY IMPAIRED PEOPLE IN HONG KONG: HAPTIC-AUDIO INTERACTION DESIGN (HAID)

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Enhancing the Museum Experience for Visually Impaired People in Hong Kong: Haptic-Audio Interaction Design (HAID)

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CERTIFICATE OF ORIGINALITY

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ABSTRACT

How can Hong Kong museums enhance the experiences of their visually impaired visitors? Visually impaired individuals face major challenges in visually oriented environments such as museums. With this in mind, in-depth field observations and interviews at the 11 major museums in Hong Kong were conducted. Proposed case studies with pilot testing and interviews were also conducted to investigate the effectiveness of a touch-activated sound system that could be adopted in museum environments. This proposed conceptual system integrated exhibit information into tactile diagrams that could be easily accessed by visually impaired individuals. The study aimed to gather information that would help visually impaired and blind individuals to understand and construct mental images of two-dimensional exhibits.

The main goal was to create a conceptual tactile-audio paper prototype using the cross-modal interaction approach (a combination of tactile diagrams and audio descriptions) that could provide multisensory feedback to the visually impaired and enable them to ‘see’ the museum exhibits without having to touch the original exhibits. The results of the conceptual tactile-audio paper prototype indicated that the cross-modalities interaction approach has great potential for helping the visually impaired construct clearer mental images. The key findings and recommendations are presented in this thesis, along with the characteristics of interactivity of the visually impaired participants in this study. These findings

should be used in the future to develop a haptic-audio interaction design museum platform.

In this study, a qualitative research approach was adopted with case studies that focused on the cross-modal interaction design to assess how multisensory feedback could be provided to visually impaired visitors, construct clearer mental images of exhibits and thus enable meaningful museum experiences. First, the literature and documents were reviewed to obtain an in-depth understanding of previous works relating to this study and investigate how museums understand and perform their roles in supporting visually impaired visitors. The findings of various studies and projects showed that museum environments, exhibitions and programmes still fail to consider the actual wants and needs of visually impaired visitors. Second, in-depth field observations and interviews with major museums in Hong Kong revealed that the visually impaired are a little-noticed segment of the museum audience and are offered few basic facilities and resources to aid their mobility and access to information about museum exhibits.

Third, semi-structured interviews using open-ended questions were conducted with visually impaired participants. The participants were asked about their viewpoints on, feelings about and understanding of subjects that could be personal and subjective. A pilot study found that many visually impaired individuals in Hong Kong were reluctant to visit museums because they felt excluded. Fourth, a second pilot study was conducted using another set of semi-structured interview questions. The selected visually impaired participants took part in tests of three medium-fidelity conceptual tactile paper prototypes that were supported by audio descriptions. The prototypes simulated the effect of multisensory feedback to investigate the effectiveness of touch-activated sound systems that integrated exhibit information with tactile diagrams. The participants were asked to draw the mental images they constructed during the tests to evaluate the effectiveness of the integrated platform. They were indeed able to capture some of the visual elements of the exhibits.

The results of the case studies demonstrated an understanding of the value of tactual and audio interpretation of the visual information of museum exhibits as an accessible medium for visually impaired visitors. They also revealed that dialogue between the visually impaired and museums could be enhanced by paying special attention to museum exhibits through the proposed cross-modal approach, i.e., the haptic-audio interaction design (HAID) system, and by rethinking and shifting the current perspective on an inclusive museum experience to enhance that experience for the visually impaired. Access to visual information about museum exhibits is crucial for visually impaired visitors, who need to construct mental images of exhibits that are detailed enough to make them feel their museum experience is worthwhile and meaningful.

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CHAPTER 1 INTRODUCTION

Overview

A traditional museum environment is a building that contains untouchable two- and three-dimensional exhibits that are presented to visitors. This study explores the potential of using haptic (touch) and audio (sound) interaction design approaches to enhance the museum experience of visually impaired visitors. This chapter introduces the key components of this thesis, including the *introduction* and *background* of this research study and a brief description of its scope to demonstrate its focus and implementation. The appropriate research aims and objectives are identified and guided by the formulated *research guiding questions*. The projected *significance of the study* follows along with the study framework, projecting the flows and relationships considered in the individual chapters.

“Hearing is a form of touch. Something that’s so hard to describe, something that comes, sound that comes to you... You feel it through your body, and, sometimes, it almost hits your face.” – Evelyn Glennie, Touch the Sound.

1.1 INTRODUCTION AND BACKGROUND

Statistics report No. 62, ‘Persons with disabilities and chronic diseases’, released by the Census and Statistics Department of the Hong Kong Special Administrative Region (2014), indicates that approximately 178,000 people in Hong Kong are visually impaired (2.4% of the total population) and that 78,000 are blind. In recent years, policymakers, researchers, engineers, architects, designers and manufacturers have discussed various approaches to improving the daily mobility and accessibility of visually impaired and blind individuals. According to Glinert and York (2008), although great strides have been made in developing assistive technology for blind people, blindness remains a priority for accessibility researchers. Most studies relating to visually impaired people have focused on such aspects as accessible virtual environments, on-line interfaces, mobile devices, navigation and way-finding (see Ciolfi & Bannon, 2002; Moreno et al., 2008; Santoro et al., 2007; Choras et al., 2011; Sánchez et al., 2013). Very few studies have focused on how visually impaired and blind visitors receive visual information about exhibits in museums (see Salgado & Salmi, 2006; Shiose et al., 2010; Reichinger et al., 2011; Carfagni et al., 2012). Despite much effort, individuals who are visually impaired are still facing major challenges in visually oriented environments such as museums and galleries. The ability to access information about museum exhibits is crucial for the visually impaired to construct mental images of those exhibits.

Carfagni et al. (2012) stated that the visually impaired are inevitably disadvantaged in the enjoyment of artworks, which are usually created for sighted people. They also mentioned that the ability of the visually impaired to access cultural and artistic areas is affected by not only their mobility and spatial navigation, but also their inability to sense the artworks themselves. According to vom Lehn (2010) the visually impaired are a little-noticed segment of the museum audience, but they still often visit visual-art-related exhibitions. Hooper-Greenhill et al. (2000) and the Social Exclusion Task Force (2006) argued that visually impaired visitors interact with companions and use the tactile technological and human resources provided by museums to make sense of their exhibits. Information and interpretation resources designed for the visually impaired have become commonplace in museums located in the UK, continental Europe and the US, where policymakers and museum representatives have been pursuing agendas of social inclusion (see also Catherine, 2005; RNIB, 2009). Such agendas have addressed the exclusion of certain parts of the population from accessing public resources due to their physical or mental abilities. Many studies have indicated that the resultant improvements have been minimal, but even limited improvements have yet to be seen in the major museums of Hong Kong (see Appendix 1).

According to Moreno et al. (2008), in recent years many museums located in the UK, continental Europe and the US, both public and private, have set up initiatives to create portable devices that make museum visits accessible to visitors with different types of needs, particularly visitors with physical constraints or impairments. Moreno et al. (2008) further commented that ‘these devices are of a diverse nature and they enrich the visitor’s experience, though this is not their primary purpose’. Most studies have focused on accessible virtual environments, on-line interfaces, navigation and way-finding and so on, with very few focusing on the accessibility of how visually impaired people and blind visitors receive information about the exhibits.

Based on a publication by Gougoux et al. (2004), many studies in the past decade have investigated and confirmed that visually impaired people have superior abilities in relation to non-visual perceptual tasks including pitch change direction discrimination, verbal memory (Amedi, Raz, Pianka, Malach, & Zohary, 2003; Roder, Rosler, & Neville, 2001; Hull & Mason, 1995), speech discrimination (Niemeyer & Starlinger, 1981), sound localisation (Gougoux, Zatorre, Lassonde, Voss, & Lepore, 2005) and tactile discrimination (Goldreich & Kanics, 2003; Van Boven, Hamilton, Kauffman, Keenan, & Pascual-Leone, 2000).

The literature also shows a recent trend in the increased use of embedded technological support in services and products suitable for different users in multiple contexts, including people with physical constraints. Technologies have created new opportunities that allow users to improve their day-to-day living difficulties and to perform activities or access unfamiliar environments previously considered impossible or challenging (e.g., to navigate spaces and appreciate art in a museum environment).

With the frequent use and advancement of sensory and cross-modal technology, there is enormous potential to exploit handheld devices (mobile phones, PDAs, MP3/4s and touch-screen devices) for use with these assistive technologies. To achieve such results, accessibility principles should be applied when developing products or services. ‘Accessibility’ is a general term used to indicate that products (e.g., a device, a service or an environment) should be accessible to as many people as possible, including those with physical constraints. Ghiani, Leporini and Paterno (2009) stated that increased accessibility must be an important feature of systems or products to allow users with different abilities to access or use them.

To understand cross-modal interaction, it is crucial to determine where and how information from different senses is combined, especially for users who have special needs and physical constraints. Jansson and Juhasz (2007) stated that users with severe visual impairment have to work without obtaining information from the sense of vision, making task performance more difficult. It is therefore especially hard for a visually impaired person to get an overview of an interface and to find and explore objects and details.

According to Haans and Ijsselsteihn (2005), touch (haptic) and sound (audio) are very powerful for visual communication and can play an important role in our daily lives. Touch and sound are even more crucial for individuals who are visually impaired and blind. Much of the benefits of haptic and audio interaction are seen in situations where users may be unable to use a visual display. In such situations, the haptic and audio modalities must shoulder the responsibility that would otherwise be undertaken by one's sense of sight. This requires the efficient use of the bandwidth of this modality (McGookin & Brewster, 2006). The integration of haptic and audio in effect serves as the 'eyes' for a visually impaired person, as it relates to evoking the simulation of art forms, visual connection, imagination and mental visual imagery through the perceiving and understanding of appropriate visual information.

According to Stein and Meredith (1993), 'Merging information across senses provides a comprehensive "picture" of sensory objects and is necessary for a reliable interaction with our environment'. Studies of the use of haptic and audio technology have grown rapidly because of recent flexible and cost-efficient software advancements, particularly as it relates to mobile technologies, touch-sensitive surfaces and tangible devices. According to Glinert and York (2008), although great strides have been made in developing assistive technology for blind people, blindness remains a priority for accessibility researchers. Most studies relating to visually impaired people have focused on such aspects as accessible virtual environments, Web interfaces, mobile devices, navigation and way-finding (Ciolfi & Bannon, 2002; Moreno et al., 2008; Santoro et al., 2007; Choras et al., 2011; Sánchez et al., 2013). Very few studies have focused on how visually impaired and blind visitors receive visual information about exhibits in museums (see Salgado & Salmi, 2006; Shiose et al., 2010; Reichinger et al., 2011; Carfagni et al., 2012). Despite much effort, the visually impaired continue to face major challenges in visually oriented environments such as museums and galleries. The ability to access information about museum exhibits is crucial for the visually impaired when they construct mental images of those exhibits.

When designing a haptic and audio interactive system, the designer must consider more complex design parameters, especially as it relates to the partially sighted and visually impaired. The central research question this study aimed to address was how a cross-modal interaction approach such as haptic-audio interaction design (HAID) could help to improve the ability of visually impaired people to access visual information and construct mental images. The two key guiding questions were as follows. First, what are the key characteristics of interactivity for the visually impaired? Second, how can the characteristics of interactivity be incorporated into a HAID platform in a way that improves accessibility for visually impaired and blind people? Interactivity and accessibility of visual information issues are the key elements to consider when addressing these questions.

1.2 RESEARCH AIMS AND OBJECTIVES

Anne Pearson was a member of British Museum Education Service and the Metropolitan Museum of Art in New York. She stated that the needs of visually impaired people in relation to visual arts have long been seriously neglected, with policymakers and art managers failing to understand the nature of the need. Throughout her many years of personal experience with visually impaired visitors in museums, she was frequently asked by visitors without sight to describe the colour of artwork or objects. They explained that they needed this information because it added to the richness of their appreciation of the art piece. In her writing (published in the book *Art Beyond Sight*), she has mentioned that promoting touch alone is not the way forward in art appreciation. She has suggested that with the integration of sound, smell, taste and texture, visitors experience many other senses and their awareness and enjoyment are heightened.

The research outcome of this study should enhance the museum experience of visually impaired visitors by providing accessible visual information through a cross-modal approach involving tactile printing and audio description of a museum exhibit. It was within the objectives of this study to examine purely visual information about two-dimensional exhibits. Case studies were conducted to observe and collect in-depth data about visitor experiences and experiments that would help to bring this research to life.

The research aims of this study can be divided into two areas: specific and general objectives.

Specific Objectives:

1. To investigate whether touch and audio description of untouchable visual information can interact with the aid of an accessible interface between visually impaired visitors and an untouchable museum exhibit; and

2. To explore the effectiveness of a system that integrates an exhibit’s visual information using the cross-modal interaction approach of HAID and how the system helps to improve the ability of the visually impaired to access visual information when constructing mental imagery.

General Objectives:

1. To analyse and understand the user experience of the HAID approach for visually impaired visitors in the museum environment; and
2. To generate guidelines and information for policymakers, Equal Opportunities Commission (EOC) departments, museum managers and curators; to aid in the development of art and design education; and to help designers design specifically for visually impaired and blind persons.

To achieve the previously stated objectives, this study proposed and developed a conceptual tactile-audio paper prototype with a HAID simulation approach for visually impaired and blind users. Participants were evaluated based on the cross-modal interaction approach via prototypes that provided low functionality and consisted of different tactile imagery and audio descriptions. The purpose was to investigate the effectiveness of an approach that could integrate an exhibit’s visual information with tactile displays and an auditory system that was easily accessible and associable by visually impaired and blind museum visitors when constructing mental images of the exhibit.

1.3 RESEARCH GUIDING QUESTIONS

The different human senses provide complementary views of environments, space, objects and dimensions. This is the primary reason why human-computer interaction (HCI) and human-centred design (HCD) activities are growing. An increasing number of recent studies and research in the commercial and the academic world has investigated these topics. It is fair to argue that the future of HCI and HCD will be highly focused on ‘experience’. The user’s experience can only be improved when applications focus on the physical, emotional, social and cultural needs of that user.

One crucial question formed the background of this research study: is it possible to achieve an accessible exhibit’s visual information using a prototype for HAID as an interactive medium between visually impaired visitors and a museum exhibit? This question influenced the components of the research approach, the most appropriate methodology and methods to use and the research aims and objectives. However, the following questions formed the basis of inquiry and helped the main research question to develop. The research questions posed in this study can be divided into two categories.

Central Research Question:

How can haptic-audio interaction design (HAID) help to enhance the museum experience for visually impaired people in a Hong Kong museum environment?

Guiding Research Questions:

1) What is the current status of Hong Kong museums' facilities and services for supporting visually impaired visitors (in terms of the overall museum environment, specific galleries and exhibitions and accessibility of visual information)?
2) How can a cross-modal interaction approach better support the visually impaired to perceive and understand visual information when constructing mental images of exhibits in a museum?
3) What are the characteristics of interactivity of visually impaired people?
4) How can these characteristics of interactivity be incorporated into designs of HAID platforms that are easily accessible by the visually impaired and blind?

In this study, all of these research questions were related through case studies, field observations and pilot studies by adopting a conceptual tactile-audio paper prototyping approach. Each of the individual case studies had two key components: 1) research activities and 2) an evaluation and a conclusion.

1.4 FRAMEWORK AND SCOPE OF THE STUDY

This thesis has four key components. First, it introduces and provides the background of the study. Second, it details the research approach across several chapters, including an introduction, a literature review, a review of the EOC of Persons with Disabilities in Hong Kong, a description of the methodology and methods adopted and a definition of the research approach. Third, it presents research activities, including case studies conducted to understand and investigate Hong Kong museum environments, characterise the visually impaired and investigate the effectiveness of HAID. In-depth file observation, user needs analysis and tactile prototyping and pilot studies were conducted to reflect the effectiveness of HAID in perceiving the visual information of museum exhibits.

Fourth, it provides an evaluation and conclusion. The final two chapters ('Critical Discussion and Analysis' and 'Conclusion') critically crosscheck and align the four key components used repeatedly throughout the study. Figure 1 shows the study framework and structure, including its activities and the relationship between the research components and chapters.

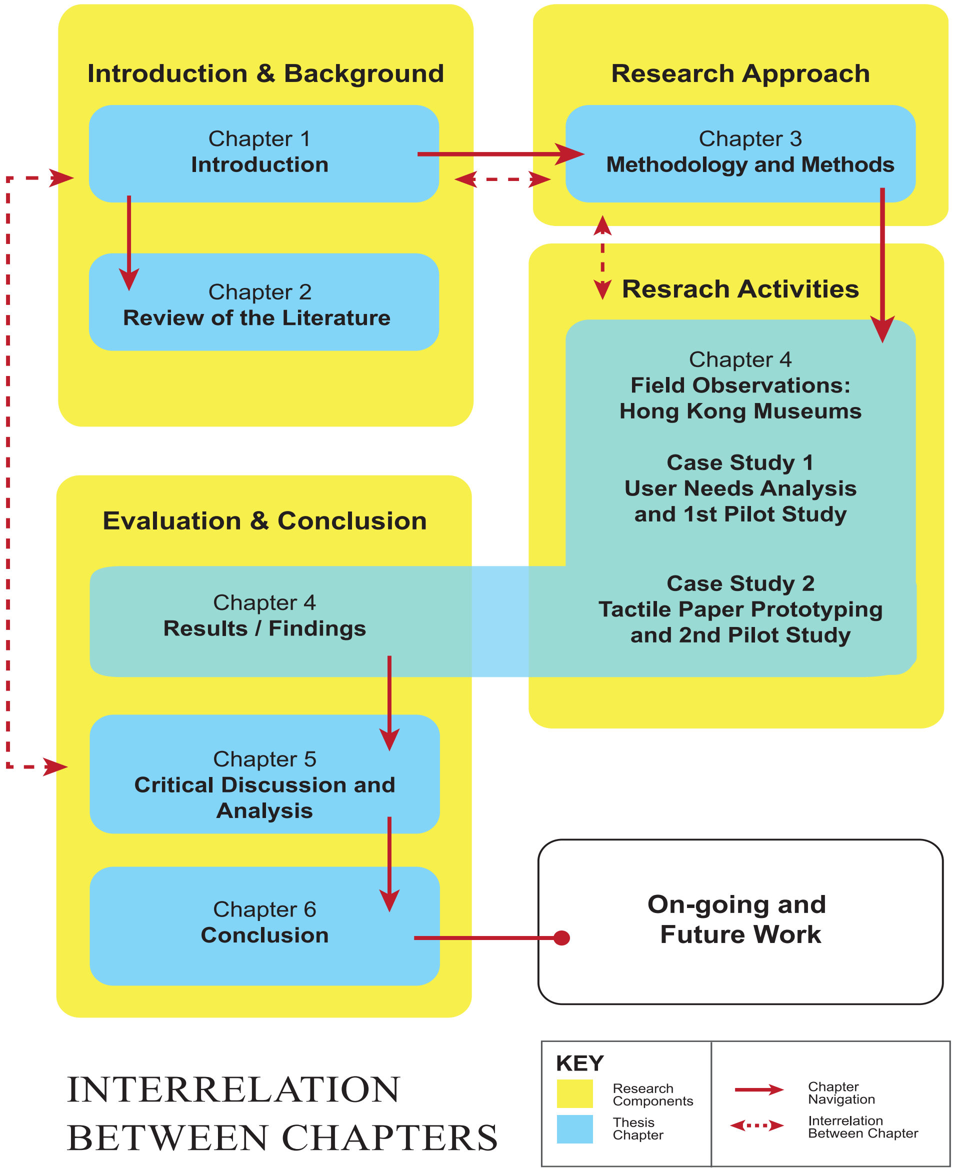

Figure 1: Framework and scope of study of the thesis. This structural diagram shows the flow of research activities and the links to chapters within the research components.

This current chapter, ‘Introduction’, begins by explaining the background of the research study. It then sets the research aims and objectives, which reflect and align the research questions along with the specific and general questions driving the study. The study framework serves to summarise this chapter and elaborates on the structure of the thesis in addition to the flows and relationships between the key components and individual chapters.

Chapter 2, ‘Review of the Literature’, extends the current chapter by reviewing the work that influenced and inspired this research. It investigates, critically reviews and contextualises critical previous works and up-to-date knowledge in relation to the research topic. The chapter begins with a broad understanding of visual impairments and blindness, followed by a description of the visual perceptions of visually impaired people and the concepts of the inclusive and universal design approaches. Another significant aspect of this thesis is its elaboration on the element of touch and the importance of the haptic–tactile interaction, in addition to the importance of audio (sound) within the contexts of visually impaired people. The chapter then discusses the cross-modal interaction approach in the museum environment in general to build a brief understanding of museology before reviewing the issues related to museum accessibility for visually impaired and blind visitors.

Once the previous research is reviewed, Chapter 3, ‘Methodology and Methods’, reflects the methodological considerations and approaches adopted by the study. After an introduction and an argument for the choice of methodologies, the chapter dedicates a section to the most appropriate research methodology. It illustrates the way in which a multi-method approach was applied to every element of the research activities conducted within this research study. After confirming the empirical research approach, the chapter details the multiple case studies, user needs analysis and pilot studies conducted, in addition to the user-centred design principles that emphasise users with special needs. Finally, it considers the principles of universal design that may make museum environments more inclusive for the visually impaired.

After the methodological approach is defined, the research activity components of the study are introduced and explained. Chapter 4, 'Case Study: Hong Kong Museum Environments', focuses on the main project of the research study: a series of case studies conducted at different stages. The first research activities considered in this chapter are *field observations* based on select museums in Hong Kong. This is followed by the Hong Kong Museum of Art Guided Tour for visually impaired people, an effective *user-needs analysis* activity involving a small group of randomly selected participants. The exercise was designed to gain first-hand observations of people interacting through touch and to understand the basic role of touch in examining objects. The exercise was also designed to study the realisation of tactile information as an interface of a visual exhibit.

Following user needs analysis, pilot studies were conducted. A case study that focused on user testing of different tactile printing materials was conducted, followed by the main pilot testing, which implemented the HAID and medium-fidelity conceptual tactile paper prototypes that were supported by audio descriptions to simulate the effect of multisensory feedback for the visually impaired participants.

In Chapter 4, the HAID case studies and pilot testing methods are clarified, and the different stages of the case studies are explained. This part of the thesis concludes with the direct results of the case studies and participants' feedback, gathered from observation and interviews. Findings of the case studies are further elaborated in the last part of this chapter.

The research activities introduced in Chapter 4 include the *tactile paper prototype* and *pilot studies*. The paper prototype was subjected to in-depth analysis, and a touch-activated sound system with audio description was examined along with participants' interactions with the prototype. The findings of this case study are presented not only to add real insights to the surface information about tactile printing and audio description, but also a means of analysing and further defining the research behaviour.

Following this component is Chapter 5, ‘Critical Discussion and Analysis’, which communicates the ideas and issues raised by the research activities through case studies and further discusses the arguments arising from the literature review presented in Chapter 3. At this point, the research is placed within a theoretical framework that questions the HAID and cross-modal approach. The chapter also examines the value of the interface as a tangible information tool connecting visually impaired people with visual information about two-dimensional untouchable museum exhibits according to the strategies and philosophies of other research.

After five chapters illustrating the research process and activities and their connection to academia, Chapter 6, *Conclusion,* looks back at the finished research. This chapter gives an overview of the thesis by summarising and evaluating the results, stating which objectives have been achieved with this inquiry and *answering and revisiting the research questions.* The thesis concludes by presenting the *limitations of the study* along with *possible future works* and potential plans.

1.5 SIGNIFICANCE OF THE STUDY

This study focused on the interactivity and accessibility of visual information for the visually impaired to improve their process of constructing mental images of untouchable museum exhibits. It ultimately sought to enhance the experience of Hong

Kong museum environments via an in-depth examination and understanding of human interaction and interpretation of touch (haptic) and audio (sound) and how visual information about untouchable museum exhibits could be delivered to and perceived by the visually impaired through an accessible option that affects their museum experience. This study intended to achieve the following significance outcomes.

1) The primary contribution of this study was its demonstration of the value of tactual and audio interpretation of visual information about museum exhibits through methodologically produced selected art pieces, in the form of tactile drawing in addition to a conceptual HAID system as an accessible medium.
2) This study sought to enhance the current information by paying special attention to museum exhibits through the proposed cross-modal approach and HAID system.
3) The physical interface considered was different from other currently available tactile museum aids in that it was neither a direct replica nor an embossed representation. Furthermore, it focused on elements or objects by providing visual descriptions that could be associated and understood by the visually impaired.
4) This study addressed the missing user's involvement or participation associated with rapid development in the user-centred design process. It considered the ways in which haptic or audio technologies are applied to

museums and reintroduced the notion of user involvement in interpreting visual information. Rather than technology being the main aspect, it was treated only as another medium.

5) This study sought to rethink and shift the current perspective to form an inclusive and enhanced museum experience for the visually impaired.

CHAPTER 2 REVIEW OF THE LITERATURE

Overview

This chapter focuses on reviewing and understanding the terminology associated with visual impairment and blindness and defining the functional approach that framed the research topic and research questions. Other work and projects relevant to this research are reviewed. The selected literature was collected from scholarly publications, conference papers, related journals and on-line sources. Most of the literature related to policy and legislation frameworks and specific guidelines were taken mainly from the US, UK and continent of Europe to attain a broader viewpoint based on best-practice examples. There is limited research on this topic as it relates to Hong Kong.

The literature review in this chapter affects different parts of this thesis. References to the literature reviewed in this chapter naturally appear in other chapters when relevant. Chapter 5, 'Critical Discussion and Analysis', further investigates some of the ideas and arguments seeded in this chapter.

2.1 INTRODUCTION

Part of this thesis is built on a growing body of literature focusing on people who are blind or have low vision and their museum experiences. In-depth understanding and review of the literature indicate that the availability of tactile objects and actions of museum staff have a large effect on the museum experience of blind. The literature is also a reminder that real barriers to the museum experience exist for the visually impaired and that museums have long ignored or marginalised people with disabilities. Earlier studies provide an important perspective and reference point for analysing and discussing the gathered research activities data.

According to a survey project funded by the National Endowment for the Arts in the US (2011), some publications in the field of museum studies, including *The Power of Touch: Handling Objects in Museum and Heritage Contexts* and *Touch in Museums: Policy and Practice in Object Handling* published in 2007 and 2008, respectively, have also addressed a range of issues and strategies related to tactile experiences in museums. In the same report, Eriksons (1998) discussed the long and rich history of tactile diagrams dating back to the 18th century. The 2003 publication *Art Beyond Sight: A Resource Guide to Art, Creativity, and Visual Impairment* also highlighted practical information about making art experiences more accessible for visitors who are blind or have low vision, and the history of touch and accessibility dating back to the 1970s and 1980s provided useful information and insights for this study, particularly in terms of the development of the conceptual tactile-audio paper prototype.

In general, the use of haptic and audio on handheld devices has already been considered in several studies. Included in this chapter is an overview of previous studies related to interface technologies and applications used for visually impaired people. These studies have generally emphasised interface design, computer games, handheld devices and virtual environments. However, very few studies have considered the synchronisation of haptic and audio technology to help visually impaired or blind people in the museum context, particularly in Hong Kong museum environments. As stated earlier, based on a preliminary investigation of the 11 major museums in Hong Kong, it was found that the basic facilities used to assist visually impaired people in museums were insufficient. Very limited facilities such as museum tactile maps, tactile guide paths, braille descriptions for exhibits and an accessible website for visually impaired people were found in these museums. No digital handheld devices to assist the mobility of visually impaired people in the museums environments were noted (see Appendix 1).

According to vom Lehn (2010), ‘museums are increasingly providing alternate and new resources to attract excluded audiences such as elderly people [and] people with physical constraints or disability, and to provide them with resources to access and experience the objects on display in museums’. However, relatively little is known about how visitors use these resources to enhance their experience of exhibits or their overall museum visit experience.

2.2 VISUAL IMPAIRMENTS AND BLINDNESS

In 1980, the World Health Organization (WHO), the United Nations' public health arm, attempted to give the terms 'disability', 'impairment' and 'handicap' strict operational meaning within a framework designed to separate them conceptually while linking them theoretically. In 2001, the WHO published its new framework for disability and health, known as the 'International Classification of Functioning, Disability and Health' (ICF). The WHO developed an international standard language and a framework, defining disability as the point where health ends. After 10 years of work, the 2001 framework introduced a radical departure from the old assumption that the term 'disability' applied to a distinct subset of people. The WHO's new definition of disability did the following:

- established parity between 'mental' and 'physical' reasons for disability;
- mainstreamed the experience of disability and recognised it as a universal human experience; and
- called for the identification of 'facilitators' that could not only eliminate barriers but also enhance experience and performance.

There are numerous formal and informal definitions of ‘visual impairment’ and ‘blindness’. The Hong Kong Society for the Blind (HKSB) and Hong Kong Blind Union (HKBU) use a subjective definition: ‘one is visually impaired if one has difficulties or it is impossible to read ordinary text or visually orientate oneself, or due to the visual impairment one has other difficulties in one’s daily life’.

One functional definition is based on fractions, a common way of expressing visual acuity. The WHO defines a person as visually impaired if he or she has a visual acuity of less than 20/70 but equal to or better than 20/400 in the better eye with best possible correction. Furthermore, a person is blind if he or she has a visual acuity of less than 20/400 or corresponding visual field loss in the better eye with best possible correction. It is impossible to know the exact number of visually impaired and blind persons, as no central record with this information exists.

According to *Special Topics Report No. 48 on Persons with Disabilities and Chronic Diseases* issued by the Government of the Hong Kong Special Administration Region (HKSAR) in January 2009, based on social data collected via the General Household Survey in 2008, there are at present 122,600 persons with seeing difficulty, including the totally blind. This accounts for 1.8% of the total Hong Kong population. There are 11,400 people suffering from total blindness, and 60% of them are elderly (aged 60 and above). Meanwhile, the number of mild to moderate visually impaired amounts to 110,000. A survey conducted by *South China Morning Post*, 3 December 2010, stated that 19.7% of people with registered disabilities in Hong Kong suffer visual problems, the second highest population (Figure 2).

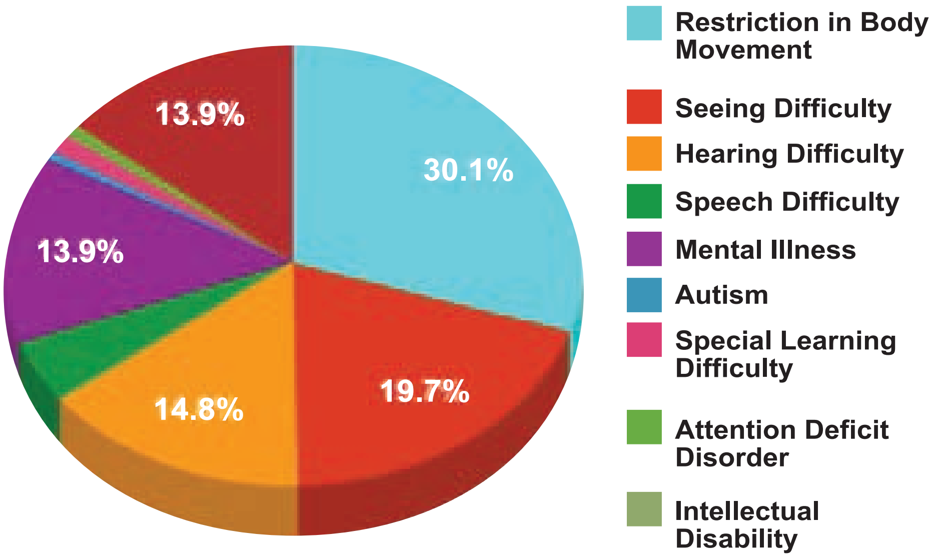

Figure 2: Visual problems rank second in terms of people with registered disabilities in Hong Kong (SCMP, 2010).

According to the HKSB and HKBU, 'visual impairment' or 'blindness' refers to a significant functional loss of vision that cannot be corrected by medication, surgical operation or ordinary optical lenses such as spectacles. The following definitions have been agreed upon and adopted based on the visual functioning of the persons involved.

Visual impairment can be classified into two categories: low vision and blindness.

There are three levels of low vision.

1. Severe low vision – persons with visual acuity from 6/120 to 6/1990, hand movement and light perception or persons with a contracted visual field in which the widest field diameter subtends an angular subtense <20 irrespective of the central visual acuity (central visual acuity refers to that of the better eye with correcting glasses).
2. Moderate low vision – persons with visual acuity from 6/10 to 6/95.
3. Mild low vision – persons with visual acuity from 16/18 to 6/48.
4. Total blindness – persons with total absence of sight or no visual function, i.e., no light perception.

Visual impairments are further classified as congenital or adventitious as follows.

1. Congenital – refers to loss of vision present at birth. Some of the more common causes of congenital visual impairment are prematurity, genetic diseases, prenatal and perinatal infections and maternal substance abuse.
2. Adventitious – refers to loss of vision acquired after birth as a result of illness or accident.

Figure 3 presents additional categorisations and definitions based on the WHO standard.

Category	**Corrected VA – Better Eye**	**WHO Definition Standard***
0	6/6-6/18	Normal
1	<6/18-6/60	Visual Low
2	<6/60-3/60	Severe Visual
3	<3/60-1/60	Blind
4	<1/60-PL	Blind
5	NPL	Blind

Figure 3: Categories of Visual Impairment based on WHO Standard

** The standard WHO definition is used in medical reports and publications. It is solely based on visual acuity and does not take functional vision into account.*

2.3 WHAT IS A MUSEUM?

The word ‘museum’ is derived from the Latin *muses*, meaning ‘a source of inspiration’ or ‘to be absorbed in one’s thoughts’. Bennett (1995) stated that museums collect and care for objects of scientific, artistic or historical importance and make them available for public viewing through exhibits of permanent collections or temporary exhibits. It is the role of the curator to look after the objects and explain their history to visitors. Furthermore, a building that is a museum can often be part of the collection itself.

Established in 1946, the International Council of Museums (ICOM) has been dedicated to the evolutionary nature of the museum and committed to reflecting the realities of the museum communities globally. In 2007, ICOM updated the definition of a museum at the 21st General Conference in Vienna, Austria, stating that a museum is ‘a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment’. Later, Alexander and Alexander (2008) stated that ‘a museum is an institution that cares for a collection of artifacts and other objects of scientific, artistic, cultural or historical importance and makes them available for public viewing through exhibits that may be permanent or temporary'.

Dudgeon et al. (2010) mentioned that museums can be said to 'bring the past to life' and are fantastic representations of the different periods of our cultural history. They enable visitors to touch, feel, see, hear, experience and smell the past. Many museums now offer a programme of events for different groups, such as families and children under 5. This is in contrast to the early museums, which mainly catered to adult audiences. Karp et al. (2006) stated in their essay '*Museum frictions: Public cultures/global transformation*' that 'modern trends in museology have broadened the range of subject matter and introduced many interactive exhibits, which give the public the opportunity to make choices and engage in activities that may vary the experience from person to person'. Xu et al. (2005) stated that museums provided less formal and more flexible learning environments than the typical classrooms, where children feel more comfortable and therefore more motivated. Curiosity & Imagination, the national network for children's hands-on learning, offers children practical, exciting and powerful hands-on activities to develop their identity and inspire their imagination.

The Museums, Libraries and Archives Council (MLA) was launched in 2000 as the strategic agency for museums, archives and libraries, replacing the Museums and Galleries Commission and the Library and Information Commission. Their policy for the museum sector asks curators and programme-makers to provide more educational and inclusive content. By providing an 'Access for All' self-assessment toolkit to museums, the MLA also makes the accessibility and diversion policies accessible to these institutions (MLA, 2007).

According to Terras (2007), the Cultural Heritage Applications unit of the European Commission launched a study called 'Digital Heritage and Cultural Content' (DigiCULT) at the end of 2001. With an overall aim of making digital resources for the cultural heritage sector more accessible to a wider audience through the use of information and communication technologies (ICT), the study provided European museums, archives and libraries with guidance on the challenges they would face between 2002 and 2006. Based on the outcomes of the study, a recommended process was proposed: the 'unlocking the value of cultural heritage' process seen in Figure 4.

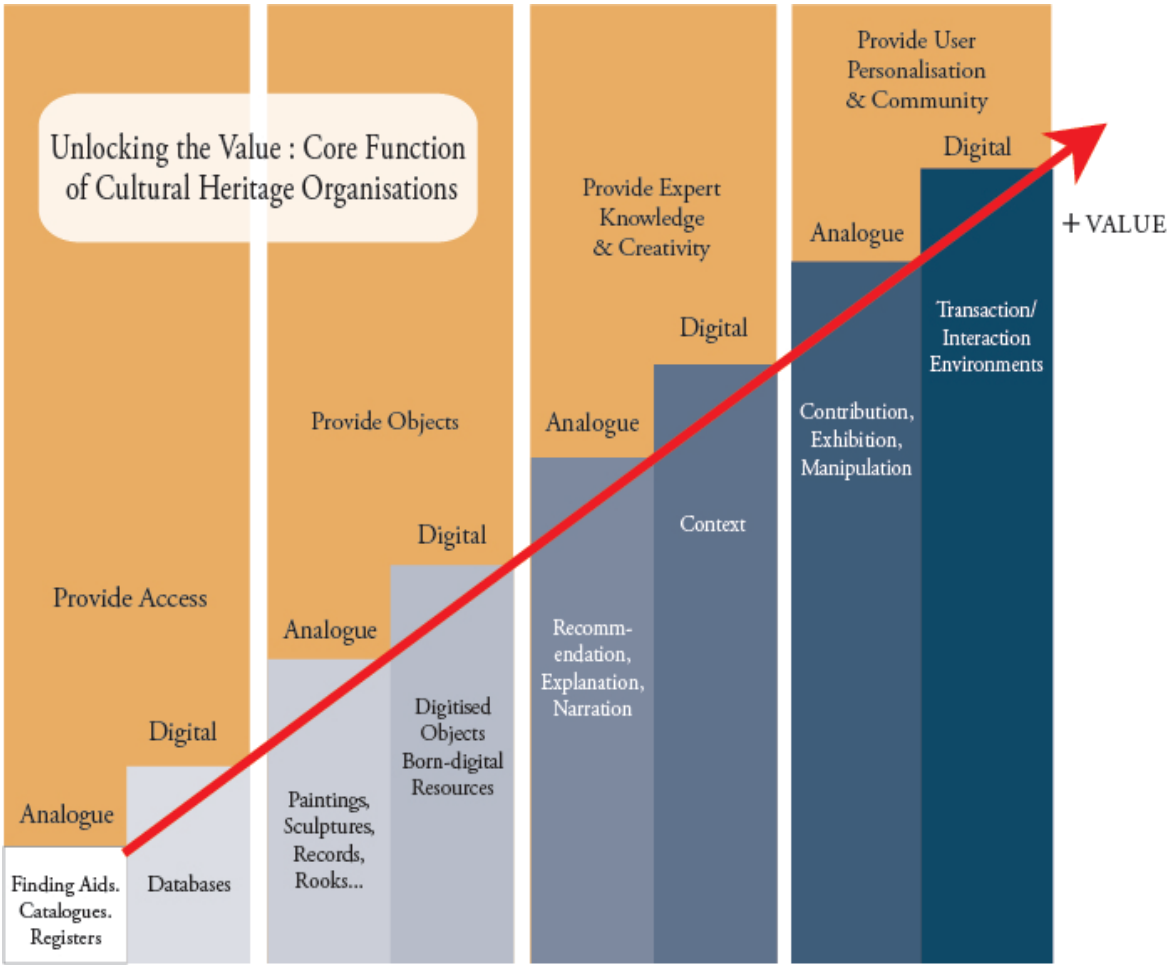

Figure 4 – 'Unlocking the value of cultural heritage', with illustrative four-layer model.

According to Welsh (2005), the function of the museum has long been discussed, and completely different views have arisen from these discussions. In the most basic form of description, museums are institutions that preserve 'precious things and ideas'. Although the role of museums in society is constantly changing, museums are still collecting and conserving valuable objects from different periods of history. When the 1995 Disability Discrimination Act (DDA) entered into legislation, providing not only physical but also intellectual access to content in museums became a legal requirement in the UK. Museums around the world are now developing new ways to enhance their educational facilities, improve access and appeal to wider audiences. The British Museum, for example, organises a wide range of events for deaf and blind visitors, holds signed gallery talks and handling sessions and presents braille labels and plaster cast reliefs of Parthenon sculptures that can be touched (British Museum, 2004).

As stated in the previous section, most blind people rely on touch to gather graphical and spatial information about objects (Heller, 2003: 161). Until the late 1990s, there were few written works available about accessibility in museums (Rayner, 1998). Today, there are plenty of resources for researchers to study and understand the development of accessibility in museums. For instance, Rayner's (1998) *Access in Mind* looked at some early learning-related activities made for or with disabled audiences in mind. *Access in Mind* was a report put together for the Intellectual Access Trust in Scotland and published in book format with the intention of guiding museums and museum researchers to broaden their understanding of inclusive heritage and cultural institutions. This report was the result of interviews and observations that took place largely in Scottish museums. The report examined the improvements in physical accessibility that took place in museums after the 1995 DDA and argued for the need to pay more attention to intellectual access and include visitors with learning disabilities. This criticism was taken into account when the tactual explorations project of the current study was organised to make it available to everyone who wished to take part.

Kusayama (2005) stated that individuals with sensory disabilities are offered less-advanced amenities than people with mobility disabilities in museums, although the multisensory approaches have become common ‘services’ in some of these institutions. Visually impaired museumgoers demand better and wider access to museum collections, and the government legislation now recognises this need officially (Candlin, 2004). It is even more necessary than ever for researchers to work towards better, inclusive and more meaningful access to the museum exhibits for such visitors.

In addition to general access debate within the museums, the ‘tactile museum’ is becoming more widely available as not only part of a conventional museum but also an establishment on its own. Although these museums are conceptually and practically very different from what this thesis proposes, for the sake of understanding the development of access and the universal design principle in museums, it is necessary to look at these important establishments. For example, founded in 1984 by the Lighthouse for the Blind of Greece, the Tactual Museum in Kallithea enables visitors to examine replicas of ancient Greek works such as Venus de Milo, one of the most important examples of Hellenistic art, the original of which is still held in the Louvre in Paris (Becatoros, 2004). Another tactile museum designed specifically for a blind or visually impaired audience is the Museo Tiflológico in Madrid, Spain. In its collection, there are reproductions of art-historical monuments, art created by artists with visual impairments and a historical navigation of the development of devices for blind people (Axel & Levent, 2003).

One other very important institution of tactile interaction is the Perkins Museum in Boston, Massachusetts, US. The Perkins Museum illustrates the history of educating blind or deafblind students of a variety of disciplines, including reading and writing, geography, math, science, music and sports. The museum displays the school's history through original correspondence, photographs and tactile images in addition to the oldest and largest tactile globe in the US (Perkins Museum, 2011).

Main museums usually offer 'touch tours', 'tactile images', 'tactile diagrams', 'braille prints' and 'handling sessions' as part of their programmes (Axel & Levent, 2003). Birmingham Museum of Art in Alabama, US; the Finnish National Gallery in Helsinki, Finland; the Jewish Museum in New York City, US; the Museum of Fine Arts in Boston and the National Gallery in London, UK are some of the museums that include touch tours, tactile replicas and audio descriptions to enable better access for their visitors.

2.3.1 A Brief History of Museums in Hong Kong

The first government-run museum, the City Museum and Art Gallery in the Hong Kong City Hall, was established in 1962. Hong Kong is considered to have started late in museum building compared with other international metropolitan cities such as New York, London, Paris and Tokyo in terms of number and scale of museums. A report presented by M+ Legislative Council Subcommittee on West Kowloon Cultural District stated that according to information provided by 'Museums of the World' in 2002, there are 107 museums in New York, 203 in London, 211 in Paris, 52 in Los Angeles and 121 in Tokyo. Based on up-to-date records, there are still fewer than 40 museums in Hong Kong.

Miss Christina Chu, the former chief curator of the Hong Kong Museum of Art during 2000–2006, provided a good observation of the rise of the Hong Kong Museum of Art in her article '*Scattered memories*'. Chu (2008) stated that the old City Hall inaugurated in 1869 by public contributions started as an important landmark situated in the central district; it was a complex that integrated a public museum, a library, a theatre and conference rooms. In 1933, a survey was conducted to evaluate the City Hall; the outcomes were described as 'primitive and poor' in the same article. In her article '*A museum of hybridity: The history of the display of art in the Public Museum of Hong Kong, and its implications for cultural identities*' (2011), Eva Man commented on 'the low-water mark in museum provision throughout the whole of the British Empire excepting only the smaller islands of the Pacific and some of the more backward African territories'.

Apart from Chu (2008) and Man (2011), a report prepared by a committee and presented to the government in 1938 described the museum as 'a repository for odds and ends from every corner of the globe . . . a collection of Australian parrots, mineralogical specimens from Wales, old clocks, etc.'. However, a report by the Architectural Department in Hong Kong (2010) stated the following:

> *. . . the second generation of City Hall became Hong Kong's most prominent and probably the earliest centre for cultural activities, and the hotbed of Hong Kong's art and cultural development. The Hong Kong Arts Festival, the Asian Arts Festival, the International Film Festival, and the International Arts Carnival, to name a few, all started in this new City Hall. In the twenty plus years to follow, the City Hall was the key player in nurturing and promoting local cultural and artistic talents, providing local audiences with opportunities to appreciate local and foreign art, and invigorating the Hong Kong art and culture scene.* (Figure 5)

The old City Hall was demolished in 1947 and rebuilt in 1962. Records show that the forerunner of the Hong Kong Museum of Art, the City Museum and Art

Gallery, was placed on the top three floors of the High Block of the new City Hall, with a gross total area of 15,000 square feet. Three years after its establishment, these facilities at the new City Hall were deemed inadequate as stated (Man, 2011). However, no other building served as a public cultural venue in Hong Kong between 1947 and 1962.

Figure 5: New Hong Kong City Hall, with the Low Block facing the Queen's Pier and the Memorial Garden and High Block to the right. The old Bank of China and HSBC buildings are in the background.

Man (2011) further revealed reports that the Museum and Art Gallery Select Committee asked for the construction of a new 90,000-square-foot museum. However, the proposal, together with several more proposals made between 1965 and

1972, was ultimately rejected as stated. In 1974, the Urban Council approved the division of the City Museum and Art Gallery into the Museum of History and Hong Kong Museum of Art, and decided to relocate the Museum of Art to the Cultural Centre site in Tsim Sha-Tsui, a major tourist area. A year later, it was decided that the City Museum and Art Gallery would be renamed the Hong Kong Museum of Art; the historical and archaeological collections were moved, and the former museum and gallery functioned until 1991, when the brand new Museum of Art was launched. The new museum was conceived of as a cosmopolitan space, one that would dedicate itself to Western and Eastern art as stated in Man's article. According to the front page of the museum documentation, 'It is the mission of the Hong Kong Museum of Art to preserve the cultural heritage of China and promote art with a local focus . . . To maintain an essential international character, the museum also presents a great variety of thematic exhibitions drawn from local and overseas sources' (Man, 2011).

Mr Tang Hoi Chiu, who served as chief curator at the Hong Kong Museum of Art between 2006 and 2012, mentioned the following:

> *. . . the collection strategy of the City Museum and Art Gallery established in 1962 was to make the museum focus on Hong Kong, tracing its roots in Guangdong Province and southern China, and reaching out to the Chinese diasporas at large. To make up for the discrepancy of Western art, exhibitions or exchange programs relating to Western and Asian culture and*

art are to provide citizens with opportunities to understand and appreciate arts of the world (Tang, 2008).

2.3.2 Museums and Visually Impaired People

Nelson Coon's (1953) publication *The Place of the Museum in the Education of the Blind* stated that the beginning of the museum movement for the blind could be credited to Johann Wilhelm Klein. In Vienna, from 1804 to 1809, Klein first used and prepared a collection of touchable teaching models for blind individuals. The museum that Klein founded developed into a collection of almost '5,000 specimens devoted to all phases of the education and history of the blind'. However, the museum was destroyed during World War II. According to Reidmiller (2003), the museum movement for the blind went beyond Vienna. A 40-page catalogue that could be traced back to the late 1890s and included all of the objects available for educational purposes for the blind was found, its creation attributed to a museum in Steglitz, Germany. Schools for the blind in Germany, Austria, France and England also recognised the importance of tactual experiences and prepared to meet the demand. By 1931 there were 39 museums in Great Britain with special collections for individuals who were blind (Reidmiller, 2003).

From 1949 to 1951, the London Science Museum provided exhibits in a separate gallery for 'hand-viewing' only (Coon, 1953). According to Coon (1953), in a large and airy room near the museum entrance, the exhibits were arranged on tables at a convenient height, a little below waist level. Just inside the door was a ‘touch-plan’ of the exhibition. A small steel block represented each table with the subject printed beneath it in braille. Notes in braille were also placed to the left of each exhibit.

According to Coon (1953), around the 1850s, the Director of Perkins Institute for the Blind, Dr Michael Anagnos, was the first to attempt to provide a museum collection for the blind in the US. The collection was housed at the institute and began with an assortment of anatomical models Anagnos brought with him from Germany. By 1881, the collection had grown to more than 1,261 items, mostly related to the field of natural history.

In 1909, the American Museum of Natural History instituted a series of lectures for blind people (Coon, 1953). A year later, through a generous gift, a permanent exhibit was arranged and more lectures were given. Other museums followed suit and began to supply services for the blind. Coon reported that from time to time in Boston ‘cooperative experiments enabled students from the Perkins Institute to be introduced to the fine arts’. During 1932–1933, both the Fogg Museum of Art and Boston Museum of Fine Arts cooperated in an experiment, ‘making history lives through handling art objects with historical and artistic merit’.

According to Rodriguez (1984), 'This act affects institutions and programs that receive federal funds, which would certainly include museums'.

The first permanent touch tours in a British museum were those designed by Ann Pearson for the Egyptian and Graeco-Roman sculpture galleries in the British Museum. These were introduced in 1990 and consisted of a number of braille/large-print signs attached to certain sculptures in each of the galleries that indicated visually impaired people could touch these particular pieces. Accompanying audio and large print guides were also made available upon request from the main desk (Hetherington, 2003). Hetherington (2003) commented that by 2003, most museums provided an accessible toilet, put in place a couple of wheelchair ramps and in rare instances displayed signs printed in a large font. However, it is still rare for anything more than this to be provided as a matter of course, except as the outcome of a lottery funding initiative in which an access audit is mandatory.

A new paradigm studied by Heath and vom Lehn (2004, 2006 and 2007) indicates that as people explore museums they examine exhibits in interaction with each other. According to their studies, museumgoers 'make sense of the pieces in and through talk and interaction' (vom Lehn, 2010; see also Piscitelli & Weier, 2002; Silverman, 2010). vom Lehn (2010) commented as follows:

> *. . . within visitor studies, a largely applied field of research, there is a large body of studies concerned with the impact of talk on people's experience and learning from works of art. Yet, few of these studies explore how particular aspects and characteristics of exhibits are rendered noticeable and worthwhile examining in interaction with others. These studies, like most research on social interaction, presuppose that the participants have average vision. They assume the participants involved in the situations at the exhibits can see and experience the works in the same way, have equal access to each other's visible actions, and thus, based on their visual faculties, are able to create shared experiences of the exhibits.*

Hetherington's (2003) '*Accountability and disposal: visual impairment and the museum*' paid explicit attention to material mediation in visitor practice. The article focused on how a visually impaired woman encountered two galleries in the British Museum and the various mediations that occurred, both through the sense of touch. The woman, Sara, described the tactile sensation of a selection of sculptures, which visually impaired visitors were allowed to touch, and as mediated by a number of material aids, such as a tactile book called 'Second Sight of the Parthenon Frieze', which had the job of making the Parthenon Frieze accessible to the visually impaired visitor. Hetherington (2003) mentioned a range of objects, braille signs, easy access ramps, stairs, toilets, audio guides and the tactile book and showed how museum practices of access and the mediating objects constituted the impaired person and her embodiment. Hetherington's (2003) work was oriented towards discourse, materiality and the body, and his approach to materiality was referenced by Callon, Law and Latour (1984).

2.4 VISUAL PERCEPTION

According to Michael (1983), Barraga (1986) and Wilson (1987), visual perception involves 'examining an object, distinguishing the essential features, understanding the relationships between the elements and integrating the information into a meaningful whole'. At the same time, these authors recognised visual perception from the perspective of sighted observers, who usually approach things based on their appearance. Sighted people have the ability to see the whole and often neglect the details until further examination. In the essay '*Berthold Lowenfeld on blindness and blind people'*, Lowenfeld (1981) stated that 'the visual learners as individuals who use their touch senses and kinesthetic experiences only rarely and rely almost completely on what they can perceive visually with whatever little eyesight they have left'.

According to Barraga (1973), when the visual sense is functioning with a high degree of efficiency, individuals are able to use their sense of sight to understand their environment. Cornelius and Casler (1991) stated that ‘visually minded individuals acquaint themselves with their environment primarily through their eyes and take on the role of spectator’. Nevertheless, in a much earlier essay entitled ‘Creative and Mental Growth’, Viktor Lowenfeld (1957) stated that ‘the very visually minded individual would be disturbed and inhibited if he were to be limited to haptic impressions’.

James J. Gibson and Richard Gregory also investigated issues related to visual perception and the blind. Gibson’s *The Senses Considered as Perceptual Systems* (1966) emphasised the importance of touch theory in the development of materials for blind people. Gibson (1972, 1988) called perception a ‘bottom-up process’, inferring that sensory information is analysed in one direction: from simple analysis of raw sensory data to ever-increasing complex analysis through the visual system. In his essay ‘*A theory of direct visual perception*’, Gibson stated that he attempted to give pilots training in depth perception during the Second World War, and that this work led him to the view that humans’ perception of surfaces was more important than their depth/space perception. Surfaces contain features sufficient to distinguish different objects from each other. In addition, perception involves identifying the function of the object, i.e., whether it can be thrown or grasped, whether it can be sat on and so on.

Gregory (1970) argued that perception is a constructive process that relies on past experiences and stored information. Prior knowledge and past experience, he argued, are crucial in perception: 'when he/she looks at something, a perceptual hypothesis will be developed, which is based on prior knowledge. The developed hypotheses are nearly always correct. However, on rare occasions, perceptual hypotheses can be disconfirmed by perceived data'.

However, Lederman (1982) stated that visual perception is tightly associated with textural perception theory. In her publication *Tactual Perception: A Sourcebook*, she defined textural perception as 'experiencing any number of surface qualities, for example roughness, smoothness, hardness, stickiness, slipperiness, oiliness, coarseness, and graininess'. Furthermore, Lederman looked to Katz (1925), who was a major figure in the study of the psychology of perception, to establish a connection between surface texture, or as he termed it 'modifications', and its perception through vibration and motion.

Katz (1925) argued strongly that vibrations were necessary to visual perception. He observed that when the finger was stationary on a surface, there was no vibration, which in turn meant there was no perception of the qualities of the surface. He believed that lateral motion was required to perceive roughness and smoothness, and that vertical motion was required to perceive hardness and softness. He also considered the contribution of another kind of information: the thermal properties of both skin and surface and their role in perceiving textures. His subjects used heat conductance to identify different materials, such as wood and metal (cited in Schiff & Foulke, 1982). He also examined the effects of hand speed and force on the perception of surface texture. Katz found that perceived roughness increased with increasing force (Lederman, 1982).

The findings of Aleman et al. (2001) showed that congenitally totally blind individuals did not perform better than sighted people on tasks aimed at measuring 'visuospatial' and pictorial imagery. However, their essay also stated the following:

> . . . *the blind participants were well able to perform the visual imagery tasks, which may imply that the representations involved in this type of information processing that go beyond the limitations imposed by the properties of single sensory channels and integrate information from different sensory modalities. Thus, visual imagery may be purely visual only to a small extent.*

Bertolo (2005) investigated visual imagery in blind subjects from a scientific approach and proved it was possible to have visual imagery perception without visual experience from the past. He presented the results based on the work of a group using visual activation in dreams. The results were related to spectral components, showing that the congenitally blind had visual content in their dreams and were able to draw them. Furthermore, their Visual Activation Index was negatively correlated with spectral component power, meaning it was possible for visually impaired and blind people to have visual perception, even when they had no previous visual experience.

Visually impaired and blind people have a different visual perception of the world than sighted people. There are also relevant differences between perceptions of the completely blind and those with a certain level of visual impairment. Any system designed for the visually impaired must be aware of these differences to provide a user interface that can adapt to the limitations and special needs of its users, particularly in terms of the ‘touch’ and ‘sound’ perception and interaction aspects, which are discussed in more detail later.

2.5 ACCESSIBILITY

The terms ‘accessible’ and ‘accessibility’ are descriptors for both tangible and non-tangible products such as devices, environments, services and systems. These products are generally designed for people with special needs, single or multiple disabilities or partial impairments. An important accessibility principle relates to giving users access regardless of their physical conditions (Ghiani et al., 2008). This section further elaborates that a cross-modal interaction system can be an effective approach to supporting various interaction modalities, including auditory, haptic, way-finding (positioning and tracking) and multiple touchscreens for real-time input or speech feedback. Thus, by applying a cross-modal interaction approach, it is possible to provide an assistive interface for users with different physical abilities or constraints. The College of North Atlantic (2011) stated that ‘another dimension of accessibility is the ability to access information and services by minimizing the barriers of distance and cost as well as the accessibility and usability of the interface’. Salgafo and Salmi (2005) stated that a well-considered interactive system with integrated modalities could help users with a wide variety of physical impairments. For example, visually impaired people often rely on the audio modality with simple input via keypad or touchscreen. Hearing-impaired people rely on the visual modality with some voice input.

Furthermore, the terms ‘accessible’ and ‘accessibility’ are most prominently used when discussing physical environments and buildings. Terms such as ‘access all areas’, ‘accessible products’ and ‘disabled access’ feature most strongly in such physical environments (Roulstone, 2010). Roulstone (2010) further explained that in this sense, most academic, policy and practice attention has been attached to environmental access. It is important to remember the point made earlier: physical access is pointless unless the educational, cultural, civic and employment domains are also accessible in the broadest sense. In 1988, Marta Russell published an article that stated the following:

> *… a key policy challenge across the developed world is the assumption that technically accessible environments which are 'standards compliant' can run themselves, especially in an era of budgetary restraints. For example many newly constructed metro/subway stations are unstaffed, which for disabled people using them for the first time may prove difficult. So in its fullest sense, access is a much broader social inclusion and socio-economic issue that goes 'beyond ramps' and takes account of the important 'activation' of well-designed social spaces with enabling human agency.*

In a recent essay, vom Lehn (2010) mentioned that over the previous decade there had been a large increase in museum funding used to refurbish and renew existing exhibitions and create new ones. This increase in funding was accompanied by growths in visitor numbers and recognition of museums' contributions to education and social inclusion (cf. Anderson, 1999; Hooper- Greenhill, 1991; Dodd & Sandell, 1998). The growth in funding for museums and the increasing importance of museums as educational institutions has encouraged studies to consider the ‘museum experience’ (Falk & Dierking, 2000). However, these studies have often been influenced by developments in the behavioural and cognitive sciences, where there is a long-standing interest in art perception (Goguen, 1999; Solso, 2004).

As people explore museums, they examine exhibits in interaction with each other. They make sense of the pieces through talk and interaction. Within visitor studies, a largely applied field of research, a large body of studies has focused on the effect of talk on people’s experience and what they learn from works of art (Piscitelli & Weier, 2002; Silverman, 2010). Yet, few of these studies have explored how particular aspects and characteristics of exhibits are rendered noticeable and worthwhile when examined in interaction with each other. Drawing on a corpus of video recordings gathered from a range of museums and galleries, Heath and vom Lehn (Heath & vom Lehn, 2004; vom Lehn, 2006a and 2007) explored, for example, how people configure the ways in which they look at, see and experience exhibits in and through social interaction. These studies, like most research on social interaction, presupposed that their participants had average vision. They assumed the participants involved in the situations at the exhibits could see and experience the works in the same way, had equal access to each other’s visible actions and thus, based on their visual faculties, were able to create shared experiences of the exhibits.

Perhaps surprisingly, research in the social sciences related to art perception and museum audiences has not addressed this lack of interest in the situation in which aesthetic experiences arise. For example, although they powerfully demonstrated the influences of social structure and education on people's understanding and concept of art, Bourdieu's (1990 and 1991) famous works implied an individual's cognitive ability to make sense of artworks. Furthermore, this preoccupation with the individual in studies of art perception is surprising because original artworks are predominantly encountered in museums where people go as a family and with friends (MORI, 2001; Wright, 1989). The encounter with works of art in museums often occurs in social situations (vom Lehn, Heath & Hindmarsh, 2001).

From the social interaction viewpoint, as vom Lehn (2010) emphasised, relatively little research has investigated how people with differential access to the visible world create a shared experience of the material and visible worlds and how they constitute objects in and through interaction. Quite recently, a few (visually impaired) sociologists (Michalko, 2001; Saerberg, 1990 and 2006) have addressed this lack of research. Their studies have primarily served as autobiographical accounts of living with blindness. They have discussed everyday activities and experiences with social situations from the perspective of a blind person (Michalko, 2001). They have provided accounts of social interaction as experienced by visually impaired participants. They have particularly focused on the ways in which visually impaired people navigate public spaces such as pavement and the problems they face when crossing streets, including navigation with a dog, a cane and a human companion (Michalko, 2001). Despite the important contribution of these studies to an understanding of visually impaired peoples' experience of social situations, relatively little remains known about the organisation of talk and interaction between sighted and visually impaired people.

Research on vision and communication has provided some insights into the difficulties that may arise in interactions involving visually impaired participants. Some studies have suggested that bodily and visual action provides participants with important information about each other's state of participation in a situation (Argyle, Lalljee & Cook, 1968). Unfortunately, few studies have drawn on these arguments, and when they have done so they have primarily been interested in trouble occurring in talk between visually impaired and sighted participants (Coates, 2003), rather than in the practical organisation of interactions through which sighted and visually impaired participants concertedly make sense of the material and visual worlds they inhabit.

In the literature, accessibility is principally conceived of as a social policy approach designed to widen access to society's resources and to encourage and enable all parts of the population to participate in society, science, education, art and culture (Hooper-Greenhill et al., 2000; Sandell, 1998; Social Exclusion Unit, 2003). These policies have supported initiatives to facilitate participation in the arts; for example, they have encouraged the widespread deployment of ramps and lifts to facilitate physical access for wheelchair users and of audio loops and subtitles for the deaf in cinemas and theatres (Arts Council of England, 2008).

Visitors who have disabilities can face additional challenges beyond those just described. They too are looking for that familiar link that can help them realise the relevance of what they are learning in a museum. Visitors with vision impairments are trying to synthesise partial impressions to create the whole (Wexler, 2009). This can make it difficult to understand things like distance and size. Using multiple senses can help a variety of visitors learn in a museum. Bodily sensations such as touch are the key to motivation because they enable the student to remember the sensory experience and help them to remember what they have learned about the artwork (Wexler, 2009).

Well-designed access can be built into the design of a museum at little additional cost to eliminate the stigma of special services and thus allow all visitors to feel welcome regardless of their disabilities. These accommodations can be integrated into the design so that they remain aesthetically pleasing and practical (Salmen, 1998). The phrase ‘design for all’ means that the devices used in the exhibition can be accessed by all users, independent of their sensory abilities or technological competencies (Ruiz, Pajares, Utray & Moreno, 2011). These kinds of adaptations should allow all visitors to move around the space together, meaning that all exhibits must be accessible to everyone. It is not enough to simply offer an alternative programme. Visitors with vision impairments should have a choice between regular and specialised programming. A museum is not allowed by law to exclude a person from a particular activity based on his or her disabilities (Salmen, 1998). There are, of course, extreme exceptions to this rule. When an adaptation may cause a direct threat of harm or change the very nature of the exhibit, an alternative experience may not be possible. However, the adaptation cannot be denied simply because it is limited by liability insurance. Compliance with the law is an on-going process that needs constant updating as both the available technology and the needs of the public change and evolve. If the museum is located in a historic building, there may be some additional exceptions. There must be a compromise between accessibility and maintaining the historical significance of the building.

According to Salmen (1998), there are nine building blocks to creating an accessible museum.

1. There must be a commitment to accessibility in the general mission statement of the institution.

2. A coordinator of accessibility should be designated. (This could be more than one person if it is a large museum.)
3. The institution should obtain information from people with disabilities.
4. Staff and volunteers should be trained on accessibility.
5. The museum should periodically conduct reviews of its facilities and programmes.
6. Short and long-term accessibility goals such as barrier removal, effective communication and new construction should be implemented.
7. Accessible programmes should be promoted, and people should be told which programmes are accessible and to whom they are accessible.
8. There should be some kind of grievance policy so that the museum is able to receive feedback and see what still needs to be done.
9. An on-going review of accessibility efforts should be conducted to make sure the museum is adequately and effectively meeting the needs of its visitors.

In addition, Coroama, Kapic and Rothenbacher (2004) conducted in-depth interviews with visually impaired and blind people and derived a list of requirements for an assistance pervasive computing system to improve their accessibility in familiar environments. The following list of findings is helpful for this study.

1. The system must increase the user's perception of his or her surroundings by telling the user which entities he or she is passing by. This seems to be the most important user requirement; it provides an extension of the user's world.
2. The system must not require the user to pinpoint a certain location to obtain the desired information. (This is especially difficult for completely blind people.)
3. The system should announce points of interest located farther away.
4. The system should help the user to navigate to these points of interest, whether outdoor or indoors.
5. The system should let the user filter objects according to classifications and present a list of entities situated in the surrounding environment, so that he or she may subsequently choose to be guided to either the nearest instance or another one on the list.
6. The system should enable communities to emerge by allowing the user to leave marks or remainders for the current user and/or other users (e.g., a message on a traffic light reading 'large crossroad ahead, must be passed quickly').

2.5.1 Accessibility of Visual Information

The findings of Aleman et al. (2001) showed that congenitally totally blind individuals did not perform better than sighted people on tasks aimed at measuring ‘visuospatial’ and pictorial imagery. However, the authors also stated the following:

> *. . . the blind participants were well able to perform the visual imagery tasks, which may imply that the representations involved in this type of information processing go beyond the limitations imposed by the properties of single sensory channels and integrate information from different sensory modalities. Thus, visual imagery may be purely visual only to a small extent.*

Bertolo (2005) investigated visual imagery in blind subjects from a scientific approach and proved it was possible to have visual imagery perceptions without visual experience from the past. He presented the results based on the work of a group using visual activation in dreams and found they had a spectral component. Congenitally blind participants had visual content in their dreams and were able to draw them; furthermore, their Visual Activation Index was negatively correlated with spectral component power. In short, it is possible for visually impaired and blind people to have visual perception, even when they have no previous visual experience.

Visually impaired and blind people have a different visual perception of the world than sighted people. There are also relevant differences between the perceptions of the completely blind and of individuals with a certain level of visual impairment. Any system designed for the visually impaired must be aware of these differences to provide a user interface that adapts to the limitations and special needs of its users, particularly in terms of the ‘touch’ and ‘sound’ perception and interaction aspects, which are discussed in more detail later.

2.5.2 Visualisation and Mental Visual Imagery

To a certain extent, individuals who are sighted or non-sighted have the ability to build imagery in their minds without the aid of external inputs. These mental images are important because the mental operations involved in reasoning with visualisations very often involve combinations of mental and external imagery.

Artidi et al. (1987) revealed that congenitally blind people have imagery that is indeed different from that of sighted people. Some aspects of visual imagery are visual and not present in blind people’s images; for example, angular size diminishes with viewing distance and perspective. However, a study outcome presented by Kenny (1982) stated the opposite, i.e., that blind people could use perspective in drawings. Kerr (1983) stated that some aspects of mental imagery construction could be evoked by multiple modalities and may be present even in the congenitally blind.

Mental images are transitory; they are maintained only by cognitive effort and rapidly fade without it (Kosslyn, 1990). The following are key properties of mental images.

1. Only relatively simple images can be held in mind, at least for most people. Kosslyn (1990) had subjects add more and more imaginary bricks to a mental image and found that people were able to imagine four to eight bricks at most. However, because the bricks were all identical, it is almost certain the limit he found was smaller for more complex objects, e.g., a red triangle, a green square or a blue circle.
2. People are able to form mental images of aggregations, such as a pile of bricks. This partially gets around the problem of the small number of items that can be imagined.
3. Operations can be performed on mental images. Individual parts can be translated, scaled or rotated and added, deleted or otherwise altered (Shepard & Cooper, 1982). People sometimes use visual imagery when asked to perform logical problems (Johnson-Laird, 1983). For example, a person given the statement ‘some swans are black’ may construct a mental image containing an aggregation of white dots (as a chunk) with a mental image of one or two black dots.

2.6 HAPTIC INTERACTION (TOUCH)

Touch

1: to bring a bodily part into contact with especially so as to perceive through the tactile sense: handle or feel gently usually with the intent to understand or appreciate

2: to strike or push lightly especially with the hand or foot or an implement

3: to lay hands upon with intent to heal

4 archaic a: to play on (a stringed instrument) b: to perform (a melody) by playing or singing

5 a: to take into the hands or mouth b: to put hands upon in any way or degree; especially: to commit violence upon

6: to deal with: become involved with

7: to induce to give or lend

8: to cause to be briefly in contact or conjunction with something

9 a (1): to meet without overlapping or penetrating: adjoin (2): to get to: reach b: to be tangent to c: to rival in quality or value

10: to speak or tell of especially in passing

11 a: to relate to: concern b: to have an influence on: affect

(Merriam-Webster's Collegiate Dictionary)

This thesis is focused on the haptic aspect, and this section focuses on the importance of touch. The main aims here are to look at touch as both a concept and an important human sense and to visit its changeable place in history.

Based on McLinden and McCall's (2002) *Learning Through Touch*, touch is a complicated and multifaceted sense. Skin has the ability to read texture, wetness, shape, elasticity, weight, density, pressure, vibrations and temperature. Related to touch, the body's 'proprioceptive' system can sense where things are without seeing them, making it possible to pass popcorn in a dark theatre or to pass a note behind one's back. Although the eyes cannot see these objects, the body knows exactly where they are. The authors further elaborated that touch provides important information-seeking abilities. The active use of touch to seek out information has been deemed 'haptic touch', relating to the bias for how things feel rather than the way they look. However, touch is not always an active search for information; it can also passively acquire information incidentally. Consider the warmth the whole body feels when sitting by a fire, or the vibrations that pulse through the body during a particularly violent bout of thunder. Furthermore, touch provides a role in daily interactions between people as they hug, kiss or shake hands.

McLinden and McCall (2002) quoted Geza Revesz, a scholar who drew comparisons between touch and visual perception, as saying that 'the eye takes in the "form" of an object as an immediate impression, through spatial examination, whereas the hand is predominately concerned with the 'structure' of an object, through serial or linear examination'. In contrast to vision, gathering information about an object through haptic touch is a slow, analytical and intimate process.

Revesz argued that active touch is superior to passive touch, which gives only a limited understanding of an object. Passive touch can bring an object to attention, but to fully understand it, one much actively touch it.

In addition, according to much earlier publications such as that by Lisenco (1971), 'haptic' is defined as those sensations received through touch. Lowenfeld and Brittain (1975) indicated that the term 'haptic' came from the Greek word 'haptos', meaning 'laying hold of'. In the article '*Observation on active touch*', Gibson (1966) called haptic interaction 'the sensibility of an individual to the world adjacent to his body by the use of his body'. Matlin (1983) stated that 'the perception of objects by touching them is called haptic perception'. Dr Natalie Barraga (1973), a professional in the vision field, stated that information could be conveyed to the human's brain through the sense of touch. Sense of touch is defined as a situation in which 'the skin must be in contact with the stimuli or movement must occur in the body'. In his publication *The World of Touch*, Katz (1925) noted that this contact allowed an individual to detect the properties of that object.

According to Berthold Lowenfeld (1981), 'haptic minded individuals observe everything tactually and kinesthetically, and will use their sight only when touch cannot be used'. Viktor Lowenfeld (1957) discovered that haptic users, even those with limited vision proficiency, would act as if blind, relying on their sense of touch to create; if a haptically minded person ‘acquaints himself with an object in complete darkness, he would remain satisfied with his tactile or kinesthetic experiences’. As defined by Klatszky and Lederman (1987), the haptic system perceives cutaneous stimuli such as pressure, vibration and temperature on the skin, and the kinaesthetic system processes movement, position and force applied to the human’s muscles and joints.

Loomis and Lederman (1986) identified haptic perception as a combination of tactile (through the skin) and kinaesthetic perception (the position and movement of joints and limbs). An important aspect of haptic perception is that it is mostly obtained by actively exploring objects with the fingers and hands. One study investigated how to improve the learning experience for visually impaired young children. One way of creating tangible human computer interfaces for visually impaired young children is to use alternative keyboards or tablets. The goal is to combine the use of real tangible materials with the advantages of information technology. The benefit of these devices compared to most haptic devices is that they are used in a simple and natural manner. The applications can be manipulated directly with fingers by touching and pressing the surface of the device. Handmade or industrially manufactured overlays can be set on top of these devices (e.g., Flexiboard [Flexi Forum, 2006)] and IntelliKeys [Inclusive Technology, 2006]).

Environment navigation and way-finding applications have also frequently used haptic technology. Information such as geometric shapes, floor plans and maps can be communicated to the visually impaired through tablets or touchscreen devices that are embedded with haptic feedback. Long and Hill (1997) described kinaesthesia as ‘a sensation and awareness of movements of muscles, tendons, and joints in the body that result from interaction with tactile and environmental stimulus’.

In a study by Roth, Kamel, Petrucci and Pun (2000), geometric shapes were taught to visually impaired students as raised figures using a printed swell paper overlay on a tablet. When shapes were explored, audio feedback was simultaneously provided. In another study by Landau (2003), students learned geometrical shapes better with the Talking Tactile Tablet by Touch Graphics than they did when using common mathematics materials intended for visually impaired students. A much earlier study by Holmes and Jansson (1997) also presented a street network in an audio-enhanced virtual map. It was found that a tactile map overlay needed less exploration time than a matrix overlay. A study by Raisama, Patomaki, Hasu and Pasto (2007) from University of Temoera in Finland included a tangible model of a tactile map created by Halmes and Jansson to offer better results for the visually impaired user.

Fritz and Barner (1997) pointed out the concerns and limitations of haptic interface technology: 'data visualization is a technique used to explore real or simulated data by representing it in a form more suitable for comprehension. This form is usually visual since vision provides a means to perceive large quantities of spatial information quickly'. However, visually impaired or blind people have to depend on other senses to perceive particular visual information. Although haptic interface technology makes digital information much more accessible and tangible, it also provides an additional medium to analyse and explore the data. They also suggested that the consideration of a system for the haptic display of common datasets that are accessible and recognisable for people with visual impairments could be an ultimate solution.

McDaniel et al. (2005) developed a system called Social Interaction Assistant that enabled visually impaired and blind individuals to access non-verbal communication cues used during a social interaction with a sighted interaction partner. They suggested that providing such non-verbal cues would enhance the social skills of those individuals. The system consisted of two components: a pair of normal sunglasses embedded with a discrete camera connected to a computer vision system and a vibrotactile belt. The computer vision system enabled identification of a person, with his or her name delivered as audio. The belt conveyed the location of the person in relation to the blind or visually impaired individual, i.e., the user of the system, in addition to the interpersonal distance between the interaction partners. The belt was fitted with seven vibration motors spread equidistantly as a semi-circle around the user's waist with the first and last tactors placed at the sides, the fourth tactor placed at the midline, two tactors placed between the left side and midline and two more tactors placed between the midline and right side. The belt conveyed five distances by altering the duration of the vibration, with longer durations inversely proportional to a person's distance. Upon conducting an experiment with the belt for location and distance recognition accuracies, the authors found it to be an effective mode of communication.

A recent article by Brock et al. (2012) showed it was possible to combine multi-touch and Kinect sensing to better capture users' hand motions on a surface. The authors applied the system to a map exploration program for visually impaired users. Beyond the exploration of tactile maps, the combined system offered an interesting and novel apparatus for learning about how visually impaired users read a variety of tactile maps with their sense of touch. The prototype included a raised-line map on top of a multi-touch table and a Kinect camera observing hands and fingers. The authors implemented and compared two algorithms for finger tracking, one using an RGB image and one using a depth image. The depth image algorithm presented errors when fingers were closed. However, no specific preparation was necessary.

The RGB image algorithm was very stable and compatible with different users' exploration strategies.

Tactile Displays/Drawings – The purpose of this study was to review effective strategies for exploring tactile graphics, with a view to creating simple guidelines that anyone could teach to help users make the most of tactile displays.

A review of the academic literature on the subject found various papers highlighting the need for a means to teach users how to approach tactile graphics. For example, Nolan and Morris (1971, cited in Berlà, 1973) found that blind children lacked experience with tactile displays and that their performance in locating symbols was very poor. It was suggested that this poor performance resulted from the children having no systematic strategies for exploring the display. Furthermore, other studies showed how teaching strategies to users improved their performance in particular tasks, such as locating points on a display (Berlà, 1973) and reconstructing a map after exploration (Berlà, 1981).

Indeed, many researchers in this field have reported on the importance of teaching blind and partially sighted children the skills to explore tactile graphics. Aldrich and Sheppard (2000) suggested that 'graphicacy'—the ability to understand and present information in graphical form—should be a key part of the school curriculum, as it is a skill increasingly needed in society. Knowledge underlying such skills may include conceptions of different points of view and an understanding of the conventions for how graphics are displayed. Such skills are particularly challenging for blind and partially sighted children, who like sighted children cannot be expected to understand graphical information without being taught how to do so (Aldrich, Sheppard & Hindle, 2002).

A good understanding of graphical or visual information may involve two types of knowledge: *conceptual knowledge* of what graphics represent, and *practical knowledge* of how to use them. Examples of the conceptual knowledge required can be found in a study by Berlà and Butterfield (1975), who asked teachers about what sort of training blind children needed to understand tactile maps. The responses included training on spatial relationships, conceptions of measurement, an understanding of geometry (concepts such as above/below, parallels and angles) and an understanding of how tactile maps relate to reality. Marek (1997) similarly highlighted the importance of children's understanding of the relationship between three-dimensional objects and their two-dimensional representations, in addition to the spatial relationships between graphic elements.

2.7 AUDIO INTERACTION (HEARING)

Hearing

1: the process, function, or power of perceiving sound;

2: to perceive or apprehend by the ear;

2: to gain knowledge of by hearing;

4 a) to listen to with attention . . .

(Merriam-Webster’s Collegiate Dictionary)

Hearing has been described as one of the ‘far’ senses. It informs the hearer of events that take place from a distance or close by. Rahn (1984) stated that humans can ‘hear in total darkness, around corners and behind their heads’. Audio/sound refers to what can be heard. Sekuler and Blake (1985) mentioned that a ‘sound starts when some mechanical disturbance produces vibrations. These vibrations are transmitted through some medium (usually air) in the form of tiny collisions among the molecules in that medium’. Rahn (1984) further observed that ‘the normal human ear has a hearing range of 16 to 20,000 Hz’. The upper portion of this range prevents people from hearing noise created by air molecules, whereas the lower limit prevents people from hearing all of the functions of their own bodies (Milne & Milne, 1962). However, most people hear best in the range of 2,000–4,000 Hz, as stated in Rahn’s ‘*Ears, hearing and balance*’ (1984).

Similar to touch, human’s perception of sound is affected by several factors, some global and some environmentally based. Hearing is unique in that it cannot be turned off, even during sleep. Pallasmaa (2005) compared this with the sense of sight: ‘the eye reaches, but the ear receives’. The listener has little control over the production of the sound by people or objects in his or her environment. Although it does not require active screening, a listener can pay selective attention to one sound over others, thereby enhancing comprehension. Hearing is the main avenue for processing oral language and also in many aspects of thinking.

Humans are generally less aware of what they are hearing than they are of the actions of other senses. It is not until sounds are removed and the atmosphere is eerily silent that the full effect of ambient sound is understood. According to Zumthor (2006), ‘Interiors are like large instruments, collecting sound, amplifying it, transmitting it elsewhere’. Sounds give a space a feeling of ease and ‘home’; Zumthor (2006) delighted in the idea that sounds connected him to other people, whether in a different room or outside a building.

A study conducted by Visell et al. (2009) showed that locomotion usually produced audible sounds. These sounds comprise a number of qualitatively different acoustical events, such as isolated impulsive signals (e.g., from the impact of a hard heel onto marble), sliding sounds (e.g., a rubber sole sliding on parquet), crushing sounds (e.g., walking on snow) and complex temporal patterns of overlapping impulsive signals (e.g., walking on gravel). Overall, the structure of such sounds is jointly determined by several properties of the source (e.g., the shape and material of the ground, the dynamic features of a walking motion, the anthropometric and non-anthropometric properties of a walker (e.g., weight, leg length, gender and emotion) and the properties of the foot surface in contact with the ground (e.g., the materials of the sole). Walking thus conveys information about the properties of the sound source, and even in the absence of explicit training listeners learn to recover properties of the walking event based on the features of the sound.

According to Li and Pastore (1991), typical research design in this field involves three stages. First, the acoustical specification of the properties of the sound source is quantified (e.g., sound frequency is strongly dependent on the size of an object). At times, this analysis aims to quantify the perceptual performance of an ideal listener who perceives a source property through one or more sound features. Second, perceptual data are modelled based on mechanical descriptors of the sound source (e.g., McAdams et al., 2004). Third, behavioural data are constructed as a function of the sound features. Studies of the human processing of the complexity of sounds provide sound designers with some important indications relating to the properties of sound that are necessary to have a perceptual effect on humans, particularly partially sighted and visually impaired people.

In auditory interfaces, sound and vocal audio are crucial feedback components that can be applied in different ways. From the computer game perspective, feedback can be designed in two ways: 1) based on audio hints only or 2) as visual feedback that makes gameplay significantly easier for both sighted and visually impaired users.

Meijer (1991) developed ‘The Voice’, which allows auditory feedback to replace vision. Columns of pixels represent images and sine waves of various frequencies that allow the listener to receive different sound outputs. Meijer (2006) stated that visualisation by sound has been widely studied and applied to software for visually impaired users for many decades. Historically, the aim has been to display visuals such as graphics, line graphs or even pictures using non-speech sound. Altering the various attributes of sound such as pitch, volume and waveform allows the sound to change according to its visual counterpart (Ghiani, Leporini & Paterno, 2009). Roth, Petrucci and Pun (2002) used audio and kinaesthetic rendering jointly and separately. They found that the audio-kinaesthetic encoding of graphs was the most usable approach to visualising shapes for visually impaired users. A year later, van den Doel (2003) investigated sound and colour using SoundView, sensing colour images by kinaesthetic. This study created an application that allowed a coloured surface to be explored with a pointing device. The idea was that the colour, hue, saturation and brightness characteristics could be mapped into sounds. This study came the closest to linking the synchronisation of sound, touch and colour. Its findings provided guidelines for the present study.

Winberg and Hellstrom (2001) developed an interface based solely on audio feedback. They also developed a sound model that made it possible for visually impaired users to play the popular game, ‘Tower of Hanoi’. They used either three or four disks, and each disk had a unique sound differing in pitch and timbre from the others. The length of the sound represented the height of a particular disk, and stereo panning was used to convey information about which peg a particular disk was on. The Tower of Hanoi application was evaluated with pairs of sighted and blind adults (Winberg & Bowers, 2004). The sighted person used a visual interface and the blind person used the auditory interface described previously. Each participant had to take turns moving the disks, and they did not have access to each other’s representations. As all of the participants managed to solve the game, it was clear that collaboration was possible, even when the participants were provided with either visual or auditory feedback.

Eriksson and Gardenfors’s (2006) study of the Swedish Library of Talking Books and Braille included audio games specifically created for visually impaired children. This type of audio game is typically played with a normal keyboard and is based on sound and visual feedback. Eriksson and Gardenfors (2006) mentioned that the auditory game was rather challenging for their four participants and concluded that non-visual computer games could not provide a good overview of the play area as compared with graspable cards. Their advice was to provide proper instructions that could help a visually impaired child to understand the mental model of the game.

Visella et al. (2009) focused on spatial navigation with sound (i.e., walking interfaces). They considered the display and perception of walking-generated sounds and tactile vibrations and their current and potential future uses in interactive systems. The study showed that the signals of non-visual information sources closely linked to human activities in diverse environments were capable of communicating information about the spaces that users traversed and the activities they encountered in familiar and intuitive ways. However, for these signals to be effectively used in human–computer interfaces, significant knowledge in many areas is required, including knowledge of the acoustic signatures of walking and the design, engineering and evaluation of the interfaces that use them.

Martinez et al. (2011) investigated visual perception substitution using auditory feedback for visually impaired or blind people. According to their system, digital images were captured by webcam and transformed into sound patterns. The authors concluded that there was a robust correspondence between image and sound features. Results provided by the system were high enough to address many of the practical situations that normally required the sense of sight. Much of this expertise has been obtained in recent years, although many questions remain unexplored. The study highlighted research directions in this multidisciplinary area of investigation and pointed to potential future trends.

2.8 HAPTIC-AUDIO INTERACTION DESIGN (HAID)

To understand the multisensory/cross-modal phenomenon, it is crucial to determine where and how information from different senses is combined, especially for users who have special needs and physical constraints. Jansson and Juhasz (2007) stated that users with severe visual impairment had to work without information obtained from the sense of vision, making it more difficult for them to perform tasks. It is therefore especially hard for a visually impaired person to get an overview of an interface and to find and explore objects and details. Touch and sound are very crucial for people who are visually impaired. In such situations, the haptic and audio modalities must shoulder the responsibility that would otherwise be taken on by the sense of sight. This requires efficient use of the bandwidth of this modality. McGookin and Brewster (2006) also mention this point. The integration of haptic and audio in effect serves as the ‘eyes’ of visually impaired people in relation to simulating visual perception and connection in addition to their sense of spatial imagination, particularly in unfamiliar environments.

In general, the use of haptic output for mobile users has already been considered in several studies. Berger (2002) suggested that cross-modal interaction should be an approach to investigating the human's visual perception. Considering the ventriloquist dummy, she mentioned that according to the human's visual system, sound seems to come from the dummy's moving mouth. According to the human's auditory system, the sound seems to be coming from the ventriloquist's mouth. Therefore, the perceptual system is faced with the challenge of incorporating these inconsistent signals into a coherent impression. This shows that the human's senses have mostly been studied independently of one another and therefore that cross-modal interaction is not well understood, particularly for the visually impaired or blind user. Oakley et al. (2006) investigated and studied an array of nine tactile actuators making up a wearable vibrotactile display. Brown, Brewster and Purchase (2006) dealt with tactons or structured vibrotactile messages carrying complex information. They studied the use of haptic feedback alone to encode three different parameters (rhythm, roughness and spatial location) exploiting several vibrotactile actuators. These studies highlighted the potential suitability of using mobile devices such as PDAs or cell phones. However, it must be noted that their user tests were limited to stationary environments.

Brewster, Chohan and Brown (2006) focused on evaluating tactile outputs supporting mobile interaction. Their study presented the benefits that could be gained from haptic feedback. The results showed that user performance significantly improved when a haptic stimulus was provided to alert users about unwanted operations (e.g., double clicks or slips during text insertion).

The previously cited works mainly focused on the advantages of exploiting the haptic system as a complement to the visual system and did not consider solutions for visually impaired people users. The literature also contains some proposals for supporting visually impaired people users' mobility. For example, in a study by Amemiya and Sugiyama (2008), a haptic direction indicator prototype was proposed to support visually impaired users in various emergency situations. User requirement studies have indicated that in specific situations (e.g., emergencies) the supporting device should be small so that it can be easily held in the hand. Shah et al. (2006) proposed a more general-purpose navigation system that would adopt tactile perception to inform the visually impaired user about obstacle distance. The authors claimed that using multiple sources of vibration to convey information about the environment was more effective than audible feedback. Variable and synchronised vibration pulses have been used to enhance the user's sense of orientation and distance. The navigation system is based on sonar sensors, an embedded micro-controller system and an array of vibrotactile actuators. To convey information to the user exploiting the sensitivity of the hand, the authors tried to combine all three tactile perception parameters: the location of the active vibrotactile actuator, the intensity of the feedback and the pulse duration. However, the proposed hardware seemed to be a stand-alone device with no possibility of adaptation to other applications (e.g., customising the output of a mobile guide).

The recent progress of handheld computers and cell phones has enabled the development of compact wearable aid systems for the blind, often in combination with RFID or similar technologies. Possible applications relate to indoor solutions to support visually impaired people in their mobility and orientation. The RadioVirgilio/Sesamonet guidance system designed by Medaglia et al. (2007) is based on a cane with an embedded RFID reader and a Bluetooth module. Sensed data is sent via Bluetooth to the handheld device (which is also connected to a remote server) that guides the user by means of speech-synthesised instructions. This solution is based on a general-purpose handheld device that requires blind users to follow predefined paths, thus limiting the user's freedom of movement. The RFID-based indoor navigation system for blind people proposed by Chumkamon et al. (2008) aims to help the user find the shortest path to a destination and to help them if they become lost. The proposed system embeds RFID tags into a footpath that can be detected by an RFID reader with a cane antenna. The dedicated device is portable and equipped with a headphone for navigation where only voice (i.e., MP3 recordings) is used to guide the users. The system, however, does not include any obstacle detector.

Willis and Helal (2005) developed an RFID-enabled navigation for the blind that allowed detected tags to provide the coordinates of their location along with other information. Orientation is supported by vibrotactile output. An interesting novelty of this system is that it does not depend on a centralised database. However, like RadioVirgilio/Sesamonet, it focuses on navigation through predefined paths marked by RFID tags. Medaglia et al. (2007) designed the GLIDEO, a solution that provided blind users with audio information about RFID-tagged objects in their surroundings (such as temperature and weight). The RFID reader is embedded in a glove to let the user freely explore the area.

Coroama's (2006) '*Experiences from the design of a ubiquitous computing system for the blind*' described an assistive system exploiting electronic markers that could provide useful information to the visually impaired. Tagged objects are detectable by a mobile device that provides descriptive information. Tomitsch et al. (2008) proposed exploiting audio-tactile location markers that used an approach of combining audible signals and tactile feedbacks to make real-world tags accessible to users. Passive near field communication (NFC) tags are used to mark an object. As NFC tags are activated at low ranges (below 10 cm), Bluetooth technology is used to locate them from greater distances. An audible signal is used to identify the position of the tag when a mobile device (i.e., cell phone) is detected in the neighbourhood through Bluetooth exploration. Although this solution exploits both auditory and tactile feedback, it seems to be somewhat expensive. Banatre et al. (2004) published a proposal for helping blind people in public transportation scenarios. Users rely on a mobile device (PDA or mobile phone) with WLAN or Bluetooth connectivity to activate a stop request or be informed about the next stop. Although the preceding reported solutions for visually impaired people provide information about the surrounding environment, Ghiani et al. (2009) stated that most of the related solutions failed to assist visually impaired people in freely moving towards the tagged objects while simultaneously avoiding potential obstacles.

2.9 CROSS-MODAL INTERACTION

According to Driver and Spence's (1998) '*Attention and the cross-modal construction of space*', the brain receives and combines information from different perceptual modalities to make sense of one's environment, such as when watching and hearing someone speak. The process of coordinating information received through multiple perceptual modalities is fundamental and known as cross-modal interaction. Cross-modality is particularly relevant to individuals with perceptual impairments who rely on sensory substitution to interpret information using alternative modalities.

Oviatt (1999) stated the following:

> *Cross-modal Interaction is a term used to describe the integration of multiple user input or system output modalities which have the potential of promoting richer and more efficient interactive experiences. Cross-modality could also overcome the constraints that hinder information flow between a system and its users when limited sensory channels are available to convey information.*

The visual modality is currently the predominant modality in HCI, but audio and haptics are increasingly being used to augment or in some cases substitute for graphical displays. Auditory display is the use of speech and non-speech sounds to convey information (Kramar, 1992). It is typically used to present information to visually impaired people, to draw attention to activity outside of the field of view or to provide additional information in situations where the eyes are occupied or there is limited screen space.

Busse et al. (2005) showed that attention to visual parts of objects could enhance processing in the auditory cortex if sound co-occurs with visual percept. In addition, Kurtum (2008) stated the following:

To date, auditory interfaces have been successfully employed in a variety of areas including monitoring applications for complex environments, such as operating rooms and aircraft flight decks, improving accessibility to visually represented information, and supporting data exploration through Sinification. Haptic displays, on the other hand, are interfaces that convey information through cutaneous or kinesthetic sensation. They allow visually represented objects to be augmented with rich physical properties, such as mass and textures, and can be used to simulate most physical sensations that can be mathematically represented, such as gravitational fields.

Based on the aforementioned studies, cross-modality is usually achieved using vibrating or robotic devices to convey haptic sensations, which allows a user to perform physical manipulations like pulling, pushing and feeling objects. Research has produced a variety of techniques for conveying information through haptic feedback. Tactons, for instance, are a form of structured tactile signal that can be used to convey abstract messages non-visually and are equivalent to visual icons and audio earcons (Brewster & Brown, 2004).

In the design of interactive systems, the phrase 'cross-modal interaction' has also been used to refer to situations where individuals interact with each other while accessing the same shared space through different sets of modalities (Winberg, 2006).

Current technological development is making it increasingly feasible to support cross-modal input and output in a range of devices and environments, yet there are no practical examples of such systems. For example, Apple's iPhone provides touch, visual and speech interaction, but there is no coherent way of collaborating using differing sets of modalities if collaborators cannot see the shared screen. Metatla et al. (2010) investigated the problem and highlighted the following:

> *Our work has so far highlighted the difficulty in designing for cross-modality collaboration and has raised interesting questions about issues such as coherence of representations and support for awareness across modalities. Moreover, our initial findings indicate that providing cross-modality mechanisms for all team members to collaborate, share, and edit diagrams has the potential to increase productivity and to significantly improve the working lives and inclusion of perceptually impaired workers.*

However, despite the progress in cross-modality research, accessibility research has shown that simply developing an accessible display does not guarantee that collaboration will necessarily be supported, and moreover that the social interaction between participants is as crucial as the ability to access and manipulate the shared content (Winberg & Bower, 2004). Furthermore, a key drawback of current collaborative systems is that they do not explicitly support cross-modal interaction where participants have access to differing modalities. This reduces the transformational potential of these systems by systematically excluding collaborators with differing perceptual needs.

2.9.1 Ubiquitous Computing

Weiser (1991) coined and introduced the term 'ubiquitous computing'. His ideas were first exposed to a large worldwide audience by way of his famous article '*The computer of the 21st century*', published in *Scientific American* in 1991, in which he said that the 'highest ideal' of ubiquitous computing was 'to make a computer so imbedded, so fitting, so natural, that we use it without even thinking about it'. In ubiquitous computing, computers become a helpful yet 'invisible' force, assisting users in meeting their needs without getting in the way. In recent years, it has been broadly adapted, particularly in designing for people with special needs and physical constraints.

One of the most frequently cited quotations from Weiser's article is the following: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." In addition, a deeper understanding of Weiser's visions can be drawn from his position towards three dominant and perhaps overhyped trends in computer science in his time: virtual reality, artificial intelligence and user agents. With a good sense for how to raise public attention, Weiser criticised these three trends as leading in the wrong direction and positioned ubiquitous computing as a kind of ‘opposite trend’. It remains a debated topic to this day.

RCET (2006) stated that the word ‘ubiquitous’ could be defined as ‘existing or being everywhere at the same time’, ‘constantly encountered’ and ‘widespread’. When applied to technology, the term ‘ubiquitous’ implies that technology is everywhere and that users use it all the time. Ubiquitous computing is often considered an advancement from the ‘desktop paradigm’. York and Pendharkar (2004) defined it more formally as ‘machines that fit the human environment instead of forcing humans to enter theirs’.

Other terms also invented to described Weiser’s idea include ‘ambient intelligence’ (Uwe, 2003) and ‘everyware’ (Adam, 2006), terms emphasising slightly different aspects. A taxonomy of properties for ubiquitous computing has been proposed. Mühlhäuser and Gurevych (2009) categorised and emphasised the role of ubiquitous computing according to different device-related aspects.

2.9.2 Embodied Interaction

Looking back at how humans have interacted with computers over the decades, numerous changes are evident. According to Hemmert (2011), ‘In the 1980s, we interacted with computers in textual ways. In the 1990s, we changed to graphical interaction – and in the most recent decade, again, these ways are changing'.

The idea of 'embodied interaction' reflects a number of recent trends that have emerged in the area of HCI. Ishii and Ullmer's (1997) '*Tangible bits: Towards seamless interfaces between people, bits and atoms*' demonstrated their vision of HCI, including how the interface could be moved 'off the screen' and into the real world. In short, they envisioned that the connection and interaction between users and everyday physical objects, environments that contain digital systems and perceptions of the digital world could be controlled through users' senses and bodily movement.

Dourish's (2001) book *Where the Action Is* proposed a theory of 'embodied interaction' to conceptualise the changes in how users interact with computers or digital devices. According to Hemmer (2011), Dourish pointed out that 'computing is moving into the social and the physical space, and he proposed the term "Embodied Interaction". Advantageously, these new styles of computing draw upon skills that users already have, skills that we, as human beings, *embody*'. As stated previously, the idea of 'embodiment' is at the centre of phenomenology, an important strain of philosophical thought that began at the end of the 19th century. Phenomenology rejects the Cartesian separation between mind and body upon which most traditional philosophical approaches are based. As the phenomenological tradition has taken embodiment as a central idea, it seems like a good place to turn for help in developing an understanding of the role embodiment can play in interactive systems.

Focusing on Dourish's ideas of 'embodied interaction', Hemmert (2011) discussed and illustrated the role of embodied interaction 'in the different physical and social spaces that we live in'. In the same essay, Hemmert (2011) stated the following:

> *. . . the new omnipresence of computation brings along a whole new world of interactivity. The ways in which we manipulate and experience the digital have undergone radical changes in the last decades, and it will be exciting to see how these ways will change in the future. In the end, it's probably not humans that should get more technical. It's technology that should get more human.*

2.10 PHENOMENOLOGY AND MUSEUMS

Phenomenology is the 'science of phenomena' (Heidegger, 1962). It is also a philosophical movement that appeared in the first half of the 20th century (Spiegelberg, 1975). It focuses on the experiences of individuals. Indeed, it aims at studying 'phenomena as consciously experienced' (Spiegelberg, 1975). This philosophical underpinning was initiated by Husserl (1936) and his student Heidegger

(1962). They encouraged researchers and philosophers to turn ‘to the things themselves’ and people to turn ‘to the world as it is already experienced’ (Ilharco, 2002). Other philosophers like Merleau-Ponty and Sartre also nurtured phenomenology through the concepts of self and embodiment (Smith, 2003). Although these other philosophers are important in the development of the philosophy of phenomenology, this study followed Heidegger’s view as it was developed in his book *Being and Time* (1962).

Phenomenology aims at studying individual experiences. Heidegger (1962) contended that human beings needed action and praxis with objects (i.e., to engage with them) to feel closer to these things (Smith, 2003). Therefore, individuals do not need to see an object or imagine it to understand it because it is only a ‘representational form of intentionality’ (Smith, 2003). This argument leads to the conclusion that being able to touch things or to manipulate them contributes to a better experience and to better interpretation.

As indicated in the title of his book, Heidegger (1962) addresses the question of time and its relation to being. Heidegger asserted that time has an ontological function, as it constitutes being, and indeed that ‘we are temporal beings not because we exist in time but because time is really what composes our beings’ (Dastur, 1993).

Temporal beings are open because individuals are always turned towards the future and the past, and their self-meaning is not fixed (Lyotard, 1992).

In addition, it seems that history plays a role in people's existence, as it can shape their present and future (Monod & Klein, 2005). In effect, historical objects represent remains of the past, and consequently they give to people their historical dimension. It is thanks to these remains that individuals know something before them existed (Heidegger, 1962). However, these historical objects have a secondary historicity; they are historical because they belonged to a past humanity and were created by historical beings (Lyotard, 1992).

In addition, the definition given by Merleau-Ponty in the introduction to his *Phenomenology of Perception* (1945) gives a more specific idea of phenomenology:

> *Phenomenology is the study of essences; and according to it, all problems amount to finding definition of essences: the essence of perception, or the essence of consciousness, for example. But phenomenology is also a philosophy which puts essences back into existence, and does not expect to arrive at an understanding of man and the world from any starting point other than of their 'facticity'. It is a transcendental philosophy which places in abeyance the assertions arising out of the natural attitude, the better to understand them; but it is also a philosophy for which the world is always*

'already there' before reflection begins—as an inalienable presence; and all its efforts are concentrated upon re-achieving a direct and primitive contact with the world, and endowing that contact with a philosophical status. It is the search for a philosophy which shall be a 'rigorous science', but it also offers an account of space, time and the world as we 'live' them. It tries to give a direct description of our experience as it is. (Merleau-Ponty, 2002)

Heidegger's phenomenology puts a special emphasis on time, human existence and experience. Therefore, it seems to be perfectly appropriate to the study of art and cultural institutions, particularly museum environments, whose goals are to display visual arts and past heritage and focus on visitor experiences.

2.10.1 Phenomenological Framework

Basically, phenomenology involves the study of the structure of various types of experience ranging from perception, thought, memory, imagination, emotion, desire and volition to bodily awareness, embodied action and social activity, including linguistic activity. Monod and Klein (2005) elaborated a framework to evaluate technologies in the museum context. The framework aims to determine whether technologies, by meeting user requirements, have interpretive characteristics, and whether technologies contribute to a good experience of the past. In their original framework, the authors included eight criteria: context, re-enactment, embodiment, self-projection, possibilities of being, historical self, inquiring being and universality in uniqueness. However, this study considered four of the criteria: context, embodiment, self-projection and possibilities of being. These criteria are defined in greater detail hereafter.

Context—the first criterion proposed by Monod and Klein (2005) to provide IT users with a phenomenological experience is context. According to the authors, context is represented by the shared values, overarching values and beliefs that contribute to meaning-making experiences. Indeed, without cultural and historical context it is difficult for individuals to have a comprehensive understanding of their personal history and of history in general. It is frequently true that at cultural heritage sites, visitors do not understand the purpose of an object or even realise its historical importance. Indeed, Schärer (1996) contended that information provided within museums is generally more structural (some general indications) than cultural (information about the earlier context of use).

Embodiment—the third dimension deemed important to the IT user experience is embodiment. Embodiment was principally developed as a notion by Merleau-Ponty (1962). The Cambridge Dictionary of Philosophy (1999) defined embodiment as ‘the bodily aspects of human subjectivity. Embodiment is not a concept that pertains to the body grasped as a physiological entity. Rather it pertains to the phenomenal body and to the role it plays in our object-directed experiences'.

Self-projection—Monod and Klein (2005) proposed self-projection as a fourth criterion. Self-projection works by allowing one to put himself or herself mentally in the shoes of historical characters and imagine what he or she could and would have done in another's situation. This type of self-projection has both cognitive and emotional aspects. The cognitive aspects are linked to the deliberations that lead to decisions and actions actually taken, and the affective aspects are related to emotions such as love, anger, surprise and joy.

Possibilities of Being—possibilities of being are the fifth phenomenological criterion. According to Monod and Klein (2005), a phenomenological experience helps people to realise the constraints that have been created by the past and the effects on their present life. This leads to the realisation that a different past could have resulted in a different present. Reflecting on alternative pasts, individuals come to realise how the present could have been different, too. Monod and Klein (2005) argued that cultural heritage sites, and more precisely historical characters, represented an important vehicle for inspiring this process.

As stated earlier, Ishii and Ullmer (1997) also emphasised and examined the concept of embodiment. According to Mingers (2001), embodiment is apparent given that 'our basic attitude is always (exception in pure contemplation) one of doing, acting, having some aim in mind, having some concern'. His explanation shed more light on the Cambridge Dictionary of Philosophy definition. Embodiment designates the sensory experiences an individual may have with objects encountered in the world.

According an essay by Jessie and Noire (2009), in 2007, Pujol Tost and Economou surveyed visitors of the Ename Museum in Belgium about their favourite rooms and devices at the end of their museum visits. The visitors identified those that were able to convey context, empathy, interactivity and sensations. More precisely, Pujol Tost and Economou (2007) found that context was one of the visitors' most important expectations. Moreover, empathy contributed to visitor engagement and satisfaction. The dimensions of interactivity and sensations (described by the visitors as the possibility to touch) also led to better learning.

Hence, the phenomenological criteria developed and identified by Monod and Klein (2005) appear to be of great importance to visitor experience. As Monod and Klein (2005) did not verify their framework in the field, the current study extended their work empirically through a field study of museum visitors. This framework served as an important component of the study's theoretical background.

2.10.2 Museum Experience

People visit museums for a variety of different reasons. Some visitors are art historians doing high-level research on original works, and others visit to spend a pleasant afternoon with their families. Some visitors come with significant amounts of prior knowledge, and some come with very little knowledge of art or the artists. Many different studies have considered the motivations and reasons for visiting an art museum. Interestingly, there always seem to be a few common themes when it comes to the reasons why people visit art museums. Although people may come to see a rare original piece or to achieve some kind of self-fulfilment, most people come to socialise or broaden their knowledge base. Some like to have an introspective time, and others enjoy a lively intellectual conversation with their companions. The biggest reason why visitors go to a museum, regardless of whether they remember to state it, is because they are hoping to learn something (Falk, 2009). All visitors come with at least some level of prior knowledge upon which they hope to build. They are learning new things that are constructed from things they already know. This means they will choose a variety of different things to look at in an exhibition, and these things may not always align with what those who have designed the exhibit are expecting them to look at. In this way, the museum becomes a choice-based learning environment (Falk, 2009).

Sometimes people attend museums by themselves, but more often friends and or family accompany them. People enjoy sharing the experience of looking at the artwork and discussing what they see. In this way, they can influence each other's museum experience. According to Henry (2010), 'Learning is both individual and a group endeavor and, as a result, is mediated socially and culturally'. Prior knowledge and familiarity can lead to a feeling of comfort for the visitor. Some novelty is interesting, but too much can become overwhelming (Falk, 2009; Henry, 2010).

As Svabo (2010) stated in her publication *Portable Objects at the Museum,* a central work about museum experiences is the book *The Museum Experience* by Falk and Dierking (1992), which provides a well-rounded understanding of what visitors do at museums and what characterises the leisure activity of going to a museum. Furthermore, it covers the museum visit from the initial phases of getting the idea of going to the museum to how visitors look back on and remember museum visits. It thus deals with the *before, during* and *after* of the museum experience.

A museum visit is a leisure activity, a social outing in line with other excursions such as a visit to the park. Visitors go to museums to have a good time, to enjoy themselves and to spend time with friends and family. Visitors do not list 'education' or 'learning' as primary reasons for going to museums. Falk and Dierking (1991) stated that the visitor's perspective of the museum is, appropriately, that of a consumer of leisure-time activities. It therefore includes images of the gift shop, restaurants and the friendliness of staff.

Falk and Dierking (1991) further explained that visitors have expectations before going to museums. Adults primarily have social expectations of the visit. They expect to have a nice time with their fellow visitors, and if these include children, adult visitors are typically quite preoccupied with them. Children's expectations differ from the expectations of adults; they are not as socially oriented. Children's interests and concerns evolve around their favourite exhibits (if they have been to the museum before) and around the gift shop and food. Children's expectations do not depend on whether they are visiting the museum as part of a school trip or visiting with family. The expectations of children visiting with family and as part of a school trip are more similar than the expectations of children and adults visiting with family.

Museum visits may be memories for life. They are out-of-the-ordinary experiences that stand out as something special in everyday life. Falk and Dierking (1991) noted that museum visits have long-term effects on learning. The authors advocated for a broad definition of learning to encompass the richness of museum experiences, and also stressed that museum learning must be measured over lengthy periods, as opposed to taking cognitive measurements of whether a museum visitor has built more specific knowledge about a given topic. The authors argued that museum learning is a complex, interactive experience that may have profound and durable effects. It is important to understand learning in various ways, and thus to consider concept, social, aesthetic and spatial learning.

2.11 UNITED NATIONS CONVENTION ON THE RIGHTS OF PERSONS WITH DISABILITIES (PWDS)

In December 2006, the General Assembly of the United Nations adopted the Convention on the Rights of Persons with Disabilities (UNCRPD) and an Optional Protocol to the Convention. The Convention was the first universal human rights treaty of the 21st century (in a race to the finish line with the Convention on Enforced Disappearance, adopted a week later).

On 1 August 2008, the Government of the People's Republic of China (PRC) made the following declarations to the Secretary-General about the UNCRPD of the HKSAR:

> *In accordance with the Basic Law of the Hong Kong Special Administrative Region of the People's Republic of China, the Government of*

the People's Republic of China decides that the Convention shall apply to the Hong Kong Special Administrative Region. The application of the provisions regarding liberty of movement and nationality of the Convention on the Rights of Persons with Disabilities to the Hong Kong Special Administrative Region of the People's Republic of China shall not change the validity of relevant laws on immigration control and nationality application of the Hong Kong Special Administrative Region of the People's Republic of China.

The UNCRPD entered into force for the PRC, including the HKSAR, on 31 August 2008. The HKSAR periodically reviews the need for the continued applicability of the relevant reservations and declarations.

This study also reviewed the convention articles, particularly Article 30 – 'Participation in cultural life, recreation, leisure and sport' and the aspect of persons with disabilities and their 'participation in cultural life', selected as stated:

1. States Parties recognize the right of persons with disabilities to take part on an equal basis with others in cultural life, and shall take all appropriate measures to ensure that persons with disabilities:

a) Enjoy access to cultural materials in accessible formats;

b) Enjoy access to television programmes, films, theatre and other cultural activities, in accessible formats;

c) Enjoy access to places for cultural performances or services, such as theatres, museums, cinemas, libraries and tourism services, and, as far as possible, enjoy access to monuments and sites of national cultural importance.

2. States Parties shall take all appropriate steps, in accordance with international law, to ensure that laws protecting intellectual property rights do not constitute an unreasonable or discriminatory barrier to access by persons with disabilities to cultural materials.

3. Persons with disabilities shall be entitled, on an equal basis with others, to recognition and support of their specific cultural and linguistic identity, including sign languages and deaf culture.

The Hong Kong Human Rights Commission is a coalition of eleven non-governmental organizations including religious, women, community organizations and students groups. It was founded in March 1988.

Although coming from different backgrounds, we share in the belief of the dignity and respect of each person and that every man and woman has inherent rights. As the "Human race is one", the Commission member organizations consider that mutual respect, equality and freedom form the foundation on which a just, peaceful, and humane society is built.

Over the years, the Commission has endeavored to promote and protect the human rights of the community. Not only does Hong Kong lack a democratic political system, its legislation also allows the government substantial power so as to maintain social control. Civilians are forced to submit to this power and therefore justice often fails to prevail. The Commission has been gathering resources in order to consolidate civil power. By doing so we hope to arouse public concern to the level where the people will push the government to reform.

Since it was founded, in addition to lobbying for the Bill of Rights and subsequent amendments to the law at local level, the Commission has also submitted reports to UN treaty bodies, attended hearings and lobbying at international level. Recognizing that public awareness and participation are vital to the development of human rights, the Commission has promoted human rights education through exhibitions, gatherings in schools and community centers. Although the Commission recognizes that its work has benefited many, there is the lingering feeling that much more can be done.

2.12 THE EQUAL OPPORTUNITIES COMMISSION (EOC) AND DISABILITIES DISCRIMINATION ORDINANCE (DDO)

The Equal Opportunities Commission (EOC) is an independent statutory body set up in 1996 and funded by the HKSAR government. The main functions of the EOC are to eliminate discrimination and promote equal opportunities. It is responsible for administering the Disability Discrimination Ordinance (DDO), a piece of legislation that prohibits disability discrimination, harassment and vilification, in addition to the other three anti-discrimination ordinances, including the Sex Discrimination Ordinance (SDO), Family Status Discrimination Ordinance (FSDO) and Race Discrimination Ordinance (RDO). The DDO came into effect in 1996 before the ratification of the Convention. Since the implementation of the DDO, Hong Kong has made considerable progress in arousing public awareness and enhancing the protection of the rights of persons with disabilities (United Nations, 2012).

The EOC does not have any specific authority in the HKSAR government decision-making process on disability issues, although it is empowered to keep under review the workings of the DDO and to submit to the HKSAR government proposals for amending the legislation when it considers necessary to do so. On a day-to-day basis, the EOC mainly influences disability-related decision making by submitting alternative reports to relevant United Nations committees, presenting submissions to the Legislative Council of Hong Kong, responding to relevant public consultations and conducting formal investigations and research to effect policy change.

The EOC works towards eliminating discrimination on the grounds of sex, marital status, pregnancy, disability, family status and race. The EOC also aims to eliminate sexual harassment and harassment and vilification on the grounds of disability and race. Furthermore, it seeks to promote equality of opportunities between men and women, persons with and without a disability and persons of different races, irrespective of family status. The work of the EOC includes investigation and conciliation, education and promotion, review of legislation and the issuance of codes of practice and guidelines.

The DDO came into full operation in December 1996. Under the SDO, it is unlawful to vilify a person with a disability in public, or to discriminate against or harass a person on the grounds of disability in the specified areas of activities.

The FSDO came into force in November 1997. Under the FSDO, it is unlawful to discriminate against a person on the grounds of family status. Family status infers a responsibility for the care of an immediate family member. An immediate family member is someone who is related to the person by blood, marriage, adoption or affinity.

The RDO came into full operation in July 2009. Race means the race, colour, and descent, national or ethnic origin of the person. It is unlawful under the RDO to vilify a person on the grounds of race in public, or to discriminate against or harass a person on the grounds of race in specified areas of activity. The areas of activity covered by the four aforementioned ordinances are broadly the same and include employment; education; provision of goods, facilities or services; disposal or management of premises; eligibility to vote and stand for election of public bodies; and participation in clubs.

2.12 SUMMARY

This chapter considers the relevant literature to not only address the influences and inspirations for the study, but also show how the study attempted to test and understand the value of touch and audio from various viewpoints. Although the review was written in the format of reported information, a subtle and indirect narrative of thought evolved along with the discussion throughout the study. The 'touch' and 'audio' modalities were associated with visual information in daily life, the history of existence and how to represent visual information to everyone using those senses and modalities, whether individually or jointly.

This chapter begins with broad definitions of visual impairment, blindness, sense of ‘touch’ and ‘audio’ and then explores the meaning of accessibility of visual information. Throughout the literature review, others’ ideas were welcomed and the value of their work acknowledged. Although this thesis seeks to convey to the reader an open-minded approach to the development of the understanding of touch and audio, its views are strict. In this study, technology was seen as a medium. That said, the relevant technologies were still discussed and put into perspective within the realm of the study. With this objective, the study was positioned as a step towards understanding the value of touch and of touch in museums through accessing untouchable exhibits using accessible visual information.

This chapter builds on the introduction by putting the research topic and objectives into context. The next chapter, ‘Methods & Methodology’, clarifies the research approach by drawing examples from field observations, user needs analysis and two case studies with different materials and proposed prototypes. These projects are explained in the succeeding chapters after the methodology is defined. In a way, the forthcoming methodologies chapter should form a bridge between the projects undertaken by this study and the literature.

CHAPTER 3 METHODOLOGY & METHODS

Overview

This chapter explains the systematic approaches and methodology behind the behaviour and actions attached to the research activities. Although it does not aim to introduce the study in full, specific references to the study are made to elaborate the relevant points in the methodology when necessary. The study is defined and explored in greater detail in succeeding chapters.

3.1 RESEARCH OVERVIEW

The three areas that researchers often emphasise when considering the appropriateness of research design, as suggested by Campbell and Stanley (1963), and Cook and Campbell (1979), and Hakim (1987) are:

1) the aims, purposes or intensions of the study;

2) the time, money and staffing availability; and

3) the availability and accessibility of information and sources.

For this study, the goal was to:

1) understand broad information about the nature of the study topic; and

2) identify and categorise knowledge related to the research questions.

This study required a deep familiarisation with the topic and an in-depth understanding of the target populations. The resulting data and information collected were useful for evaluating the research questions and ultimately determined the research process.

Hartley and Muhit's (2003) '*Using qualitative research methods for disability research in majority world countries*' stated the following:

> *Qualitative research embraces the view that as far as peoples' perceptions are concerned, there is no one single truth. In other words,*

> *different people in different places at different times, interpret things differently. This philosophical viewpoint serves to challenge the validity of socially oriented data that is collected using quantitative methods. It demands an alternative set of methods for exploring peoples' perceptions, one that is contextually and culturally related. It therefore, seeks to find the answer to questions about the meaning and individual interpretation of life. It is used to answer open questions relating to peoples' attitudes and beliefs, in a given contextual setting.*

According to Wirz (1996) and Stone (1999), the published research related to disability in the majority of the world is somehow limited. Disability research has historically and frequently adopted the quantitative methodology (Mitchell, 1999; Holeman, 1993). However, Baxter and Jack (2008) published a study that adopted a qualitative methodology. They provided an overview of the qualitative methodology and types of case studies and developed propositions. Based on a review of many quantitative and qualitative studies, including the aforementioned studies, the qualitative research methodology was deemed the more appropriate methodology for the current study.

Why should the qualitative research methodology be used in disability research? A good understanding of disability research is crucial to conducting an effective and efficient study. The targeted populations of this study were visually impaired people, who were considered a vulnerable group. There were many sensitive issues and considerations to be made, and therefore extra caution was required during the interview and pilot study sessions. Some important considerations are stated in the chapter entitled 'Interviews and Pilot Study'. Hartley and Muhit (2003) stated, 'Qualitative methods are effective tools when the target group is vulnerable, as inevitably so, when focusing on people with disabilities'. They also mentioned that most of the disability research published over the preceding decade had been quantitative, focusing on either the prevalence of impairments, biomedical issues or the efficacy of interventions in numerical terms. This is problematic for conducting disability research on a number of counts. The authors also commented that the introduction of the social and rights model provided a long overdue challenge to the individual/medical model of disability. This served to reflect the social construct of disability that had previously been ignored, and particularly applied to the aspects of social and cultural art environments/events/activities for visually impaired and blind people.

A definition by the International Classification of Functioning and Disability (ICF) clarified the difference between impairment (described as the deviation from the normal functional or structural integrity of a tissue, an organ or a part of the body) and disability. 'Disability' is an umbrella term for impairments, activity limitations and participation restrictions. Disability is characterised as the outcome or result of a complex relationship between an individual's health condition, personal factors and other external factors that represent the circumstances in which the individual lives. Due to this complex relationship, different environments may have very different effects on the same individual with a given health condition. The ICF has also described the role of participation as involvement in a life situation.

Based on the aforementioned statement, qualitative research has provided a framework in which medical, social and rights models can be combined to give a comprehensive/holistic picture of a disability and to achieve improvement in disability services and research. Furthermore, there is a need to embrace this 'universal model', particularly from the user-centred design (UCD) process and development standpoint. The medical model has traditionally been associated with the quantitative approach and as such has struggled to be meaningful when used in situations relating to peoples' complex and dynamic perceptions. These perceptions are more effectively described qualitatively. Therefore, this study adopted the qualitative research methodology to gain a complete understanding of disability.

General Characteristics of Qualitative Research—a list of the characteristics involved in conducting qualitative research are compiled as follows, based on studies by Hoepf (1997), Campbell and Stanley (1963), Biklen and Bogdan (1982), Lincoln and Guba (1985), Patton (1990) and Eisner (1991).

1. *Qualitative research uses the natural setting as the source of data. The researcher attempts to observe, describe and interpret settings as they are, maintaining what Patton calls an 'empathic neutrality'* (*Lincoln and Guba, 1985; Patton, 1990).*
2. *The researcher acts as the 'human instrument' of data collection (Hoepf, 1997).*
3. *Qualitative researchers predominantly use inductive data analysis (Hoepf, 1997).*
4. *Qualitative research reports are descriptive, incorporating expressive language and the 'presence of voice in the text' (Eisner, 1991).*
5. *Qualitative research has an interpretive character, aimed at discovering the meaning events have for the individuals who experience them and the interpretations of those meanings by the researcher (Patton, 1990).*
6. *Qualitative researchers pay attention to the idiosyncratic and pervasive, seeking the uniqueness of each case (Patton, 1990).*
7. *Qualitative research has an emergent (as opposed to predetermine) design, and researchers focus on this emerging process and the outcomes or product of the research (Biklen & Bogdan, 1982; Lincoln & Guba, 1985; Patton, 1990).*

8. *Qualitative research is judged using special criteria for trustworthiness* (*Lincoln & Guba, 1985).*

According to Richard and Morse (2007), qualitative research methods are best suitable if the purpose is to:

1. *Understand an area where little is known or where previously offered understanding appears inadequate;*
2. *Make sense of a complicated situation, multi-context data and changing or shifting phenomena;*
3. *Learn from the participants in a setting or a process the way they experience it, the meanings they put on it and how they interpret what they experience;*
4. *Construct a theory or a theoretical framework that reflects reality rather than the researcher's perspective or prior research results; or*
5. *Understand phenomena deeply and in detail.*

Based on a review of the preceding literature, the qualitative research methodology was deemed the appropriate approach for carrying out this research project. The methodology was used as a guide throughout the research, particularly during the data collection and analysis phases. These phases determined the results of the final outcomes and findings. Insights from the following strengths and weaknesses table used by Patton (2002) were helpful while carrying out this study.

Strengths and Weaknesses of Qualitative Research—understanding the strengths and weaknesses of qualitative research should help to provide a holistic view of the methodology. The strengths and weaknesses of qualitative research are listed in the following table (Table 01). These strengths and weaknesses served as a checklist of what strengths to emphasise and weaknesses to compensate for to maximise data collection while conducting this study. They also indicated where data were inefficient or inadequate.

Table 01: Strengths and Weaknesses of Qualitative Research (Patton, 2002)

Strengths
• Qualitative research data are based on the participants' own categories of meaning. • Qualitative research is useful for studying a limited number of cases in depth. • It is useful for describing complex phenomena. • It provides individual case information. • It can be used to conduct cross-case comparisons and analysis. • It provides understanding and a description of people's personal experiences with phenomena (i.e., the 'emic' or insider's viewpoint). • It can be used to describe, in rich detail, phenomena as they are situated and embedded in local contexts. • The researcher can identify contextual and setting-related factors as they relate to the phenomenon of interest. • The researcher can study dynamic processes (i.e., documenting sequential patterns and change). • The researcher can use the primarily qualitative method of 'grounded theory' to determine a tentative but explanatory theory about a phenomenon.

• Qualitative research can be used to determine how participants interpret ‘constructs’ (e.g., self-esteem, IQ). • The data are usually collected in naturalistic settings in qualitative research. • Qualitative approaches are responsive to local situations, conditions and stakeholders’ needs.
Weaknesses
• The knowledge produced may not be generalisable to other people or other settings (i.e., findings may be unique to the relatively few people included in the research study). • Qualitative research makes it difficult to make quantitative predictions. • It makes it more difficult to test hypotheses and theories. • It may have lower credibility with some administrators and commissioners of programmes. • It generally takes more time to collect qualitative research data than it does to collect quantitative research data. • Data analysis is often time-consuming. • The results are more easily influenced by the researcher’s personal biases and idiosyncrasies.

Taylor, Williams and James (2005) created a very detailed and precise table comparing the qualitative and quantitative research methods. This table (Table 02) provides a view of how to compensate for and complement the strengths and limitations of the two methodologies to capitalise on their strengths and offset their limitations. To compensate for the limitations of one approach, most agree that the strengths of the other approach must be adopted. This is very clear and easy to understand for the novice researcher.

3.1.1 Case Study

After considering the research objectives, practical constraints (location, time, funding, etc.), availability of sources and physical constraints of the potential participants, a case study approach was adopted for this study. Hartley and Muhit (2003) strongly recommended the case study approach in their discussion of research methods for people with disabilities. The case study method aims to develop in-depth analysis of a programme, an event, a process or an individual. This study used multiple sources of data through reviewing documents, archival records, field observations, interviews and pilot studies to illustrate the case in-depth. Long interviews were conducted with a limited number of participants to develop patterns and relationships of meanings as experienced and described by those participants. The objective of phenomenological research is to understand the essence of human experience of a phenomenon, as described by participants.

Yin (2003) mentioned that a case study should be considered when 1) the focus of the study is to answer ‘how’ and ‘why’ questions, 2) the behaviour of the participants cannot be manipulated, 3) it is necessary to cover contextual conditions that are relevant to the phenomenon under study or 4) the boundaries between the phenomenon and context are unclear. Furthermore, according to Merriam (1988), qualitative methodology emphasises the ‘process, discovery, insight, understanding, and context’ and contributes ‘to the knowledge base and practice of education’. Furthermore, according to Creswell (1994), qualitative methodology categories emerge from information rather than from identification ‘a priori by the researcher’ and that ‘this emergence provides rich context-bound information leading to patterns or theories that help explain the phenomenon’.

The following brief definitive table of the case study methodology provides a clear direction for the process of this study.

Definitions of Case Study from Different Authors

Researcher/ Author	**Definition**
Merriam (1988)	A qualitative case study methodology emphasises ‘process, discovery, insight, understanding, and context’ and contributes ‘to the knowledge base and practice of education’.
Bromley (1990)	A case study is a systematic inquiry into an event or a set of related events that aims to describe and explain the phenomenon of interest.
Creswell (1994)	In a qualitative case study methodology, categories emerge from information rather than from identification ‘a priori by the researcher’ and ‘this emergence provides rich context-bound information leading to patterns or theories that help explain the phenomenon’.

Yin (2003)	A case study should be considered when 1) the focus of the study is to answer ‘how’ and ‘why’ questions, 2) the behaviour of the participants cannot be manipulated, 3) it is necessary to cover contextual conditions that are relevant to the phenomenon under study or 4) the boundaries between the phenomenon and context are unclear.
Thomas (2011)	Case studies are analyses of persons, events, decisions, periods, projects, policies, institutions or other systems that are studied holistically using one or more methods. The case that is the *subject* of the inquiry is an instance of a class of phenomena that provides an analytical frame—an *object*—within which the study is conducted and which the case illuminates and explicates.

To ensure comprehensive data collection, the limitations of the case study method were considered while deciding the approach for this study. By understanding the limitation, it is possible to find an alternate solution to compensate for the weaknesses of the method.

3.1.2 Types of Case Study

The selection of a specific type of case study design is informed by the overall study purpose. In general, there are seven types of case study: 1) explanatory, 2) exploratory, 3) descriptive, 4) multiple case, 5) intrinsic, 6) instrumental and 7) collective. However, Yin (2003) categorised case studies as exploratory, descriptive and explanatory, and Stake (1995) identified case studies as intrinsic, instrumental or collective. The following definitions for three types of case study that are relevant to this study could optimise the final outcome.

Definition and Examples of the Three Types of Case Study

Case Study Type	**Definition**	**Published Study Example**
Exploratory	This type of case study is used to explore situations in which the intervention being evaluated has no clear, single set of outcomes (Yin, 2003).	Lotzkar & Bottorff (2001). An observational study of the development of a nurse-patient relationship. *Clinical Nursing Research, 10,* 275–294.
Descriptive	This type of case study is used to describe an intervention or a phenomenon and the real-life context in which it occurred (Yin, 2003).	Tolson, Fleming & Schartau (2002). Coping with menstruation: Understanding the needs of women with Parkinson's disease. *Journal of Advanced Nursing*. Gallo & Horton (1994). Assessing the effect on high school teachers of direct and unrestricted access to the Internet: A case study of an East Central Florida high school. *Educational Technology Research and Development*.

Intrinsic	Stake (1995) used the term 'intrinsic' and suggested that researchers with a genuine interest in a case should use this approach when the intent is to better understand the case. It is undertaken not because the case represents other cases or illustrates a particular trait or problem, but because in all of its particularity and ordinariness the case itself is of interest. The purpose is NOT to come to understand some abstract construct or generic phenomenon. The purpose is NOT to build theory (although that is an option) (Stake, 1995).	Hellström, Nolan & Lundh (2005). 'We do things together': A case study of 'couplehood' in dementia. *Dementia*.

Based on the literature review, the descriptive case study approach was deemed suitable for this research project. This approach allowed intensive analysis of an individual unit (e.g., a person, group or event) and stressed developmental factors in relation to context (Baxter & Jack, 2008) with the selected participants (visually impaired people) and the museum environment serving as the context. This study was conducted based on in-depth field observation and interviews with visually impaired participants. As Thomas (2011) stated, 'this type of case study is an analysis of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods'. Furthermore, based on Siggelkow's (2007) statements, as the real-life cases were complex and provided rich data, they were a great source for sharpening current theory, especially in situations where theoretical knowledge was limited.

3.2 DATA COLLECTION

Qualitative data from the case studies consisted of detailed descriptions of events, people, interactions and situations. One of the strengths of using case study research is the ability to use multiple methods of data collection (Merriem, 1998). This study used varies types of data collected through comprehensive literature reviews, intensive field observation and in-depth interviews and pilot studies. This required a systematic plan of operation. To achieve this goal, a conceptual framework for conducting research (Figure 6) was adopted to organise, control and carry out the study process efficiently and also to accomplish the study's final outcomes within the proposed timeframe. The research phase outline is presented later.

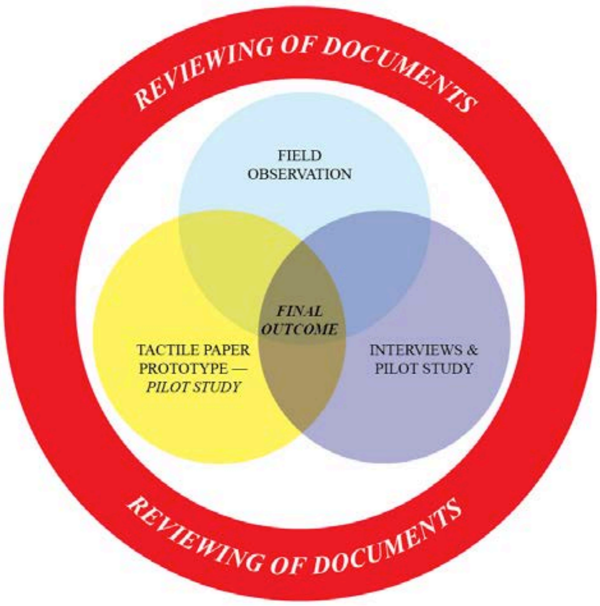

Figure 6: Data collection framework.

3.2.1 Documents

Merriam (1998) suggested that the researcher must first decide whether a document is relevant to the study and whether the information is complete, and then determine the authenticity and accuracy of the document. Determining the credibility of the sources is often required. The researcher should look at the origin, author, intended audience and resources used to create the document. Lincoln and Guba (1985) defined a document as 'any written or recorded material' not prepared for the purposes of the evaluation or at the request of the inquirer.

A major part of the data collected for this study was based on the selected written and recorded documents. Data were collected based on an initial round of field observations, interviews and a pilot study, which according to Merriam (1998) is the most effective data collection instrument used for case study research. Document research helps to uncover meaning, develop understanding and discover insights relevant to research questions. The documents used in this study included a range of academic literature, articles, conference papers and public documents such as newspaper articles and brochures. The main sources included *Art Beyond Sight* (2003), all six of the *Haptic & Audio Interaction Design (HAID)* conference papers, and the international conference papers '*Computers Helping People with Special Needs (ICCHP* – last 10 years) published by vom Lehn.

Records provided insights into a setting and/or group of people that were very useful for this study. They provided useful information about the culture of the institutions and participants involved in the study, and assisted in the development and evaluation of the research questions, objectives and methodology. Information from documents was particularly useful in formulating the interview questions and identifying events to be observed. The information contained in the documents was very useful in the interviews and participant observation activities, particularly in terms of clarifying and providing support for the analysis.

3.2.2 Field Observation

The field observations of Emerson, Fretz and Shaw (1995) described experiences and observations the researchers witnessed first-hand. They described field observation as a resource for 'preserving experience close to the moment of occurrence'. This type of data collection typically involves recording the events as they take place. Merriam (1988) noted that field notes usually include a verbal description of settings and conversations. She advised leaving the margins open for additional comments, reactions and interpretations.

In-depth field observations and interviews were completed early in this study. The 11 highest rated museums in Hong Kong (based on the HK Tourism Board, 2011) were selected.

The main aims of the field observation were to observe the environment of the museum and specifically:

1. *to observe and understand the current status of the digitisation of the art museum;*
2. *to observe and understand the current status of the museum's facilities in supporting visually impaired and blind people (in both the overall museum and specific exhibitions);*
3. *to identify the cultural aspects of the museum and the educational programmes relevant to this research project; and*
4. *to meet people who were 'experts' in the field of museum environment design, particularly in relation to programme development and planning for disabled visitors.*

The findings showed that the basic facilities used to assist visually impaired people in the museums were insufficient. Very limited facilities such as museum tactile maps, tactile guide paths, braille descriptions for exhibits and an accessible website for visually impaired people were found in these museums. The Hong Kong Museum of Art provided services that were accessible to visually impaired and blind people (see Appendix 1).

3.2.3 Interview and Pilot Study

The interviews and pilot study comprised additional primary data collection methods. Merriam (1998) emphasised that the main purpose of an interview is to obtain information that cannot be collected through observation. Along with gathering factual knowledge, interviewing is an ideal method for obtaining information about a subject's personal feelings, perspective, opinions and interpretations. The interviews and pilot study were conducted to obtain in-depth information about the participants. Cohen and Manion (1980) mentioned that one of the advantages of interviewing is its higher potential to gather more information than any other method of data collection. Reinharz (1992) emphasised the advantage of interviewing as a method of obtaining access to an individual's thoughts and memories in his or her own words rather than those of the researcher. This was particularly important in this study, as it involved visually impaired and blind participants.

Preliminary interviews and pilot studies were conducted during the first phase of this study. Twelve visually impaired people were selected for the interviews. For the pilot study, selected participants were asked to complete a conceptual paper prototype test. The test included three types of tactile imagery with different degrees of tactile detail and heights. The imagery was supported with a manual auditory function. During the prototype testing, the manual auditory description closely followed the finger movement of the participants while touching the tactile imagery to imitate or simulate the effect of the HAID feedback. The preliminary interviews and pilot study had two major goals: 1) to refine the research question(s) and methodology and 2) to develop a framework for data collection and analysis. The refined interview questions and conception paper prototype were used in the second phase of this study.

The interviews consisted of semi-structured interviews with open-ended questions based on the research questions. Topics covered in each interview included 1) the participant’s visual impairment background, 2) the participant’s visual impairment experience, 3) the participant’s visual perception and 4) the accessibility of the museum (particularly in terms of the participant’s understanding of the exhibits and the information he or she received). In addition, the participants were asked to complete the conceptual paper prototype supported with a manual auditory function (a manual human speech description that closely followed the movement of the participant while touching the tactile imagery to simulate the effect of the HAID feedback and sensation). The interview questions were modified as appropriate to the context of the interviews, but always reflected the research aims, objectives and questions. This is why the semi-structured interview with open-ended questions approach was adopted in this study.

Semi-Structured Interview and Open-Ended Questions—according to Kvale (1996), interviews are: 'attempts to understand the world from the subjects' point of view, to unfold the meaning of peoples' experiences, to uncover their lived world prior to scientific explanation'. The advantages of the semi-structured interview and open-ended questions are important, particularly in relation to information transfers between participants and researchers. von Hippel (2005) characterised information as 'sticky, (i.e., it is actually very hard to transfer information about users' needs and contexts from the users to the developer). Therefore, it was important to allocate enough time to speak with the participants in connection with the interviews and pilot study. It was important to learn more about 1) the background information of the participants, 2) how the participants faced and overcame problems in everyday life, 3) the problems the participants continued to find hard to master and 4) the ideas the participants had for solving those problems, particularly from a visual perception and interpretation viewpoint.

Based on the UCD approach, the most frequently used planned interview scenario has historically been the post-test interview, during which questions about the user interface and its goals, function and efficiency have been put to the test participant. This approach was adopted in this study. The participants were asked to express ideas for improvement or other applications. This typically led to more explicit and longer answers. The questions usually began with 'what', 'why' and ‘how’. An open-ended question was asked to obtain the participant’s viewpoints, feelings or understanding of certain subjects, which could be personal and subjective. It helped to provide an in-depth understanding of the participant. The information collected was crucial for refining the research questions and the interviews questions for the second phase (which was scheduled to be carried out before the end of October 2012). The timeline is discussed in a later section (‘Planned Study Schedule’). The participants were asked follow-up questions to clarify or pursue any interesting subjects further. Closed questions with preferred answers that included a rating scale or yes/no questions were also asked.

All of the questions for the interviews and pilot study were based on the ‘tactile imagery guiding principles’ proposed by Fuller and Watkins (2010) and the ‘elements of visual image interpretation principles’ proposed by Lillesand and Kiefer (1994) as a fundamental guide (see Appendices 2 and 3).

The pilot study used the conceptual paper prototype as mentioned earlier. A pilot study is a small experiment designed to test logistics and gather information before a larger study is conducted to improve the quality and efficiency of the latter. The pilot study may reveal the deficiencies of a proposed experiment or procedure, and these can then be addressed before resources are expended on a large-scale study.

The book *Experimental Design for the Life Sciences* by Ruxton and Colegrave (2006) suggested a few useful points pertaining to conducting a pilot study:

1. *Check that the instructions given to participants (e.g., randomisation procedures) are comprehensible.*
2. *Check that the participants are sufficiently skilled in the procedures.*
3. *Check the reliability and validity of results.*
4. *Detect a floor or ceiling effect (e.g., if a task is too difficult or too easy there will be skewed results).*
5. *Identify adverse effects (pain, suffering, distress or lasting harm) caused by the procedure.*

When dealing with participants with physical constraints, such as visually impaired and blind target populations, some important considerations must be made when conducting interviews or pilot studies. Aldridge (2007) stated the following:

> *. . . it has been argued that research that employs qualitative methods among vulnerable groups must reconcile the conflict between meeting recognized academic criteria, or measures of research 'strength', while at the same time appropriately and effectively representing the experiences and needs of vulnerable respondents.*

Goodley and Moore (2000) also identified the ‘bottom-up’ approach to research, where studies are primarily located ‘in the lives of disabled people themselves’:

> *This points not only to the need for flexibility and diversity in terms of dissemination practices, but also to the idea that research design and implementation must be equally tractable. Thus, as researchers engaged in qualitative research we should not only explore tried and tested methods of investigation, but must also try and test methods that may not at first seem obvious.*

All collected data and obtained information were used to develop a preliminary outline of the categories of this study. The data were identified and categorised to refine and improve the second round of interviews and the pilot study. They were also used to help evaluate whether the interview results would be useful in answering the research questions. Through critical analysis, the methodology was evaluated further and enhanced where needed.

3.2.4 Paper Prototyping

In UCD, paper prototyping is a widely used low-fidelity usability inspection method to evaluate drafts in an early stage of product design. This study focused on tactile paper prototypes for user interfaces. The participants evaluated the HAID technology via mock-ups that provided low functionality and consisted of different tactile imagery.

Miao, Kohlman, Schiewe and Weber (2009) investigated tactile paper prototyping (TPP) with blind subjects and stated that TPP user interfaces were an effective approach that could be evaluated with blind users in an early design stage.

Conceptual Tactile-Audio Paper Prototyping—Miao, Kohlman, Schiewe and Weber's (2009) evaluation method should allow for user interface evaluations that also respect the users' needs. The integration of haptic prototyping techniques into their methodology is conceivable, as interface elements with a structured surface can be used to indicate certain details in compensation for highlighting visual mock-ups. The aforementioned case helped to provide some useful guidelines for the tactile paper prototype in this study. To be able to perform tests with visually impaired people and blind subjects, 1) a conceptual tactile paper prototype based on the HAID setting was used, 2) tactile imagery consisting of different contents and visual elements and information were used and 3) participants had to identify the contents and visual elements and information. To analyse the effect of the combination and synchronisation of the haptic and audio technologies, a manual human speech audio followed the finger movements of the participant as he or she touched the tactile image.

In a much earlier study, Heller (2000) and Kennedy (1993) stated that tactile pictures (tactile and two-dimensional imagery) had a great deal of potential utility for visually impaired and blind people. The following served as a guide while conducting the TPP method.

1. *Consider general issues when hosting blind users.*
2. *Provide adequate facilities according to the special needs.*
3. *Check for special hardware and software required.*
4. *Design mock-ups not for sighted but for blind users.*
5. *Even better, have blind people design the mock-ups.*
6. *Proofread the mock-ups before conducting the test.*
7. *Check the recording before and during the test, as repetition is expensive.*
8. *Provide a sufficient number of assistants.*
9. *Make sure that mock-ups are provided synchronously to each subject.*
10. *Allow for sufficient time to explore the mock-ups.*
11. *Explain from the blind users' perspective.*

3.3 VALIDITY AND RELIABILITY

Merriam (1998) defined *internal validity* as the extent to which the findings from a research study were congruent with reality. A researcher can pursue many strategies to ensure internal validity. Yin (1994) suggested that three principles could help 'to deal with the problem of establishing the construct validity and reliability of a case study': 1) create a case study database, 2) use multiple sources of evidence and 3) maintain a chain of evidence. One model established by Sapsford and Jupp (1996) to access validity included triangulation, respondent validation and reflexivity. According to Sapsford and Jupp (1996), this was accomplished by 'comparing the data produced by different methods'. This supported the proposed multiple data collection methods such as the reviewing of documents, field observations, interviews and pilot study.

3.4 SUMMARY

This chapter presents the methodological approach adopted to realise the thesis objectives and describes how a creative research methodology was appropriately planned and structured. It introduces my roles and actions as a researcher and illustrates the relationship between these roles and actions by drawing examples from the practices adopted in addition to tables and diagrams. Although no new methodology was invented for this study, the collective application of methods formed a new way to present the methodologies mentioned in this chapter, a process that I declared as the 'practice of touch'. This declaration was made not only because this study focused on seeking the missing tactile information about an untouchable object, but also to recognise the value of the sense of touch and the continuity of the human element in the process of ‘making’. This chapter also clarifies the similarities, differences and common uses of practice-based and practice-led research. In doing so, it pinpoints how the current research sits within the boundaries of both, and how it must eliminate misconceptions within the field to realise its position.

In addition to addressing the practices of this study via four projects, I also declare my writing as a practice, and cherish its traces from previous drafts, depending on the section and work being discussed. I realised this process by adapting a visual artist’s method as a model for writing, a method involving drawing/erasing layers onto the same paper over and over and leaving traces behind each time to be able to draw again. Although I found this to be a messy way of working, it taught me that research is an organism and that as a researcher I must sometimes let go of the process. When applied to writing, this process feeds the artistic development of the research and the academic development of the bricoleur. This led me to consider writing as a journey, and with the aid of Foucault’s author-function concept I learned to see the experience behind actions as the author of the process (not the persona of an individual, but the ‘voice’ of a narrator/researcher). I tried to illustrate the relationship between my actions and methods through a simple diagram early in the thesis, and later on within a more developed table to include how the research was realised and what influenced it. This table is placed at the end of this chapter, as it summarises the methodology in relation to my practice.

After this clarification of roles and methods, it is now appropriate to move on to the projects and report their conclusions. This is done in the next two chapters before progressing to the 'Critical Discussion and Analysis' of the thesis and its concepts, rather briefly but firmly and as a whole.

CHAPTER 4 CASE STUDY: HONG KONG MUSEUM ENVIRONMENTS

Overview

The development and implementation of the field observations, pilot studies, prototype testing and drawing test were fundamental parts of this study and the crucial primary data collection approaches. In this chapter, the development and implementation approaches are introduced through three separate case studies: field observations conducted in Hong Kong and two separate pilot studies that focused on aspects of the accessibility of visual information and the usability of user interface design, based on the proposed concept of Haptic-Audio Interaction Design (HAID). A simulated paper prototype was tested with a group of visually impaired participants.

In the final pilot study, two museum masterpieces were transformed into tactile displays and later synchronised with audio descriptions. Drawing tests were conducted in the last stage of the pilot study, which revealed the effectiveness of the cross-modal interaction design approach in helping visually impaired people to improve their construction of mental imagery.

4.1 INTRODUCTION

The day-to-day living environment is significantly becoming an information society, an environment in which information is a fundamental resource used in all walks of life, particularly in the forms of graphics, images and visuals in print and digital media. As the world becomes more complex, there is an increasing need to make greater use of visual information at work and school and in social and leisure environments. Moore’s (2000) study of the Royal National Institute of Blind People (RNIB) in the UK discussed one’s need to be able to access and understand such information simply to function as a kind of social being. According to the same study, a lack of access to information prevents individuals from playing their part as citizens and makes then unable to benefit fully from all that society has to offer, which also contributes directly to social exclusion and discrimination.

In the mid-1980s, the Hong Kong government published the *Design Manual Access for the Disabled*, which incorporated legislation to accelerate the improvement of the accessibility of public space to better aid individuals with disabilities. The manual was meant to align with the implementation of the United Nation Declaration on the Rights of Disable Persons (1975) guidelines, which promoted social equality and integration for individuals with disabilities. The Equal Opportunities Commission (EOC) of Hong Kong implemented its strategy to overcome barriers to buildings and community facilities in the mid-1990s, which involved promoting the anti-discrimination ordinances, including the Disability Discrimination Ordinance. In recent years, the foci of the associated policies and guidelines have extended to cultural facilities and community areas such as museums, parks and community halls and centres. However, the visually impaired still face major difficulties in visually oriented environments such as galleries, museums and heritage sites.

In this chapter, the research methods are presented along with the procedures and findings of the individual case study and pilot testing, which developed a conceptual tactile-audio paper prototype that simulated the idea of a haptic-audio interaction design (HAID) approach for the visually impaired. The cross-modal interaction approach was proposed and tested to assess how multisensory feedback could be provided to visually impaired visitors. The aim was to investigate the effectiveness of the HAID platform in helping the visually impaired to construct mental images of exhibits and thus enable meaningful museum experiences.

First, documents related to how museums understand and perform their roles in supporting visually impaired visitors were reviewed. The findings of various studies and projects showed that museum environments, exhibitions and programmes still fail to consider the actual wants and needs of visually impaired visitors, especially in terms of the accessibility of visual information (see Buyurgan, 2009;

Fuller & Watkins, 2010; Jiménez Hurtado et al., 2012; Carfagni et al., 2012). Second, in-depth field observations and interviews were conducted in 11 major museums in Hong Kong, and the findings revealed that the visually impaired were a little-noticed segment of the museum audience and that the museums offered very few basic facilities and resources to aid their mobility and access to information about exhibits.

In the first case study, semi-structured interviews with open-ended questions were conducted with 12 invited visually impaired participants. The participants were asked about their viewpoints, feelings and understanding of subjects, which could have been personal and subjective. A preliminary pilot study was also conducted and found that many of the participants were reluctant to visit museums in Hong Kong because they felt excluded. In the second case study, another pilot study and addition semi-structured interviews were conducted. The selected visually impaired participants took part in tests of three medium-fidelity conceptual tactile-audio paper prototypes that were supported by audio descriptions to simulate the effect of a HAID approach that offered multisensory feedback. The purpose of this pilot study was to investigate the effectiveness of touch-activated sound systems that integrated an exhibit’s visual information with its tactile displays. Finally, the participants were asked to draw the mental images they had constructed during the tests to evaluate the effectiveness of the cross-modal interaction approach that integrated haptic (touch) and sound (audio). They were indeed able to capture some of the visual elements of the exhibits. The results and findings are presented in a later part of this chapter.

Based on the identification and understanding of the user needs and variables important to the visually impaired participants, prototypes were designed and evaluated. Based on the findings in this part of the study, a conceptual tactile-audio paper prototype that simulated the HAID approach was proposed and developed. The final outcomes of that process and the overall findings of this study should contribute new information and guidelines to key stakeholders such as policymakers, museum representatives, gallery owners, curators and designers. Furthermore, the findings should provide insights into the design of visual art events intended to create a more equal and inclusive social environment, including for those visitors who are visually impaired or blind.

4.2 FIELD OBSERVATIONS: HONG KONG MUSEUMS

Emerson, Fretz and Shaw (1995) described field observations as ways of 'preserving experience close to the moment of occurrence'. This type of data collection involves recording events as they take place. Merriam (1988) stated that field notes usually include a verbal description of settings and conversations. She advised researchers to leave the margins open for additional comments, reactions and interpretations. In-depth field observations and interviews were conducted during the early stages of this study. The main foci of these field observations were investigation and understanding of the current Hong Kong museum environments and their accessibility for visually impaired visitors.

4.2.1 Procedure

The 11 highest rated museums in Hong Kong (HK Tourism Board, 2011) were selected for in-depth field observations and interviews. The overall aim was to observe and analyse mobility and accessibility in the museum environment. The specific aims were to:

1. review the current status of museum digitisation (both hardware and software);
2. review the current status of the museum's facilities for supporting visually impaired and blind people (both the overall museum environment and specific galleries and exhibitions);
3. identify the cultural aspects and educational programmes of the museums that were relevant to the study; and
4. meet people who were museum 'experts', particularly in relation to exhibition curation, design, programme development and planning for disabled visitors.

When analysing our field observations, we followed the guidelines laid out in the RNIB's (2009) '*Access to exhibitions and collections for blind and partially sighted people*'. These included whether the museum was:

1. inviting visitors to touch works of art that were in some way tactile, perhaps as part of a touch trail, a guided tour or a tactile exhibition;
2. describing works of art/audio descriptions;
3. producing tactile images or models representing works of art;
4. allowing people to get close to works of art, perhaps to use low-vision aids such as magnifiers, and ensuring works of art were well lit;
5. commissioning artwork that was appreciated through senses other than sight; and
6. providing information about works of art in accessible formats (e.g., large print, audio cassette, braille) and transcribing information into audio and braille.

4.2.2 Results

The museums had insufficient basic facilities to assist visually impaired visitors. The visually impaired could not access visitor information, interior settings were rather challenging to navigate and display text was too small in general. Museum staffs were sometimes uncertain about the facilities and resources the visually impaired could access. Furthermore, the museums had very few facilities such as tactile maps, tactile guide paths, tactile diagrams of exhibits, braille descriptions for exhibits, guided tours, educational programmes and websites that the visually impaired could access.

An investigation of 11 Hong Kong museums managed by the Leisure and Cultural Services Department revealed insufficient basic facilities for visually impaired people. There were very few facilities such as tactile maps, tactile guide paths, braille descriptions of exhibits and websites accessible to visually impaired people. An overview of the facilities for visually impaired and blind visitors at the 11 Hong Kong museums managed by the Leisure and Cultural Services Department is provided as follows.

Museums	Tactile Guide Paths	Tactile Maps	Braille Descriptions of Exhibits	Audio Kits	Tactile Imagery	Guided Tours	Visually Impaired Workshop
Hong Kong Museum of Art	Entrance of the museum only; not in the exhibition hall.	YES	NO	YES (for regular visitors only)	NO	YES (however, guides are not trained to facilitate visually impaired/blind people)	NO
Hong Kong Heritage Museum	Entrance of the museum and information counter only; not in the exhibition hall.	YES	YES (on limited exhibits only; leaflets and booklets)	NO	NO	YES (however, guides are not trained to facilitate visually impaired/blind people)	NO
Hong Kong Science Museum	NO	NO	NO	NO	NO	NO	NO

Hong Kong Museum of History	Entrance of the museum and information counter only; not in the exhibition hall.	NO	NO	YES (for regular visitor only)	NO	YES (however, guides are not trained to facilitate visually impaired/blind people)	NO
Hong Kong Space Museum	NO	NO	NO	YES (for regular visitors only)	NO	NO	NO
Hong Kong Museum of Coastal Defense	NO	NO	NO	NO	NO	NO	NO
Law Uk Folk Museum	NO	NO	NO	NO	NO	YES (however, guides are not trained to facilitate visually impaired/blind people)	NO
Dr Sun Yat-sen Museum (Hong Kong)	NO	NO	NO	YES (for regular visitors only)	NO	YES (however, guides are not trained to facilitate visually impaired/blind people)	NO
Hong Kong Railway Museum	NO	NO	NO	NO	NO	YES (however, guides are not trained to facilitate visually impaired/blind people)	NO
Lei Cheng Uk Han Tomb Museum	NO	NO	NO	NO	NO	NO	NO
Sam Tung Uk Museum	NO	NO	NO	NO	NO	YES (however, guides are not trained to facilitate visually impaired/blind people)	NO

4.3 USER NEEDS ANALYSIS AND FIRST PILOT STUDY

Gould and Lewis (1983) recommended focusing early on users and tasks, performing empirical measurement and adopting an iterative design. Gould (1985) later described the system design and development process as comprising four phases: the gearing-up, initial design, iterative development and system installation phases. In this study, user needs analysis was conducted as part of the initial design phase. The iterative development phase focused mainly on iterative usability testing.

User needs analysis is widely recognised as the core of human-centred design. To develop a truly usable platform, interaction or system for visually impaired people, analysis of user needs is particularly crucial. There are many variations in the way users think and behave. The diversity in all people—who and where they are, what they are doing, how they are doing it and what they hope to achieve—is influenced by their physical, physiological and psychological characteristics. The social, political and cultural contexts in which people carry out their everyday activities are also influencers.

In this study, the main focal point in conducting user needs analysis was the identification and understanding of the current problems faced by the visually impaired visitors when accessing information in and moving around museums.

Indeed, the visually impaired users' requirements, perceptions and expectations of museums were taken into account throughout the entire study, including the design and development of the prototypes, pilot study planning and final mock-up of a fully operational prototype. It was also considered how individuals who were visually impaired could access and interpret visual information in their daily activities. Their visual perceptions and perceptions of the devised cross-modal interaction system were also foci. Finally, preliminary tactile diagram testing was conducted in the first pilot study.

According to Ruxton and Colegrave (2006), a pilot study is a small experiment designed to test logistics and gather information before a larger study is conducted with the aim of improving the quality and efficiency of the latter. The pilot study has the potential to reveal the deficiencies of a proposed experiment or procedure, which can then be addressed before resources are further expended.

4.3.1 Procedure

A user needs analysis interview was conducted with 12 visually impaired participants in separate sessions. The members and social workers of Hong Kong Blind Union introduced the visually impaired participants. All of the participants had visited museums. Semi-structured interviews were conducted to allow the participants to talk comfortably. The questions focused on the participants' experience of visiting museums, their motives or intentions for those visits and their expectations of accessing information about the exhibits. The interviews also included open-ended questions that focused on the participants' preferred museum environments, whether they needed assistive technologies or facilities to navigate the museums and the accessibility of information about the exhibits.

Preliminary tactile diagram tests were conducted after the interviews. These tests included three different of types of tactile diagrams. The first diagram (Figure 7) was taken from the *Black Book of Color*, a tactile book by Cottin and Faria (2006). It adopted the 'spot UV' or 'spot varnished' printing technique to represent the tactile effect. The second diagram (Figure 8) was taken from the book *Invisible Power*, produced by the Japanese Blind Association (2000). A 'thick pigment' layer, which provided a soft and embossed surface, created the tactile effect. The printing method suggested by Axel and Levent (2002) in *Art Beyond Sight* was adopted for the third tactile diagram (Figure 9). The diagram was printed on microcapsule (swell) paper. The three diagrams consisted of different materials, degrees of tactile detail and density and height of tactile effects. Each diagram was supported by verbal description of the interviewer. The participants were asked open-ended questions during the tactile diagram tests.

Figure 7: First tactile diagram –'Spot UV' or 'spot varnished' printing technique that had a tactile effect.

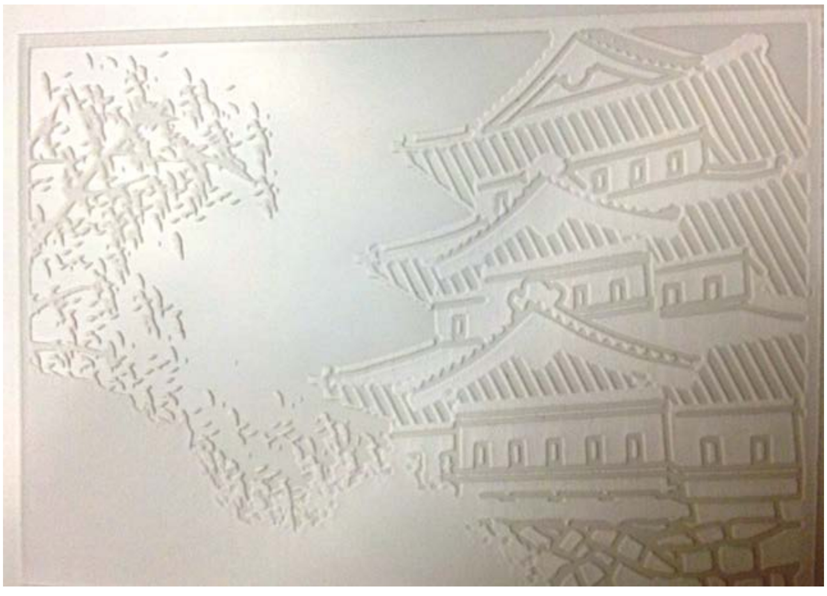

Figure 8: Second tactile diagram – 'Thick pigment' layer that provided a soft and embossed tactile surface.

Figure 9: Third tactile diagram – Printed on microcapsule papers (swell paper); recommended by Art Beyond Sight.

4.3.2 Results

Through the participants' interviews and preliminary tactile diagram testing, insights were obtained that could be used in the HAID simulated conceptual tactile-audio paper prototype design in the second pilot study. All of the participants mentioned that the museums they had visited lacked enough accessible information to allow them to independently circulate and appreciate the exhibits. They had to depend on their companions to describe the museum space and each exhibit. This frustrated them, and they felt they were interrupting their companions, who could not appreciate the exhibits. Essentially, they were reluctant to go to museums because they felt excluded.

The results of the tactile diagram tests indicated that the third diagram (Figure 9) on the microcapsule paper was best for simulating the sense of touch. It conveyed the richest tactile information and generated better perceptions of visual, depth and spatial composition. None of the participants had ever used tactile diagrams in museums and were impressed by how they overcame the limitations of other methods. As independence in gaining information about exhibits was important to them, some had tried reading braille descriptions. However, doing so can be a slow process; the information can be limited, and not all visually impaired people can actually read braille. Six out of the twelve visually impaired participants mentioned that although listening to audio descriptions through a handheld device was helpful, it was still hard to visualise the exhibits. They all mentioned that being able to touch an exhibit made it easier to understand.

Based on these findings, a user-centred design approach was proposed, comprising a HAID tactile paper prototype that would combine a tactile diagram and audio description to provide multisensory feedback. Wickens et al. (2004) stated that prototyping played a central role in both heuristic evaluation and the usability testing of product concepts. These are key factors in a user-centred design process and more generally in ergonomics engineering. They are also crucial in conducting studies with people with disabilities.

4.4 CONCEPTUAL TACTILE-AUDIO PAPER PROTOTYPING AND SECOND PILOT STUDY

Miao, Kohlman, Schiewe and Weber (2009) developed a method for evaluating user interfaces while respecting subjects' needs. Their methodology provided some useful guidelines for the development of the medium-fidelity HAID conceptual tactile-audio paper prototype used in this study. When performing the user testing, tactile diagrams were used; these diagrams were well printed on microcapsule paper, differed in their visual elements and included visual information that had been simplified but still covered all of the important elements of the original exhibits. Audio descriptions supplemented the diagrams. The focus was on how the visually impaired participants interacted, reacted and responded while using the prototype, and how they identified the visual elements, content and so on as they constructed their own mental images.

In this section, the design and development of the conceptual tactile-audio paper prototype is presented. It is identified as the major outcome of this study, as it integrated the visual information of two-dimensional museum exhibits that were converted into touchable tactile displays and audio descriptions that were easily accessible to the visually impaired. Based on the main theory behind this work, the conceptual tactile-audio paper prototype followed the idea of opening up the concepts of touch and sound and was used to further investigate and discuss the effectiveness and limitations of the experimentation of haptic (touch) activated integral auditory (sound) systems. The following guided questions were asked throughout the development of the prototypes and the implementation of the case study.

1. Can the conceptual tactile-audio paper prototype present the visual information of the two-dimensional museum exhibits?
2. Can the conceptual tactile-audio paper prototype improve the mental imagery construction of the visually impaired?
3. Can the conceptual tactile-audio paper prototype represent HAID simulation?
4. Does the tactile display provide enough/too much haptic simulation that is easily accessed by the visually impaired?
5. Does the audio description provide enough/too much visual description that can be associated and understood by the visually impaired?
6. Can the visual information be perceived and understood by the visually impaired based on the adaption of the conceptual tactile-audio paper prototype?
7. Can the proposed idea of HAID enhance the museum experience of the visually impaired?
8. How can the museum experience of visually impaired visitors be enhanced with the proposed HAID?

The second pilot study involved three different user tests, semi-structured interviews and in-depth observations. All of the questions used in the interviews and pilot studies were based on Fuller and Watkins's (2010) '*Research on effective use of tactile exhibits with touch activated audio description for the blind and low vision audience*'. Lillesand and Kiefer's (1994) '*Elements of visual image interpretation principles'* were used as the guiding principles for the interview questions (see Appendices 2 and 3) images were expected to:

1. increase awareness, knowledge or understanding of a particular topic, concept, phenomenon or theory;
2. increase engagement or interest in the theme(s) of the exhibit;
3. change attitudes about a particular topic, concept, phenomenon or theory;
4. change behaviour about an exhibit topic; and
5. increase perceptual, observational and interpretive skills as a result of the exhibit experience.

In the development of the HAID conceptual tactile-audio paper prototype, various possibilities and proofs of concept were explored. This was an open-ended preliminarily exploration, and the tools used had to be both flexible and affordable because time and resources were limited. In addition, the International Usability Standard: ISO 13407 (Figure 10) was adopted. ISO 13407 specifies the following principles and activities that underlie user-centred design:

1. there is an explicit understanding of specific users, tasks and environments;
2. users are involved throughout design and development;
3. the design is driven and refined by user-centred evaluation;
4. the process is iterative; and
5. the design addresses the whole user experience.

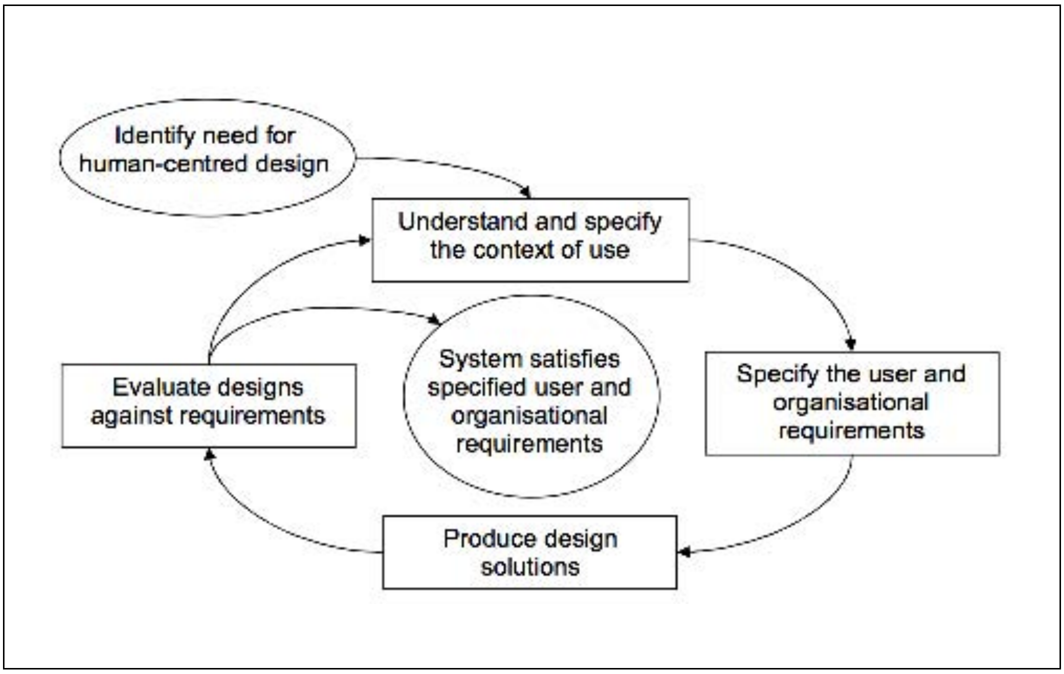

Figure 10: User-centred design process model; ISO 13407 (1999).

This standard describes how these principles and activities can be applied to specifying and measuring the usability of the final design, specifying and evaluating usability during the design process and specifying and measuring a workable system. It includes three annexes, providing an example of how to specify the context of use, examples of usability measures and an example of a usability requirement specification.

4.4.1 Procedure

Six completely blind participants were invited to participate in the user testing. The participants were asked to complete conceptual tactile paper prototype tests. Findings from the first pilot study, interviews and in-depth observations were used to inform the information structure of the conceptual tactile paper prototypes used in the second pilot study. Two tactile diagrams on microcapsule paper were used, supplemented by professionally produced audio descriptions.

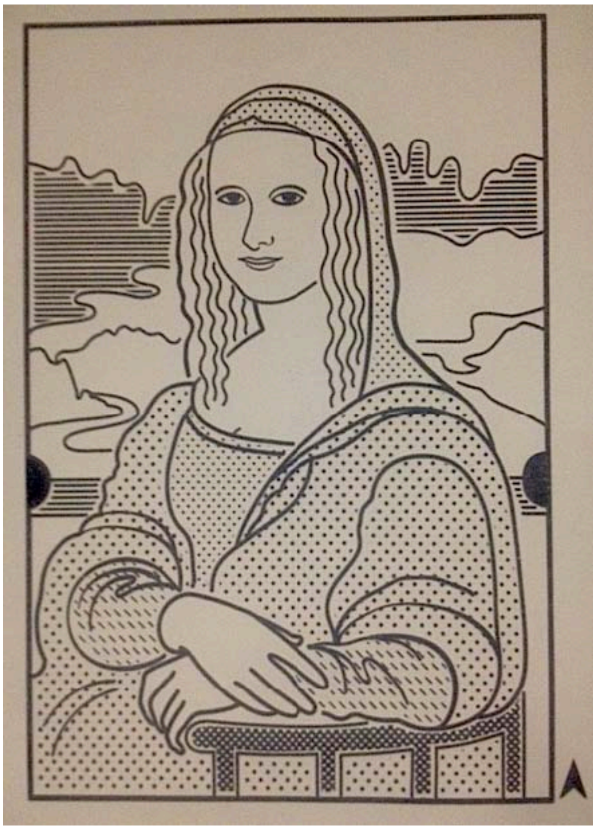

Figure 11: Tactile diagram – 'Mona Lisa' by Leonardo da Vinci.

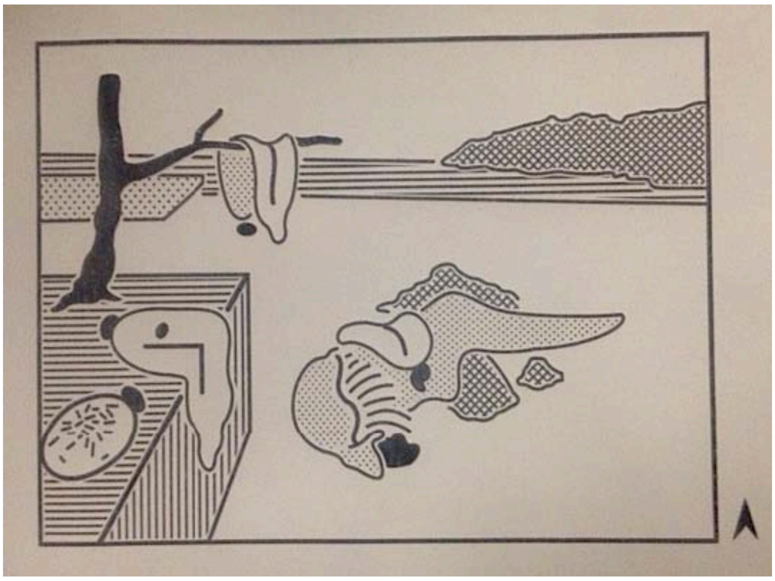

Figure 12: Tactile diagram – 'The Persistence of Memory' by Salvador Dali.

The first diagram (Figure 11) was a recreation of Leonardo da Vinci's Mona Lisa and the second (Figure 12) was a re-creation of Salvador Dali's Persistence of Memory. The audio descriptions used in conjunction with these diagrams are currently used by the Musée du Louvre (Figure 11) and the New York Museum of Modern Art (Figure 11) to assist visually impaired visitors. Three separate tests were conducted.

First Test: The participants were told to touch and explore the tactile diagram without receiving any information or descriptions. The Think Aloud Protocol method (Chandrashekar et al., 2006) was adopted, and participants were encouraged to talk about their interpretations, ask questions and so on.

Second Test: A brief introductory audio description was activated before and during the interaction with the tactile diagram. The participants were again encouraged to talk about their interpretations and ask questions. Limited guidance and suggestions were given.

Third Test: A brief introductory audio description was activated before and during the interaction with the tactile diagram. More guidance and suggestions were given, specifically to identify the object to which the audio description was referring. An extra function—'point description' (Figure 13)—was also offered to the participants. The participants could press buttons embedded in the tactical diagram to hear audio descriptions of the selected visual element/object. Upon the completion of all three tests, the semi-structured interviews were conducted. Finally, the participants were instructed to draw the images they had constructed mentally during the testing.

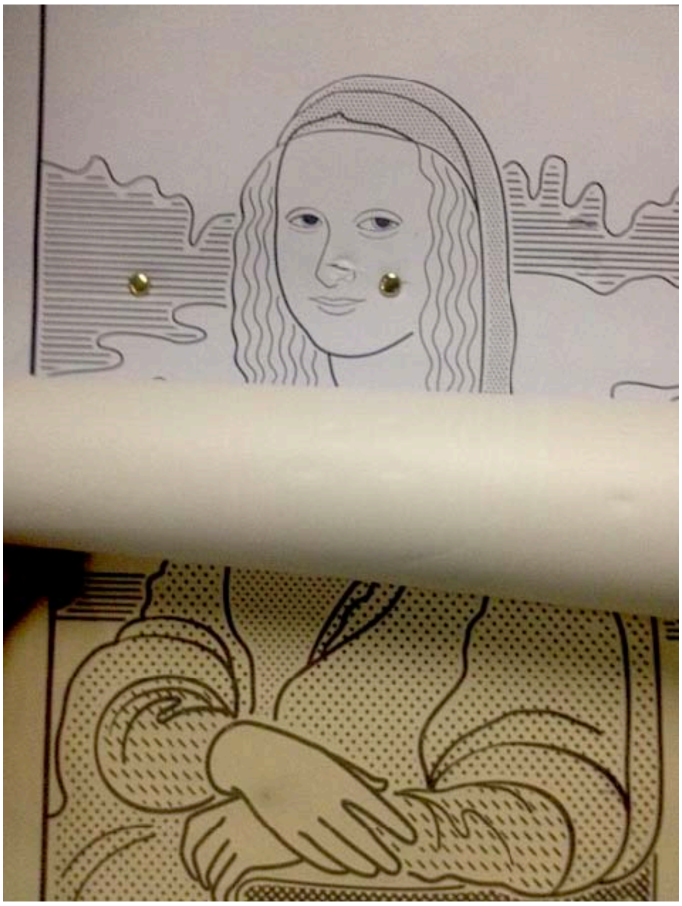

Figure 13: HAID simulated tactile paper prototype – To create the sensation of pressing a button to activate the 'point description' function on the prototype, metal pins were embedded in the back of the diagram. The diagram was glued to a form-board, which stimulated haptic force feedback when participants pressed on the tactile surface.

4.4.2 Results

The three HAID tactile paper prototypes and drawing tests revealed that tactile diagrams without audio descriptions were meaningless; the participants expressed major confusion and uncertainty. They valued the brief introductory audio description because it provided a brief image of the tactile diagram. Furthermore, the participants varied in their relation to and interest in the visual arts. This strongly indicated that a HAID museum platform would need to personalise the information it offered to suit the individual preferences of visually impaired visitors. Along these lines, the participants appreciated the ‘point description’ function that enabled them to further enhance their mental images of the exhibits.

However, the participants still found it difficult to identify objects in the tactile diagrams at the beginning of the tests, even with the use of the audio descriptions. They were also concerned about various elements of those descriptions, such as their lengths and speed, optional functions to pause or repeat, the actual narration and the lack of directional information about the spatial composition of the tactile diagram or tactile element. Finally, all of the participants said that if museums used HAID platforms they would be motivated to visit and encourage others to do so.

The results of the drawing test were mostly positive. The participants’ drawings (Figures 14–16) showed that they had imagined the general shapes of the selected visual elements in the tactile diagrams. This indicated the great potential of the cross-modal interaction approach to help visually impaired people evoke and construct clearer mental images, which could ultimately enhance their museum visits.

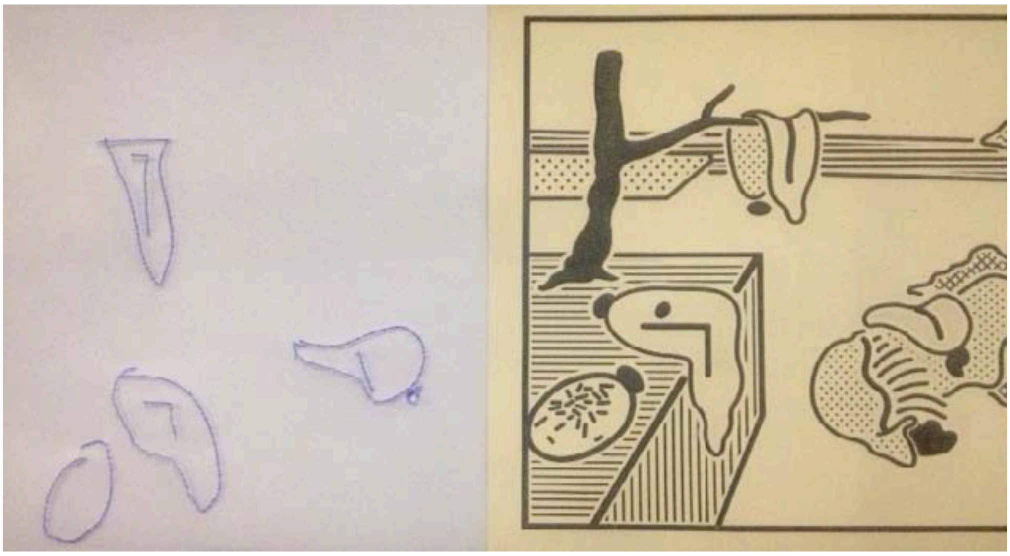

Figure 14: Drawing test – The shape and spatial composition of the visual elements are well captured.

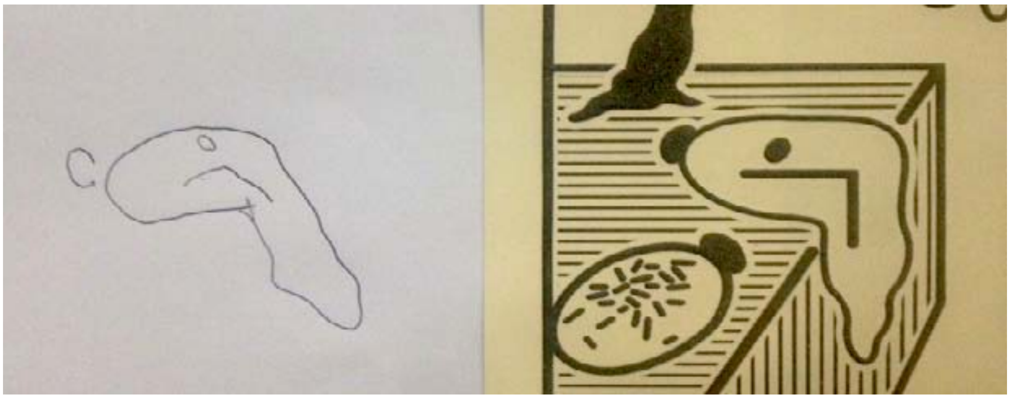

Figure 15: Drawing test – The shape of the object is very close to the original visual element.

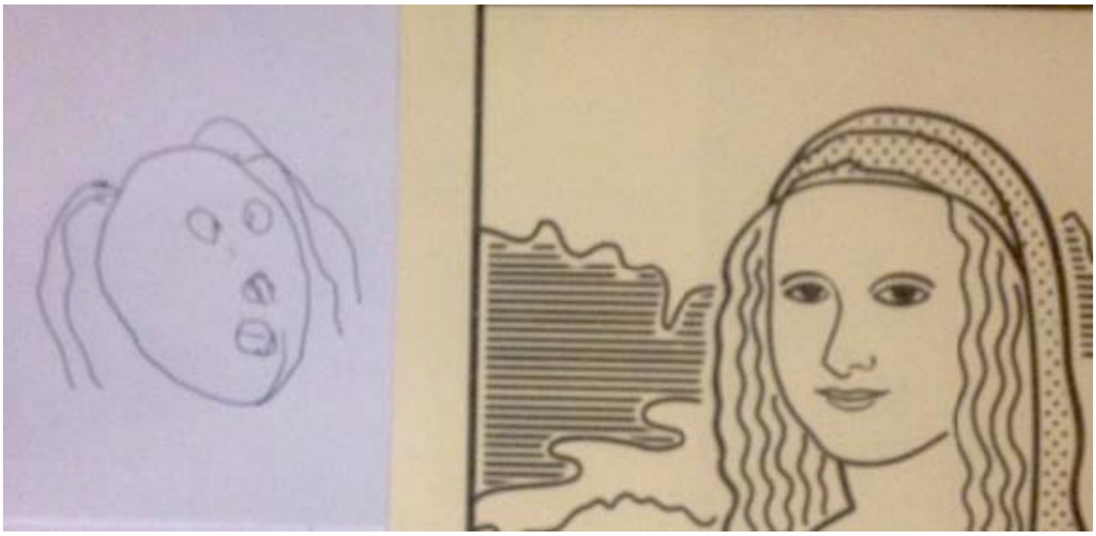

Figure 16: Drawing test – The participant identified the visual elements in the tactile diagram and their spatial composition.

4.5 CONCLUSION AND RECOMMENDATIONS FOR CASE STUDIES

Access to information about museum exhibits is crucial for visually impaired visitors, who need to construct mental images of exhibits that are detailed enough to make them feel that their museum experience has been worthwhile. The concept of creating a barrier-free and accessible museum environment for visually impaired and blind visitors should be redefined; accessibility of the physical environment is equally important to accessibility of exhibit information and content. Although the conceptual tactile-audio paper prototype focused on touch (haptic) and sound (audio) as the main ways to establish multisensory interaction and feedback, it also encouraged the participants to express their feelings and insights about the use of cross-modalities to perceive and understand the visual information, the challenges involved in accessing such interfaces and the availability of such accessible options in Hong Kong museum environments.

The results showed that the adaption of the cross-modal interaction approach to creating a HAID platform that provides multisensory feedback for visually impaired visitors has great potential to help these visitors construct mental images of exhibits. At the same time, it would also improve the social inclusiveness of the visually impaired. The iterative process used in this study allowed for the design of a system based on the user needs of the visually impaired, addressing their capabilities and limitations. Future research should be undertaken in line with all of the following recommendations that stemmed from the pilot studies and interview sessions with the visually impaired participants.

1. A 'pre-visit introduction' is crucial in preparing the visually impaired to interact with unfamiliar museum exhibits. The brief introduction given during the second pilot study provided brief imagery of the tactile diagrams.
2. A 'personalised' option, such as the 'point description' option discussed in this thesis, is needed in assistive interaction systems to offer visually impaired or blind individuals an enriching and engaging museum experience.
3. Assistive interaction systems in museums should feature cross-modal interactions/interfaces with a combination of haptic/tactile and audio elements.

4. ‘Reference points’ should be included on the tactile diagrams used in these systems to help visually impaired users associate the spatial composition of the tactile diagrams. This would effectively provide a ‘guided tour’ of exhibits.
5. The audio aspects of the systems should include the ability to pause, repeat or speed up or slow down the narrative.

The atmosphere and exhibitions in a museum and their spatial connection influence the museum experience of the visually impaired. The research activities implemented in this study were limited and did not allow all of the related aspects to be tested in terms of how they affected the individual’s museum experience. Thus, it became crucial to create a high-fidelity HAID platform in the real-life context for another round of user testing and evaluation to collect all of the necessary data and achieve a more in-depth understanding of how to improve social inclusiveness and interaction by enhancing the museum experience for visually impaired visitors.

CHAPTER 5 CRITICAL DISCUSSION AND ANALYSIS

Overview

This chapter focuses on a critical discussion and an overall analysis of the concepts and ideas formed throughout this study, guided by the identified research aims and objectives and the formulated research questions. It begins with a discussion of the integration of touch and sound interaction. This is based on results and findings from the user needs analysis and the first pilot study, which focused on comparing the different types of tactile display materials and audio descriptions that were best at simulating the sense of touch and conveyed richer tactile information that provided better perceptions of visual information, depth and spatial composition.

Further discussion and analysis of the methods adopted in this study and the methodological problems are presented. The chapter ends by considering the problems and challenges from different aspects and the stakeholder standpoint.

5.1 INTEGRATION OF TOUCH (HAPTIC) AND SOUND (AUDIO) FOR THE VISUALLY IMPAIRED

This study focused on the accessibility of visual information for the visually impaired to improve their process of constructing mental imagery of untouchable museum exhibits, with the ultimate aim of enhancing their experience of Hong Kong museum environments. It attempted to stay away from searching and investigating the historical meaning of 'object knowledge and museum' or the philosophical context of 'phenomenology perception'. Instead, it emphasised an in-depth examination and understanding of the human interaction and interpretation of touch (haptic) and audio (sound), in addition to how the visual information of the untouchable museum exhibits could be delivered and perceived by the visually impaired through an accessible option that affected their museum experience. This does not mean the study was not committed to identifying and understanding the reasons for such perception and performing corrective actions.

At the beginning of this study, there were uncertainties and anxieties about staying away from the conventional path; however, the findings and outcomes reflected a bridging of the gap between museum exhibits and visually impaired visitors. This also means that the approach actually brought the 'museum object' closer in this study. The methods implemented in this study, such as field observations, user needs analysis, case studies, pilot studies and conceptual paper prototype testing provided significant findings and an all-round understanding of user-centred design approaches, a workable cross-modal interaction approach and an accessible option for the visually impaired to improve the perceiving and understanding of visual information.

As the conceptual tactile-audio paper prototypes were created and developed, visual information about museum exhibits were mostly identified and interpreted by sight only—in some cases by touch or sound—and then used as material to convey and interpret the visual information about the selected two dimensional exhibits as the accessible prototype. Discussion and analysis of the relationship between haptic (touch) and audio (sound) was applied throughout the entire prototype creation and research activity stages of the user needs analysis and literature review. In other words, the visual information presented via the prototype and the selected museum exhibits were closely associated with user characteristics and needs. This indirectly yet strongly reflected the user-centred design process discussed in Chapter 2.

During the literature review stage, the findings revealed limited literature and documentation focusing on the accessibility of visual information about museum exhibits for visually impaired or blind visitors in a museum environment. Despite much effort, individuals who are visually impaired are still facing major challenges in highly visual-oriented environments such as museums. The accessibility of visual information about exhibits within a museum environment is crucial for the visually impaired to construct visual mental images for the exhibits. Based on these findings, a user-centred design (UCD) was proposed to create a haptic-audio interaction design (HAID) simulated tactile paper prototype that adopted the cross-modal interaction approach (a combination of tactile display and audio description) to provide multisensory feedback for the visually impaired.

Salmen (1998) stated that the most effective way to communicate a museum’s dedication to accessibility is to include an accessibility policy statement or a declaration within the overall mission statement of the museum. A museum’s philosophy on its commitment to accessibility may be integrated into all of its functioning activities, such as its policies, guidelines, plans, budgets, meetings, conferences, panels and community outreach, to form its accessibility statement.

The accessibility of visual information about museum exhibits is crucial for visually impaired visitors to construct visual mental images of the untouchable exhibits and ultimately to enhance their museum experience, with the aim of a more accessible and inclusive museum environment in Hong Kong. Given its objectives of gaining a deeper understanding of ‘touch and audio’ interaction as a fundamental concept, this study in general investigated the effectiveness and concerns associated with HAID by adopting a cross-modal interaction approach that provided multisensory feedback for visually impaired visitors, which had the potential to help them evoke and construct visual mental imagery and add a unique quality to an interface. The investigation led to analysis of user needs and to pilot testing of tactile displays and/or audio descriptions that offered visual information accessible to visually impaired visitors, with a focus on the touch-activated audio description interactive approach. The idea of the conceptual tactile-audio paper prototype, an interaction design prototype, formed an appropriate case study. The prototype was used as an accessible interface between visually impaired participants and museum exhibits, and the concept was supported by other case studies and experiments as discussed in previous chapters.

The results of this study reflected the research questions and objectives, which focused on the accessibility, user experience and considerations of the cross-modal interface design approach for the visually impaired. The findings reveal information about social inclusion and communication, which strongly affect visually impaired individuals by allowing them to explore, learn and share their museum experiences with others in addition to their personal insights on museums exhibits. However, despite the highly adopted human-centred design approach and the rapid development of assistive technologies to assist individuals who are visually impaired or blind, users' involvement and participation throughout the design process is crucial; it focuses on what should be done from the viewpoint of user need, in addition to the consideration of and consequences for the visually impaired. The findings also reveal concerns and recommendations for a user-interface design that can adopt the cross-modal interaction approach to accessing visual information and enhance the museum experience of the visually impaired. Creating simpler, easier access requires more humane interaction approaches.

5.2 SINGLE MODALITY OR CROSS-MODALITIES

The act of touch starts from the moment an individual wants to reach out and feel what he or she sees. The urge to touch is almost spontaneous. One touches with one's eyes if one has sight; this is followed by thought, and then the thought touches back, as stated by Derrida (2005). Touch occurs all the time; it can be a physical interaction or a state of mind delivered by sound or verbal description. However, the sound or verbal description must take a recognisable or associable form to trigger the process of mental imagery construction.

The results of the conceptual tactile-audio paper prototype showed that tactile display without verbal description could mean as much as a textural surface to the visually impaired. In this case, the modality of audio (sound) could serve as a form of touch based on thought.

5.3 PROBLEM WITH DIRECT REPLICAS

Although some museums provide options that allow visually impaired or low-vision visitors to touch direct replicas of certain exhibits, certain concerns have been raised based on the viewpoints of the visually impaired. Providing a replica of a museum exhibit may preserve the original, but what does this do to the experience of visitors, particularly those without sight? Are direct replicas too detailed for the visually impaired, who rely solely on their sense of touch?

An identical embossed version taken directly from a two-dimensional painting is defined as a form direct replica. Such replicas often present all of the details of the original artwork. Although such replicas provide an accessible option for the visually impaired to touch the replica, the amount of detail on the replica surface may be overwhelming for these individuals. The representation and interpretation of visual information about a two-dimensional artwork on a tactile display version should result in a simplified version of the original artwork (Axel & Levent, 2002). All of the tactile displays created for this study were carefully converted and made into simplified versions so that they could be easily understood by the visually impaired participants during the pilot testing processes.

When developing an accessible and interactive museum exhibit system for the visually impaired, types and degrees of visual impairments should be considered. How individuals react, choose to manage or are affected by their own disability also define whether an exhibit's information design is a success (Onol, 2011). Therefore, the interpretation of tactile display and audio description should accommodate various optional features as part of the accessible interface if possible to allow the user to personalise his or her experience.

CHAPTER 6 CONCLUSION

Overview

The previous chapters review the case studies and investigate the effectiveness of the haptic-audio interaction design (HAID) approach through the proposed conceptual tactile-audio paper prototypes. Pilot testing and interviews were conducted. Encouraging and positive findings indicate a high potential for helping the visually impaired to perceive visual information and improve the process of mental image construction. This chapter concludes the thesis. Answers to the research questions formulated in Chapter 1 are summarised, and an evaluation of the research process and a reflection on the actions and approach taken to achieve the main objectives of the study are given. The discoveries made during the investigation are also discussed. Future development of this study and further studies of related research topics are also suggested.

6.1 ANSWERS TO THE RESEARCH QUESTIONS

Central Research Question: How can haptic-audio interaction design (HAID) help to enhance the museum experience for visually impaired people in a Hong Kong museum environment?

Key Research Questions: 1) What are the key characteristics of interactivity for the visually impaired? 2) How can the characteristics of interactivity be incorporated into a HAID museum platform design that leads to greater accessibility for the visually impaired and blind?

In response to these research questions, this study took an important first step towards investigating and understanding the inclusivity of the Hong Kong museum environment and how it facilitates visually impaired and blind visitors. Furthermore, the ways in which visually impaired people react to the concept of the HAID approach as proposed in this study were considered through field observations and a series of case studies.

A document published by the United Nations (2012), *The Universal Declaration of Human Rights*, stated that 'everyone has the right to freely participate in the art and cultural life of the community'. Many efforts have been made to shift the perspective of accessibility to create more inclusive art and cultural environments for individuals with disabilities. However, the visually impaired still face multiple challenges in perceiving and understanding information about museum exhibits. The accessibility of visual information about museum exhibits is crucial for visually impaired visitors to construct visual mental images about untouchable exhibits, enhance their museum experience and ultimately create a more accessible and inclusive museum environment. With the objective of gaining a further understanding of ‘touch and sound’ interaction as a fundamental concept, this study investigated the effectiveness of and concerns over using HAID and the cross-modal interaction approach. This approach provides multisensory feedback for visually impaired museum visitors and may help them to evoke and construct visual mental imagery.

The study analysed user need and then conducted pilot testing using tactile displays and/or audio descriptions that offered visual information accessible to visually impaired visitors. The study focused on the touch-activated audio description interactive approach. A conceptual interaction tactile-audio paper prototype was used as an accessible interface between the visually impaired participants and museum exhibits. The concept was also supported by other case studies and experiments discussed in previous chapters.

The results reflected the research questions and objectives, which focused on accessibility, the user experience and the cross-modalities interface design approach for the visually impaired. The findings reveal information about the aspects of social inclusion and communication that strongly affect visually impaired individuals by allowing them to explore, learn about and share their museum experiences and personal insights into museum exhibits. Users' involvement and participation throughout the museum design process is highly crucial when focusing on what should be done from the viewpoint of user needs and on the considerations and consequences of the effects on the visually impaired. This involvement should create a simpler, more accessible and more humane interaction approach for the visually impaired.

6.2 REVISITING THE RESEARCH OBJECTIVES

Objective 1) To investigate whether a touch interaction and audio description with untouchable visual information can be achieved with the aid of an accessible interface between visually impaired visitors and an untouchable museum exhibit.

Objective 2) To explore the effectiveness of a system that integrates an exhibit's visual information using the cross-modal interaction approach of HAID and how the system helps to improve the ability of the visually impaired to access visual information when constructing mental imagery.

In the study, HAID was simulated using conceptual tactile-audio paper prototypes that integrated the visual information of two-dimensional museum exhibits by converting it into touchable tactile displays that included audio descriptions. The prototype was easily accessed by the visually impaired participants. The conceptual tactile-audio paper prototype was used as the main tool in this study to explore the concepts of touch and sound and the effectiveness and limitations of haptic (touch) activated integral auditory (sound) systems. The ultimate goal was to enhance the museum experience of the visually impaired via a proposed accessible option that improved their perception and understanding of the visual information of the museum exhibits. To achieve the aims of this study, the cross-modal interaction approach of HAID was adopted. The research involved field observation, user needs analysis, a literature review and pilot testing with visually impaired participants.

The results indicated that when the participants used tactile displays without audio descriptions or vice versa, they found it difficult to understand the information presented. The visually impaired visitors generally received descriptive information about exhibits from their companions or from museum staff who offered guided tours of the museum. Some also obtained information from braille descriptions or audio devices. The findings of this study indicate that the ways in which visitors currently receive descriptive information is not complete and must include both tactile and audio information.

Researching with the conceptual tactile-audio paper prototype revealed several findings. To be most effective, the tactile display should not be a direct replica of the original exhibit or artwork, but a carefully simplified version with the right amount of visual information that is easily accessed and understood by the visually impaired. The touch-activated audio description should be carefully narrated with visual descriptions that are easily understood by the visually impaired and complement the tactile display. According to the findings of this study, the cross-modal design option is an effective and accessible interface system that allows the visually impaired to perceive and understand visual information and improves mental imagery construction for museum visitors.

Access to detailed information about museum exhibits is crucial for visually impaired visitors to construct mental images of the exhibits and feel that their museum experience is worthwhile. The concept of creating a barrier-free and accessible museum environment for visually impaired visitors should be redefined to include not only an accessible physical environment, but also accessible exhibit information and content. Using the cross-modal interaction approach to create a HAID platform that provides multisensory feedback for visually impaired visitors has great potential to help the visually impaired construct such mental images. An effective HAID platform would also improve social inclusion. When developing the HAID platform, there should be a strong focus on the user's point of view, and the result should be a simple, easy-to-access and more humane interaction solution.

6.3 LIMITATIONS OF THE STUDY

This study provided valuable insights into museum environments in Hong Kong and an in-depth understanding of HAID and the adopted cross-modal interaction design approach. It also revealed the interactivity characteristics of the visually impaired through a series of case studies and interviews. The insights gleaned from this study should contribute to user-interface planning and development in addition to social inclusiveness and communication. This study provided opportunities to conduct field observations at multiple museums and interact with museum representatives. These experiences provided well-rounded insights into the current museum environment and an understanding of the mentality of museum representatives. It is important to acknowledge and discuss some of the limitations that were encountered throughout this study. Hopefully, these experiences can prove useful for future research. The following is a list of some of the limitations encountered.

1. Challenges with Group Interviews—the interviews with groups of visually impaired participants presented a challenge in terms of controlling their active participation and responses, especially as the interviews were conducted by only one interviewee without any assistants or helpers. It was common for more than one participant to respond and speak out at the same time. As a result of the overlapping responses, some of the responses could not be recorded clearly. One-to-one interviews and the pilot studies were conducted

to overcome the aforementioned issues. This resulted in a much longer research time than expected.

2. ‘No Photo and No Video’ Policy—making field observations under the ‘No Photo and No Video’ policy within the museums or exhibition halls presented another challenge. Only limited photographs could be taken for the field observations of the museums included in this study. Audio notes and sketches were time consuming and unreliable in some ways. Therefore, in some cases, telephone call surveys to museum hotlines followed by field visits (conducted to crosscheck the collected information) were used to overcome such limitations and not conflict with museum policy.

3. Tactile Display and Audio Description References and Prototype Making—the inconsistent formatting of tactile display and audio descriptions was an issue for the user-experience analysis and pilot studies. Therefore, reproduced references were required to create more unified and consistent prototypes for the pilot testing exercise. A limited supply of the required materials, the cost of the materials and the machine used to reproduce these references were other limitations encountered throughout this study.

4. Multidisciplinary and Multitasking Role—due to the multidisciplinary nature of this study and given that multiple roles were required, it was very challenging to stay focused on all aspects. Attention was focused on the research activities and conceptual prototype making instead of the academic writing and research paper publication. It was a challenge to strike a balance across all of the aspects. The experiences from the research activities and prototype making had a strong effect on the outcomes of this study and on the thoughts and ideas for possible future work inspired by this study.

6.4 POSSIBLE FUTURE WORKS

In this section, potential future works inspired by this study are discussed and presented. Several opportunities are explored that could allow for more research related to this study, with the aim of creating a more accessible and inclusive environment for visually impaired and blind individuals.

The conceptual tactile-audio paper prototypes experiment showcased the effectiveness of the cross-modal interaction system and concluded that the HAID platform was suitable for implementation in rich visual-oriented environments. A future work should include the creation of a HAID exhibition in a real-life museum or gallery setting by converting a series of two- and three-dimensional masterpieces using the cross-modal interaction approach. This would allow for the further observation and investigation of user feedback in real-life environments. This exhibition could also be used to support the idea of setting up a social enterprise or a non-profit organisation that focuses on improving accessibility for the visually impaired in museum environments using the tools discussed in this study. More ideas about possible future work related to this study are presented as follows.

1. This thesis should be summarised to make it more accessible and inclusive and align it with the fundamental idea of this study. One idea is to abstract all of the crucial points and insights from the study in point form with diagrams. This would allow for an easy-to-read version of this document and allow anyone in a related field or profession or students to refer to this study as a guide or reference.
2. This thesis should be converted into a unified braille version with a compatible audio book to allow any visually impaired or blind individual to access it easily. This would also allow them to give further feedback or continue the discussion related to the topic.
3. Tactile materials and audio technologies that are more affordable to build should be explored. This would decrease costing concerns or budgetary issues for museums or heritage sites. Hopefully, these organisations will opt for accessible options for the visually impaired and blind.

4. The possibility of developing an international unified tactile-audio interaction system code or guidelines should be explored. This would maximise accessibility of different venues for the visually impaired. It would also be a way to improve inclusiveness in learning and social activities. In addition, it would offer more opportunities to share materials and resources.
5. A social enterprise that provides HAID services to museums, heritage sites or other art and cultural venues should be established. These services would help to improve the accessible facilities or programmes of these organisations and create more inclusive environments. Ultimately, a tactile diagram/display/drawing and audio description databank (like a photo or image bank) could be created and serve as an open-access resource hub and platform for visually impaired individuals and education-related institutions and libraries while offering services to the commercial sector when help in this area is needed.
6. The possibility of applying 'touch-activated sound' or the cross-modal interaction approach to three-dimensional printed objects should be explored. How current three-dimensional printing methods can be used to avoid the problem of direct replication, as mentioned in the 'Literature Review' and 'Critical Discussion and Analysis' chapters, should also be explored. This project outcome could also benefit individuals with learning difficulties or autism, another large area of research.

7. One of the findings obtained through the interviews with visually impaired participants revealed that there are limited job options for the visually impaired community. This situation directly affects their ability to be financially secure and therefore affects their quality of life. One idea inspired by this study was to collaborate with blind schools or vocational education institutions to provide intensive training or workshops on tactile displays or tactile diagram making, audio description production and product development in relation to HAID.

This thesis should inspire potential future work in many areas, especially in museum environments, heritage sites and educational institutions. The proposed cross-modal interaction approach should be further developed to help provide more equal and accessible environments for disadvantaged groups in society. This approach could be used in high- or low-tech environments and could be very affective in providing accessible options for individuals with special needs.

APPENDICES

APPENDIX 1:

An overview of the facilities for visually impaired or blind visitors in the 11 Hong Kong museums managed by the Leisure and Cultural Services Department (LCSD).

Museums in Hong Kong	***Tactile Guide Paths***	***Tactile Map***	***Braille Descriptions for Exhibits***	***Audio Kits***	***Tactile Imagery***	***Guided Tour***	***Visually Impaired Workshop***
Hong Kong Museum of Art	Entrance of the museum only, not in the exhibition hall	YES	NO	YES (for regular visitors only)	NO	YES (guides are not trained to facilitate visually impaired/blind people)	NO
Hong Kong Heritage Museum	Entrance of the museum and information counter only, not in the exhibition hall	YES	YES (on limited exhibits only, leaflets and booklets)	NO	NO	YES (guides are not trained to facilitate visually impaired/blind people)	NO
Hong Kong Science Museum	NO	NO	NO	NO	NO	NO	NO
Hong Kong Museum of History	Entrance of the museum and information counter only, not in the exhibition hall	NO	NO	YES (for regular visitors only)	NO	YES (Guides are not trained to facilitate visually impaired/blind people)	NO

Hong Kong Space Museum	NO	NO	NO	YES (for regular visitors only)	NO	NO	NO
Hong Kong Museum of Coastal Defense	NO	NO	NO	NO	NO	NO	NO
Law Uk Folk Museum	NO	NO	NO	NO	NO	YES (guides are not trained to facilitate visually impaired/blind people)	NO
Dr Sun Yat-sen Museum (Hong Kong)	NO	NO	NO	YES (for regular visitors only)	NO	YES (guides are not train to facilitate visually impaired/blind people	NO
Hong Kong Railway Museum	NO	NO	NO	NO	NO	YES (guides are not trained to facilitate visually impaired/blind people	NO
Lei Cheng Uk Han Tomb Museum	NO	NO	NO	NO	NO	NO	NO
Sam Tung Uk Museum	NO	NO	NO	NO	NO	YES (guides are not trained to facilitate visually impaired/blind people	NO

APPENDIX 2:

All questions for the interviews and pilot study are based on the 'tactile imagery guiding principles' proposed by Fuller and Watkins (2010).

An inclusive and holistic approach to guide the museum staff, exhibit curators, designers and fabricators through the process is highly recommended. The following useful guiding principles for approaching the use of tactile exhibits have been developed.

Guiding Principles:

1. Increase **awareness, knowledge or understanding** of a particular topic, concept, phenomenon or theory;
2. Increase **engagement or interest** in the theme(s) of the exhibit;
3. Change **attitudes** about a particular topic, concept, phenomenon or theory;
4. Change **behaviour** towards an exhibit topic; and
5. Increase perceptual, observational and interpretive **skills** as a result of the exhibit experience.

Tactile exhibit elements should be aligned with the principles of universal design as follows. The exhibit must:

1. Be useful for people with diverse abilities;
2. Accommodate a wide range of preferences and abilities;
3. Be simple and intuitive to use;
4. Provide the added dimension of communicating perceptual information regardless of the ambient conditions or the user's sensory abilities;
5. Have no moving parts that are hazardous to use;
6. Require a minimum of effort to use; and
7. Exemplify a design that accommodates an easy approach and can be used regardless of the user's body size, posture or visual acuity.

APPENDIX 3:

An overview of the ‘elements of visual image interpretation principles’ proposed by Lillesand and Kiefer (1994) as a fundamental guide is given as follows.

Elements of Visual Image Interpretation (Lillesand & Kiefer, 1994) – although most individuals have had substantial experience in interpreting conventional photographs in their daily lives (e.g., newspaper photographs), the interpretation of images often departs from everyday photo interpretation in three important ways: (1) the portrayal of features from an overhead, often unfamiliar, perspective; (2) the frequent use of wavelengths outside of the visible portion of the spectrum; and (3) the depiction of the earth’s surface at unfamiliar scales and resolutions. Although these factors may be insignificant to the experienced image interpreter, they can represent a substantial challenge to the novice image analyst. A systematic study of aerial photographs usually involves several basic characteristics of features shown on a photograph. The exact characteristics useful for any specific task and the manner in which they are considered depend on the field of application. However, most applications consider the following basic characteristics, or variations of them: shape, size, pattern, tone (or hue), texture, shadows, site and association.

Shape refers to the general form, configuration or outline of individual objects. In the case of stereoscopic photographs, the object’s *height* also defines its shape. The shape of some objects is so distinctive that their images may be identified solely from this criterion. The Pentagon Building near Washington, DC, is a classic example. All shapes are obviously not this diagnostic, but every shape is of some significance to the photo interpreter.

Size of objects on photographs must be considered in the context of the photo scale. A small storage shed, for example, may be misinterpreted as a barn if size is not considered. The relative sizes of objects in photographs of the same scale must also be considered.

Pattern relates to the spatial arrangement of objects. The repetition of certain general forms or relationships is characteristic of many objects, both natural and constructed, and gives objects a pattern that aids the photo interpreter in recognising them. An outdoor drive-in theatre, for example, has a particular layout and pattern of parking spaces that aid in its identification. Drive-in theatres have been misidentified as housing subdivisions by novice photo interpreters who did not carefully consider size, shape and pattern. Likewise, the ordered spatial arrangement of trees in an orchard is in distinct contrast to that of forest tree stands.

Tone refers to the relative brightness or colour of objects on photographs. Without tonal differences, the shapes, patterns and textures of objects may not be discerned. Colour photography enables an interpreter to exploit differences in *hue*.

Texture is the frequency of tonal change on the photographic image. Texture is produced by an aggregation of unit features that may be too small to discern individually on a photograph, such as tree leaves and leaf shadows. It is a product of their individual shape, size, pattern, shadow and tone. It determines the overall visual smoothness or coarseness of image features. As the scale of the photograph is reduced, the texture of any given object or area becomes progressively finer and ultimately disappears. An interpreter can often distinguish between features with similar reflectances based on their texture differences. An example is the smooth texture of green grass as contrasted with the rough texture of green tree crowns on medium-scale air photos.

Shadows are important to interpreters for two opposing reasons: (1) the shape or outline of a shadow affords an impression of the profile view of objects (which aids interpretation) and (2) objects within shadows reflect little light and are difficult to discern on photographs (which hinders interpretation). For example, the shadows cast by various tree species or cultural features (bridges, silos, towers, etc.) can definitely aid with their identification in air photos. Furthermore, the shadows resulting from even subtle variations in terrain elevations, especially in the case of low-sun-angle photographs, can aid in assessing natural topographic variations that may be diagnostic of various geological landforms.

Site refers to topographic or geographic location and is a particularly important aid in the identification of vegetation types. For example, certain tree species are expected to occur on well-drained upland sites, and other tree species are expected to occur on poorly drained lowland sites. Furthermore, various tree species occur only in certain geographic areas (e.g., redwoods occur in California, but not in Indiana).

Association refers to the occurrence of certain features in relation to others. For example, a Ferris wheel may be difficult to identify if it is standing in a field near a barn, but easy to identify if it is in an area recognised as an amusement park.

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