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SCHOOL OF SCIENCE
DEPARTMENT OF INFORMATICS AND TELECOMMUNICATION

BSc THESIS

Enhancing the museum experience through seamless and intuitive digital guidance

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ATHENS

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ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ΣΧΟΛΗ ΘΕΤΙΚΩΝ ΕΠΙΣΤΗΜΩΝ

ΤΜΗΜΑ ΠΛΗΡΟΦΟΡΙΚΗΣ ΚΑΙ ΤΗΛΕΠΙΚΟΙΝΩΝΙΩΝ

ΠΤΥΧΙΑΚΗ ΕΡΓΑΣΙΑ

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ΑΘΗΝΑ

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ABSTRACT

In the last decades, technology has created a culture of instant gratification to the point where people expect to be able to access information and entertainment at a moment's notice. The desire for rapid content consumption is reflected in individuals opting for more captivating and fast-paced activities. In response to this shift, museums and other cultural institutions have had to adapt to engage and educate their visitors. Adopting digital guides and interactive technologies allows them to cater to the needs of modern audiences and their expectations of fast and easy access to information. This comes with the risks of excluding visitors with disabilities or limited exposure to such technology. Therefore, it is crucial to thoroughly study the design of digital museum applications.

This thesis aims to investigate the design of a digital museum guide app that effectively reduces distractions and minimizes non-informative screen time, enabling visitors to fully engage with and appreciate the museum's exhibits. By simplifying the app and incorporating user-friendly gestures, this study seeks to provide a seamless and inclusive digital guidance experience for visitors with different accessibility barriers.

SUBJECT AREA: Human-Computer Interaction

KEYWORDS: Mobile Application, Audio Guide, User Interface Design, Ubiquitous Computing, User Interfaces for All, Digital Cultural Heritage

ΠΕΡΙΛΗΨΗ

Τις τελευταίες δεκαετίες, η τεχνολογία έχει δημιουργήσει μια κουλτούρα άμεσης ικανοποίησης σε βαθμό που η πρόσβαση σε πληροφορίες και ψυχαγωγία αναμένεται να είναι στιγμιαία. Η επιθυμία για γρήγορη κατανάλωση περιεχομένου αποτυπώνεται στο γεγονός ότι ο κόσμος επιλέγει πιο εντυπωσιακές και ταχύρρυθμες δραστηριότητες. Για το λόγο αυτό, τα μουσεία και λοιπά πολιτιστικά ιδρύματα χρειάστηκε να προσαρμοστούν ώστε να εκπαιδεύσουν και να κινήσουν το ενδιαφέρον των επισκεπτών τους. Η απόκτηση ψηφιακών οδηγών και διαδραστικών τεχνολογιών, τους επιτρέπει να ικανοποιούν τις ανάγκες του σύγχρονου κοινού τους και τις προσδοκίες τους για άμεση και εύκολη πρόσβαση στη πληροφορία. Αυτό συνεπάγεται το ρίσκο να αποκλειστούν επισκέπτες με αναπηρίες ή με περιορισμένη έκθεση σε αντίστοιχες τεχνολογίες.

Σκοπός της παρούσας είναι να εξεταστεί ο σχεδιασμός μιας ψηφιακής εφαρμογής μουσειακού οδηγού που μειώνει τις αποσπάσεις και τον χρόνο που απαιτείται η χρήση της οθόνης για μη ενημερωτικούς λόγους. Με τον τρόπο αυτό, επιτρέπει στους επισκέπτες να αλληλεπιδράσουν και να εκτιμήσουν τα εκθέματα του μουσείου στο έπακρο. Απλοποιώντας την εφαρμογή και ενσωματώνοντας κινήσεις εύκολες στη χρήση, η παρούσα πτυχιακή επιδιώκει να προσφέρει μια απρόσκοπτη ψηφιακή μουσειακή εμπειρία για όλους, ανεξάρτητα από αναπηρίες ή ψηφιακού γραμματισμού.

ΘΕΜΑΤΙΚΗ ΠΕΡΙΟΧΗ: Αλληλεπίδραση Ανθρώπου – Η/Υ

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ: Κινητή Εφαρμογή, Ακουστικός Οδηγός, Σχεδιασμός Διεπαφής Χρήστη, Διάχυτη Υπολογιστική, Διεπαφές Χρήστη για Όλους, Ψηφιακή πολιτισμική κληρονομιά

To my mum, my dad and Nefeli

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PREFACE

This project took place in the Department of Informatics and Telecommunications of the National and Kapodistrian University of Athens as a bachelor thesis under the supervision of Dr Maria Roussou. Its duration from its start until its completion was one semester.

1. INTRODUCTION

1.1. Subject and Motives

The quest to incorporate digital technologies in cultural institutions has sparked the emergence of immersive exhibitions and increased creativity in presenting information to foster memorable experiences and meaningful connections with the topics at hand. Meanwhile, technology can potentially detract from those experiences if it becomes obtrusive or challenging. This is often the case when interacting with the technology requires taking the visitor's attention from the actual heritage content to perform operational tasks. Especially for visitors with disabilities or limited familiarity with technology, innovative approaches may break immersion, disrupting the flow of thoughts and emotions that the exhibits are meant to evoke.

As Kidd and Nieto McAvoy noted, "deep immersion in an experience is best achieved when the technology becomes invisible – that is, it fades into the background rather than itself being the experience as noted above" [1]. To best incorporate digital solutions in cultural settings, they must be user-friendly, easy to navigate, and provide clear instructions to encourage visitors to interact with the technology. Especially for visitors with disabilities or limited familiarity with technology, such approaches may serve as a distraction, disrupting the flow of thoughts and emotions that the exhibits are meant to evoke.

The present thesis seeks to address this challenge and explore the design of a more inclusive and frictionless digital audio guide using a simplified interface and Near Field Communication technology [2] to trigger app workflows. The goal is to reduce cognitive load, improve accessibility, and enhance the overall museum experience for all visitors. We use the Museum of Informatics and Telecommunications of the National and Kapodistrian University of Athens as a case study to attempt to contribute to the broader field of museum studies and encourage a shift towards more inclusive and transparent museum experiences.

1.2. Context of Use

The Museum of Informatics and Telecommunications, or MI&T, founded in 2019, is one of the museums of the National and Kapodistrian University of Athens, NKUA. It is currently not open to the public as it is undergoing construction. The MI&T hosts the archive and collections of the Department of Informatics and Telecommunications, DIT. One of its key objectives is to promote awareness and interest in the field among the general population.

Specifically, the museum will offer a comprehensive history of Informatics and Telecommunications from the 1940s to the present day in Greece and the rest of the world. It will highlight the research and educational activities of the department, illuminating the history of Informatics as a science and its effects on our daily lives. The museum aims to expose the concept of computational thinking and its applications to the public. Its target audience includes the DIT community of students and researchers, prospective students, specialized visitors, and the general public.

The MI&T is located on the ground floor of the Department of Informatics and Telecommunications, below its Reading Room, where the first University-wide Data Centre was initially housed. The museum will consist of 4 main halls, as depicted in Figure 1: the Entrance, the Introduction room, the Main hall, and the public part of the museum's Archive.

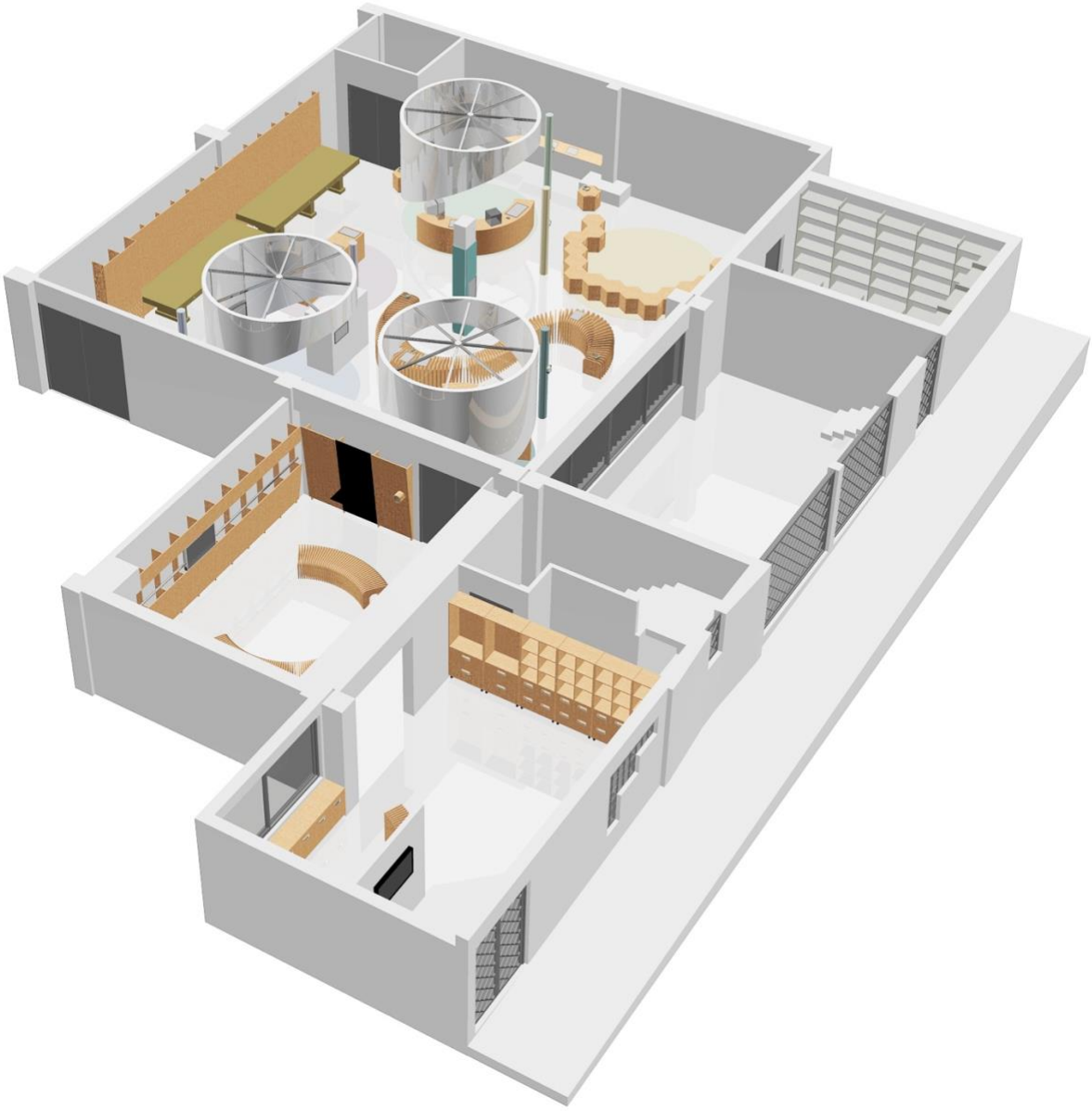

Figure 1: Digital 3D floor plan of the Museum of Informatics and Telecommunications. NKUA, eStories, 2021

In the Introduction room, the visitors will explore an interactive timeline of the history of Informatics and Telecommunications, wall prints and showcases with objects from the department's collection and a special exhibit of the logarithmic rule as a precursor of computers. The Main hall will host six core sections: the Mathematical Computer (the 40s-50s), the Business Computer (the 50s-60s and into the 70s), the Personal/Home Computer (the 80s), the Networked Computer (the 90s), the Creative Computer (the 00s), and the Ubiquitous Computer (the 10s+).

The MI&T seeks to put the visitor at the center of the museum experience. It aims to make the visitor actively participate in the exhibition by interacting with some of the exhibits. There will be digital tables, flexible digital interactive surfaces, audio stories, and social interaction among visitors will be encouraged. The architectural design of the MI&T consists of suspended ceilings and color-coded open areas that let the visitor walk around freely, explore, and examine any of the six time periods sub-areas.

Figure 2: Digital 3D rendering of a unit within the Main hall of the Museum of Informatics and Telecommunications. NKUA, eStories, 2021

The museological study conducted for the Museum of Informatics and Telecommunications has addressed a plethora of design decisions to accommodate visitors with disabilities, including the installation of a ramp at the museum's entrance, restrooms for disabled visitors, free-standing exhibits and display cases at an appropriate height, open space areas with wide corridors for wheelchair movement, rest areas or benches, and signs with suitable typeface, color, size, and height for easy reading [3].

With its multitude of interactive activities and multimedia exhibits, and its commitment to creating an inclusive environment, the Museum of Informatics and Telecommunications is designed to provide an immersive experience for all. This thesis aims to explore the design of a seamless audio guide in such an environment, highlighting its benefits in providing more accessible access to information and facilitating a deeper engagement with MI&T's artifacts.

1.3. Structure

This thesis consists of 4 chapters, which can be summarized as such:

1. Introduction: The previous sections outline the focus of this work and present an overview of the Museum of Informatics and Telecommunications, which will act as the use case for this thesis.
2. Background and Related Work: Chapter 2 delves into the literature of museum guides and the respective user experience research conducted to identify their

users' needs and ways to improve. It also mentions concepts and research projects that inspired this work, such as ambient intelligence and universal design.

3. Design: Chapter 3 consists of the idea around the design of the mobile application, and the user-centered design process. It provides an in-depth look at the user personas developed, user scenarios and several requirements and specifications to cater to their needs. High-fidelity prototypes are also included, along with descriptions of their usage.
4. Conclusions and Future Work: Chapter 4 discusses the results of the design process and possible areas for future work, including the integration of the audio guide with more advanced features, the development of a user testing and evaluation plan and the implementation of the app.

2. BACKGROUND AND RELATED WORK

2.1. Museum Guides

In this section, we will examine case studies and concepts of existing museum guides and their impact on the research focus of this thesis; we will analyze their design and features and identify aspects relevant to this thesis.

To attract visitors in the competitive landscape of entertainment options, cultural hubs must provide captivating experiences. Mobile technologies have played a significant role in attracting new audiences to museums accommodating visitors with varying preferences and needs. Roussou and Katifori [4] investigated the user experience of mobile museum narratives. They found that while diverse content can enhance the experience, it poses challenges, such as balancing visitors' attention between the screen and the physical space, ensuring proper navigation, balancing story and interpretive content, and catering to diverse user profiles.

Among the many mobile-based solutions, the Bring Your Own Device, or BYOD, approach allows visitors to use their own smartphones or tablets during their museum visits. This model has become increasingly popular in museums of all sizes due to its cost-effectiveness and the fact that visitors are already using their devices for recreational purposes during their visit, such as taking pictures of the exhibits or seeking additional information [4]. However, there are also challenges to consider when implementing the Bring Your Own Device solution, namely the need for a stable and reliable network connection and ensuring that the content is accessible to visitors with different devices and operating systems and mitigating distraction from the exhibit content [5].

An example of a project that has gradually adopted the Bring Your Own Device model is the "British Museum Audio" [6] guide for the British Museum in London. It consists of a museum map and additional multimedia content for the museum's galleries and exhibitions. Until 2022, the guide could not be downloaded on the visitors' devices and had the form of a mobile-like lightweight device owned by the museum. Nowadays, it comes in the form of a mobile application that offers a more personalized experience by allowing visitors to save their favorite tours or download content to their devices.

In 2014, five years after its initial launch, a need for a user-centered redesign was noticed. A research paper presented at the "Museums and the Web" conference in 2015 [7] revealed the findings of a qualitative study performed at the British Museum regarding visitors' behavior and preferences towards audio guides.

The research revealed that 75% of the guide's users heavily depended on it as their primary means of navigating and obtaining information. Around 15% to 20% of the users made "sporadic and often disinterested use of the audio guide" and often appeared to quit after a few stops. This behavioral pattern valued the freedom to explore the museum at their own pace, and only approach exhibits that sparked their interest. Another interesting observation was that this group was very involved with their devices, phones, tablets, or cameras.

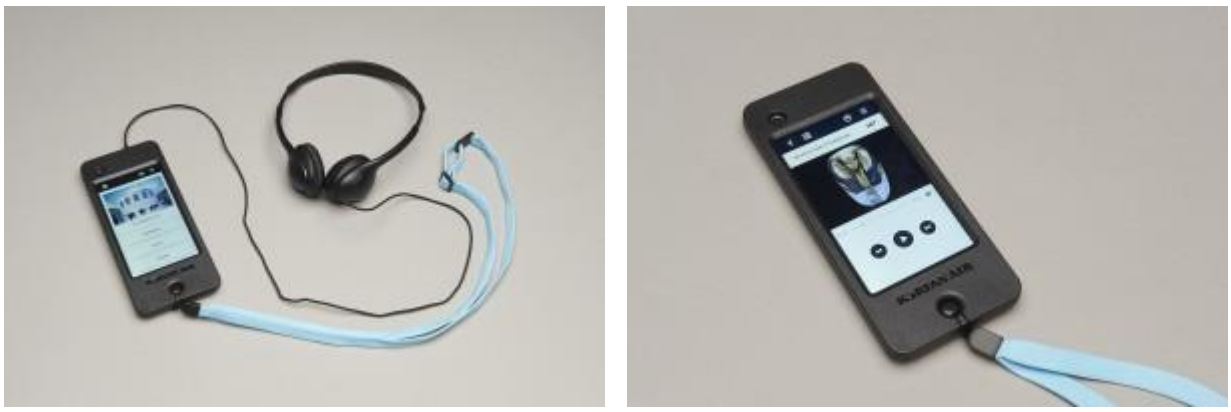

Figure 3: British Museum Audio guide's equipment and audio media player, 2015. GLAMi Nomination, Audio guide at the British Museum

Currently, the guide is compatible with mobile devices and consists of a gallery- and tour-based mode. The tour-based mode consists of self-guided tours with a list of stops and an estimated duration. Visitors choose a tour and follow the guide's instructions via audio and text. Alternatively, in the gallery-based mode, visitors can selectively explore the exhibits and browse at their own pace listening to the stops in any order they desire.

To use the guide, visitors can enter the number next to the exhibit into the app's keypad. Each stop lasts approximately 2 to 3 minutes, showcasing the artifact's high-quality images and additional resources such as related exhibits and other reading materials.

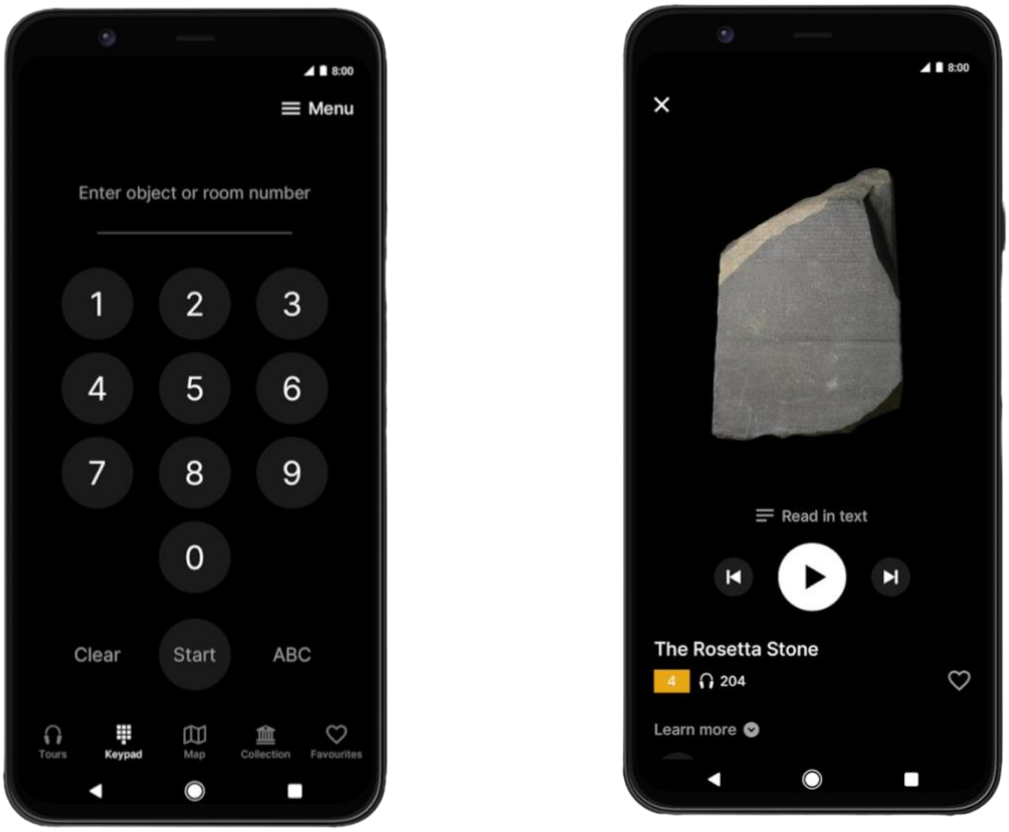

Figure 4: British Museum Audio's application screenshots of the audio media player and keypad screen, 2023. The British Museum Audio app

Regarding accessibility, the app states that its visitors should be able to "navigate easily between sections, select a tour, listen to a tour, change the text size, use the app with a screen reader", meeting the Web Content and Accessibility Guidelines 2.1 standard.

Additionally, as showcased in Figure 4, the audio content is accompanied by a “Read in text” option, benefiting individuals with hearing impairments.

Despite being an accessible and usable application grounded in user research and a valuable case study for this thesis, the “British Museum Audio” still presents certain limitations. Its reliance on entering a key or browsing the app’s collection to access information may disrupt the visitors’ immersion by moving their interest from the exhibits to the screen.

Another potential issue of the “British Museum Audio” guide is the absence of social engagement, attributed to its lack of features that inspire visitors to share their experience with their social circle. To incorporate the social aspects of a museum experience in this study, we examined a project that focuses on providing museums with such features, “the GIFT Box” [8].

“The GIFT Box” is an EU-funded research project that has developed a smartphone app for museums to encourage visitors to share their narratives and emotions based on the exhibits they encounter during their visit. The program has collaborated with multiple museums that worked as case studies and aided the research process. The “GIFT App” is a simple interface allowing visitors to share their own multimedia creations inspired by the museum’s artifacts.

Each visitor may give or receive up to three “gifts”, each consisting of a picture of the selected object, a voice message of their thoughts and a text hint with instructions to find the exhibit. The gift can be as long or short as the giver intends to and can be sent to people within the museum or elsewhere.

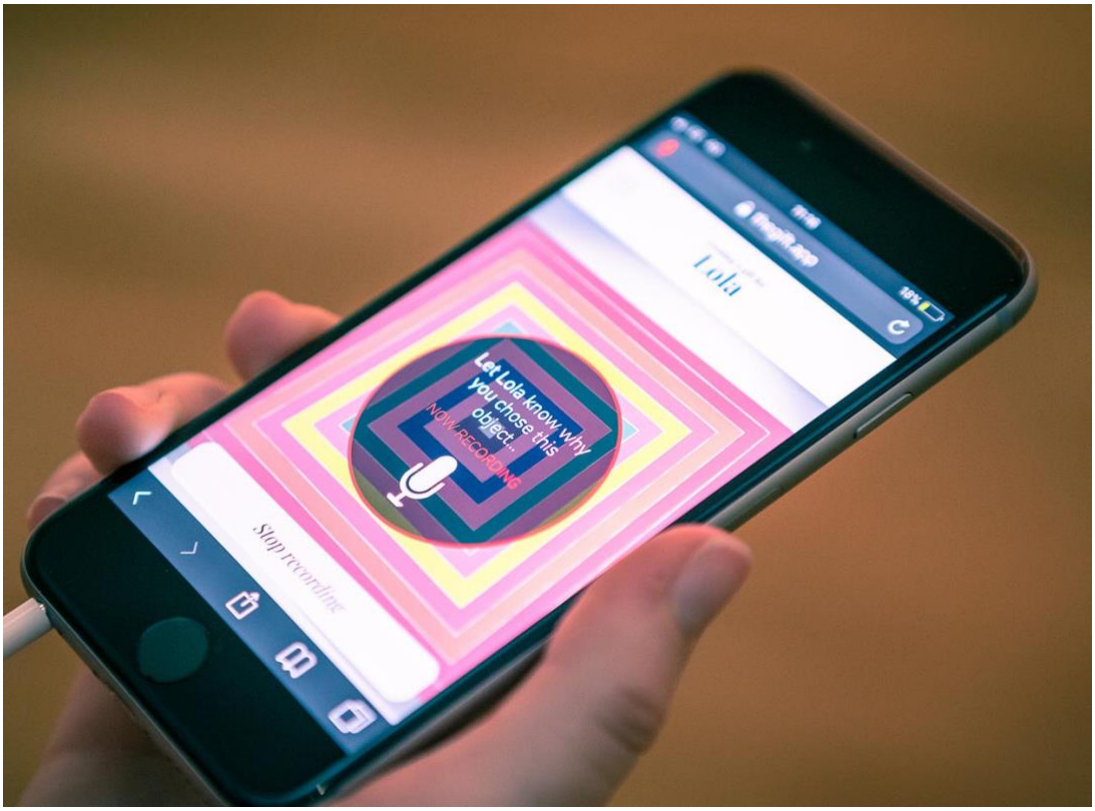

Figure 5: Recording screen of the GIFT mobile application. Gift project, Blast Theory

One of the pilot cases of the gifting experience at the Brighton Museum & Art Gallery resulted in several noteworthy findings [9]. Visitors in the study reported that they viewed the museum from a fresh perspective, “imagining what their receiver would like, or what their giver had thought they would like” [10], which also led to them feeling connected to

the objects they sent or received. The application's instructions were given in both text and audio, delivered in a casual tone, and vocabulary influencing the gifting process and overall museum experience. The research revealed that directing the experience toward audio was a successful method to keep the visitors from shifting their attention to their devices.

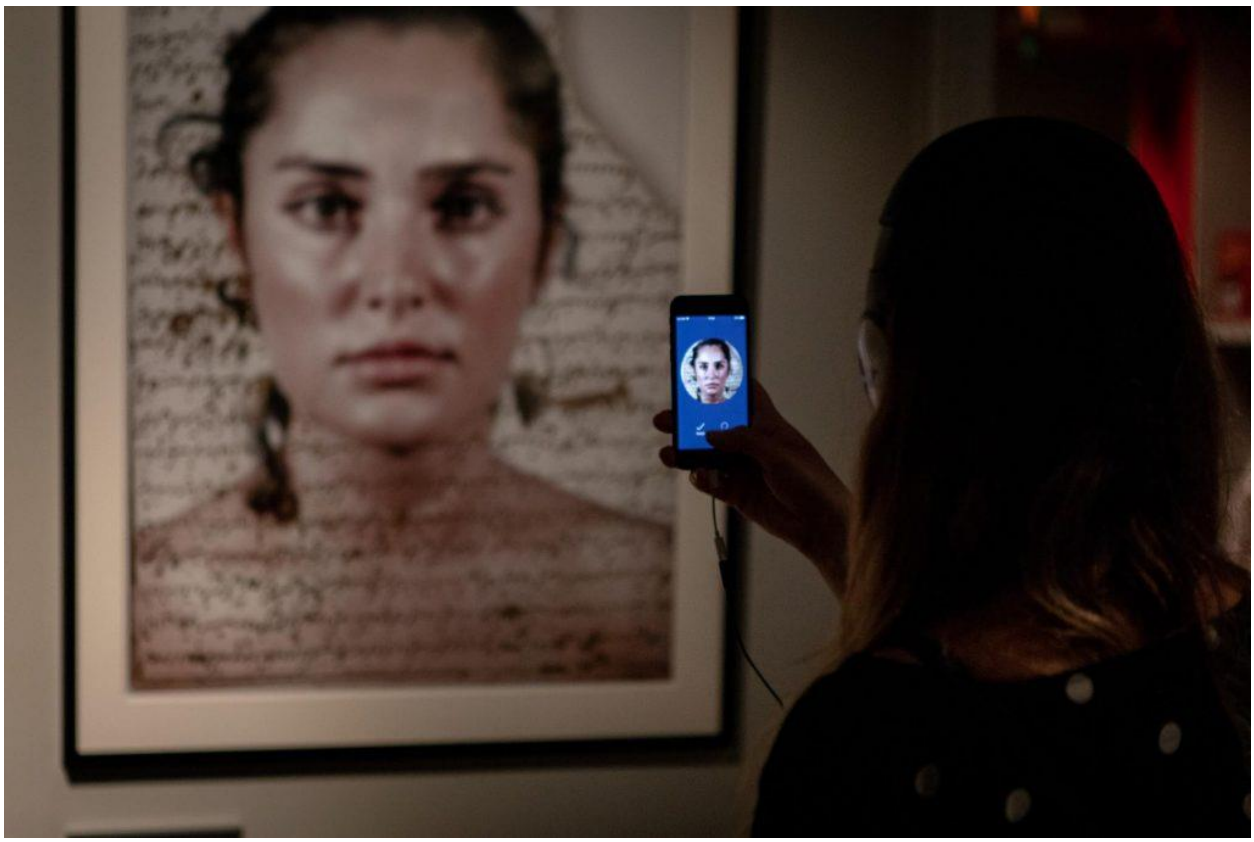

Figure 6: A visitor of the Brighton Museum & Art Gallery that has found the exhibit of the gift they received through the GIFT application. MW19 Boston, The GIFT Framework: Give Visitors the Tools to Tell Their Own Stories

The "GIFT App" serves as a means for sharing user-generated content and achieving social impact while facilitating a multifaceted appreciation and more thorough exploration of the exhibits, aspects that we seek to incorporate in our research.

Fostering a frictionless guiding experience within the scope of accessibility is another key objective of this thesis. Notably, "Out Loud" [11], an inclusive audio guide for the Andy Warhol Museum in Pittsburgh, uses Bluetooth to show visitors stories based on their location. It focuses on accessibility and specifically aims to design an optimized experience for visually impaired visitors.

In terms of design, the user research showed that visitors preferred a sense of independence within the museum and the freedom to make their own choices [12]. In response, each artwork is accompanied by short audio clips of categorized content, such as an introduction, historical context, and visual description, rather than a single longer clip with all the information. Visitors also expressed their desire to limit physical interactions as they often use service dogs, canes, or guides to navigate within the museum.

"Out Loud" is compatible with iOS and supports VoiceOver, the system's built-in feature to describe on-screen elements and Dynamic Type for text size customization. While implementing the application, researchers concluded that announcing state changes, such as audio autoplay, cross-checking text-to-speech conversions and maintaining a

consistent semantic structure are crucial to ensure successful screen-reading compatibility. They also took advantage of “Magic Tap”, a two-finger double tap which can be assigned to an app-specific action as they discovered that VoiceOver users were instinctively using it to perform intuitive actions such as pausing the audio.

To fully accommodate users with visual impairments, the interface adjusts to the use of VoiceOver. When VoiceOver is enabled, a visual description audio file is prioritized and moved at the top of the audio clips list, following a brief introduction. Upon user testing, a pattern was noticed indicating that all of the participants who relied on the VoiceOver functionality to navigate through the app preferred to choose when to play the next audio chapter, while testers who did not use VoiceOver favored autoplay. To cater to both preferences, the default setting is to autoplay, but this functionality is disabled when VoiceOver is activated.

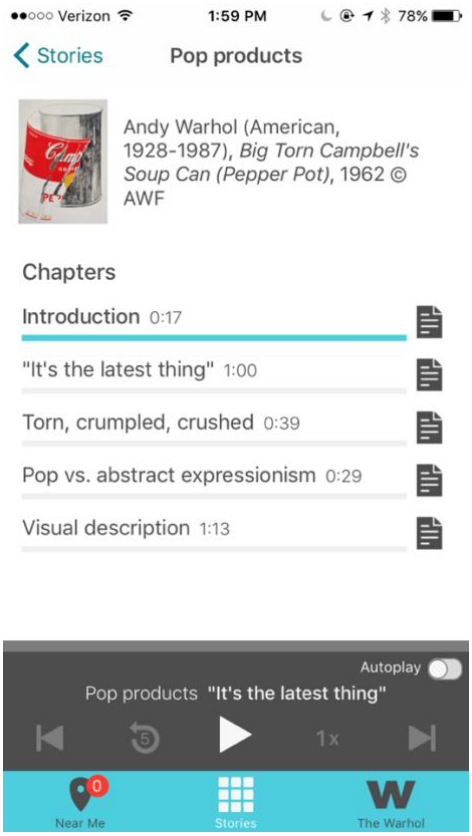

Figure 7: Out Loud’s application screenshots of audio media player. MW17 Cleveland, A Path With Choice: What We Learned From Designing An Inclusive Audio Guide

The application consists of two modes (Figure 7), the “Stories” view, which displays all available audio descriptions and the “Near me” view, which filters the audio based on location. To achieve the latter, it used Bluetooth low-energy beacons. The initial strategy was to place one beacon per exhibit and deliver the audio of the one with the strongest signal. This implementation proved unsuccessful and caused the guide to autoplay incorrect audio, switching between objects. Consequently, an adaptation was made, and beacons were placed to cover an entire room, filtering the audio per room instead.

Sharing the same goal for a seamless museum experience, Pedersen et al. conducted a research [13] on designing a soundwalk with “no interface” in the process of creating Bezæt, an audio walk for the history of the squatter movement in Copenhagen. The idea entailed of users listening to audio stories narrated by members of the movement as they would walk through their neighborhoods.

Their initial design using map-based navigation relieved a set of drawbacks during the testing phase. The GPS positioning was not accurate enough to guide the users successfully and often caused user frustration, while the map interface proved to be a source of distraction. Given that the purpose of the experience is to immerse users in the urban environment, Bezæt's design was revisited to deter users from looking at the screen of their devices and instead direct their attention to their surroundings. The map-based prototype was replaced with a minimal GUI containing solely the necessary audio controls and a single map screen showing the starting point of the walk. This translated to an increased need for highly descriptive audio navigation instructions and orientation hints. The design evaluation showed that the lack of GPS and a map interface did not hinder the participants' ability to navigate the soundwalk route. Many reported feeling more in control of the experience and enjoyed the simple design.

"Talking Statues" [14] aimed to achieve a non-disrupting interface for an outdoor cultural experience as well. In 2014, Sing London, alongside several partners, created a website that would host "conversations" of users with statues found around London [15]. Given that the experience primarily catered to pedestrians passing by the statues, it was deemed necessary to eliminate the need for users to download an application in advance. A website was created for this purpose, and the user journey was designed as follows.

After locating a statue, the user taps their phone on the statue's tag, scans the QR code or manually types a URL address to trigger the launch of the website, which imitates a Phone Call screen. The user accepts the "call" from the statue, and a pre-recorded audio file is played. Following the call, the user is redirected to the statue's page to access further information, view a map of other available statues, and share their experience with others.

Figure 8: Adhesive signs added on each statue, prompting visitors to tap for NFC, scan the QR code or type in the URL. MW2015, BoW, Statue Stories Chicago

Figure 9: Audio file streaming launched by interaction with the statue'. MW2015, BoW, Statue Stories Chicago

The project examined how Near Field Communication could attract non-traditional audiences, such as the youth or people with disabilities, and encourage them to participate in participating cultural activities. Observations and interviews with users of Talking Statue showed that people of different ages and museum-going frequencies were using the NFC technology. Even though iOS mobile phones, the most commonly used type among participants, did not support NFC at the time of the study, users still opted for alternative methods. However, 40% of users were able to use NFC to access Talking

Statues, potentially due to the assistance of research staff who helped older or less technologically confident users and lent devices to those without NFC-compatible phones. Some of them stated that the facilitators' help was crucial to their ability to access the content. Although instructions were sometimes misunderstood, such as users trying to tap the sign with their fingers or feet instead of their phone, 80% of users agreed that "using NFC/QR tags made the experience more enjoyable".

Almost a decade later, NFC usage has increased, and more smartphone users are familiar with the technology [16]. However, their user research showed that more explicit instructions are needed to make the interaction more inviting to older or unfamiliar users. While Talking Statue is intended for an outdoor setting where the statues are scattered throughout the city, its call-and-answer interaction could become tedious and repetitive in a museum context where exhibits are more closely situated. Nevertheless, the overall design of the application closely aligns with the scope of this thesis. It serves as a significant source of inspiration alongside certain aspects of the previously mentioned projects.

2.2. Ubiquitous Computing

According to Mark Weiser, 1991, ubiquitous computing, also called ubicomp, "enhances computer use by making many computers available throughout the physical environment but making them effectively invisible to the user" [17].

Ubiquitous computing is a concept whose primary objective is to make human interaction with technology more natural, similar to the way humans interact with the physical world. This can be achieved by using natural forms of communication, such as speech, touch, gestures, and haptics, called Natural User Interfaces [18], to supplement or replace traditional GUI interfaces. These natural interfaces carry minimal cognitive overhead and should, by definition, be easier to use for children, inexperienced users, and those with disabilities, who would find traditional interfaces less accessible.

In the context of cultural settings specifically, their main challenge is "to design a multimedia presentation in such a way that it will convey the information to the visitors, thus enriching the visit experience, without distracting their attention from the exhibits themselves" [19]. User experience evaluations ([4], [19], [20], [21], [22]) and related work mentioned in 2.1. have proven that digital museum guides can hinder visitors from focusing on their surroundings, often absorbed by the screen, or preoccupied with navigating the interface.

Although the MI&T digital audio guide we have designed does not fully align with the principles of ubicomp, it inspired the subject of this thesis and led to the idea of using Near Field Communication to provide a more seamless experience. At this point, BYOD is a widespread model that allows us to approach unobtrusive guidance, though eventually, our goal would be to utilize the full potential of ubiquitous computing.

2.2.1. Near Field Communication

Near Field Communication, also known as NFC, is a form of ubiquitous interaction which allows for short-range wireless communication between two compatible devices. It was developed by Philips and Sony in 2002 and is based on radio-frequency identification, RFID, a technology that enables two devices to communicate with each other by sending and receiving radio signals. NFC uses a base frequency of 13.56 MHz to transfer data up to 424 Kbit/s at a distance of 4 cm [2]. The communication requires an initiator device, which triggers and controls the data transfer and a target device that replies to the

former's request [23]. Although NFC technology currently operates in multiple modes, some of which are the [24]:

1. Reader/Writer mode, where a contactless reader, such as an NFC reading device or mobile phone, can access or modify information stored in a contactless tag. This is a case of passive NFC technology as only one device generates the radio frequency and energy required to communicate with an inactive object.
2. Peer-to-Peer mode, where two NFC devices are brought together to exchange data. In this active NFC communication, the peers recognize each other and generate their own radiofrequency field and broadcast data within that field.
3. Card emulation mode, where an NFC device operates as a contactless card, often used for contactless payments or ticketing in public transport.

During the COVID-19 pandemic, NFC became exponentially popular in a plethora of fields as it was an efficient solution to adopt within a short time window to ensure the safety of the population. A survey by ABI Research was conducted in 2022 to determine the behavior and understanding of consumers regarding Near Field Communication [16], while considering the pandemic's impact on their familiarity with it. The study collected answers from 2620 participants worldwide, aged 18 and over, who had used contactless technology at least once.

Their findings showed that 95% of them were at least somewhat familiar with NFC contactless technology and it was stated that a steady increase in NFC usage is expected in the near future. Given that such a large fraction of the population is equipped with a basic intuition to interact with an NFC tag successfully, it became our tool of choice to create a ubiquitous system within cultural institutions.

2.3. User Interfaces for All

In the context of designing mobile interfaces for all users, it is important to consider the principles and methods of inclusive design. As noted by Stephanidis [25], the primary objective of inclusive design is to create products and services that can be used by the widest possible range of individuals, regardless of their abilities.

The design of mobile interfaces is centered around finger-based gestures that rely on a multi-touch interface. While this may be intuitive for experienced users, for individuals who lack digital literacy or have disabilities, such gestures can pose significant challenges and create barriers to accessing the full range of features and functionalities offered by mobile devices. These users may struggle to hold the device in the correct position, view the screen, and perform delicate touch actions, rendering many mobile apps and features inaccessible [26].

To achieve inclusivity and accessibility, it is important to seek alternative methods and technologies that enable all users to interact with the application successfully and effortlessly, regardless of their physical abilities or digital literacy levels. Ultimately, our goal is to ensure that visitors with disabilities can equally benefit from every feature of the mobile application, just like visitors who do not have disabilities and are fluent in mobile device use.

3. DESIGN

3.1. The Idea

The increasing cognitive load we have been trained to handle by the constant use of technology in our daily lives has created the expectation for museums and cultural hubs to provide their visitors with access to digital resources that enhance their visit. Despite the trend towards digital museum guides, many of these guides fail to provide a seamless and inclusive experience for visitors with disabilities or limited digital experience.

This thesis examines the creation of a digital guide for the Museum of Informatics and Telecommunications of the National and Kapodistrian University of Athens. It aims to offer visitors a simplified and intuitive interface that delivers digital guidance without sacrificing their immersion in the exhibits.

To ensure visitors with different accessibility barriers can have access to an equally rewarding visitor experience in terms of content and usability, the application incorporates gesture-based and contactless technologies, such as Near-Field Communication. The interface is designed to be intuitive and mitigate potential distractions, allowing visitors to fully immerse themselves in the museum exhibits while ensuring that information is always accessible. This way the app will serve as a discreet assistant that will enhance the overall museum experience without sacrificing visitor engagement or disrupting their immersion in the museum's content.

Finally, a "souvenir" feature of the MI&T museum guide app enables the extension of its social impact to the digital realm through a camera page and a recording page. The concept involves each exhibit having its own simple Augmented Reality camera screen that will show basic information about it in the form of an overlay, allowing the visitors to capture photos or videos tagged with the name of the exhibit. Alternatively, a recording page may be selected instead to create a sound-based reminder of the exhibit and their interaction with it. These features provide a unique, self-captured digital keepsake that can be saved to the visitor’s device, allow them to share their experience with others and create a lasting token of their time at the museum.

3.2. User Groups

The Museum of Informatics & Telecommunications digital guide is committed to providing an enjoyable experience for all its visitors, including those who may face technological challenges or have disabilities. The application caters to the diverse needs of its visitors by offering a straightforward and intuitive interface.

To achieve this, in this thesis we have chosen to focus on two main user groups who have distinct preferences and requirements for museum guidance: who may have physical disabilities and those who experience low vision. We believe that by designing with these groups in mind, we can create an application that is more usable and accommodating for “All” [25].

Visitors with fine motor difficulties consist of the first user group of the application. For the sake of clarity, this group will henceforth be referred to as ‘Visitors with limited dexterity' throughout this thesis. Within this group lie people who may have physical disabilities that make it challenging for them to use traditional touchscreen devices or to fully view and touch exhibits. They aim to access supplementary content related to the exhibits without feeling restricted or challenged by potential physical limitations.

The second user group, ‘Visitors with low vision’, often face challenges in traditional museums due to visual impairments. These individuals may struggle to view exhibits,

read information, or follow written instructions, making it difficult for them to fully experience and appreciate exhibitions. Their primary motive for using the digital guide is to gain a better understanding of the exhibits through detailed audio descriptions without the need for excessive phone interactions.

3.3. User Personas

The different expectations of each user group's profile lead to a variety of needs that ought to be taken into consideration while designing the application. To help comply with usability principles and achieve user satisfaction, two user personas have been created to represent the two user groups mentioned in 3.2.: 'Visitors with limited dexterity' and 'Visitors with low vision' which are visitors with visual disabilities and physical limitations associated with low dexterity. The persona writing follows Nielsen's technique as described in Personas – User Focused Design [27] and aims to present the users as human beings rather than lifeless characters. Therefore, it consists of demographic data, technology and museum experiences, relationship with the field of Informatics and Telecommunications, and their personal needs and preferences in terms of the application use.

By focusing on these specific personas, we aim to ensure that the MI&T digital guide application accommodates visitors with these disabilities and provides a seamless and inclusive experience.

3.3.1. Visually Impaired Visitor

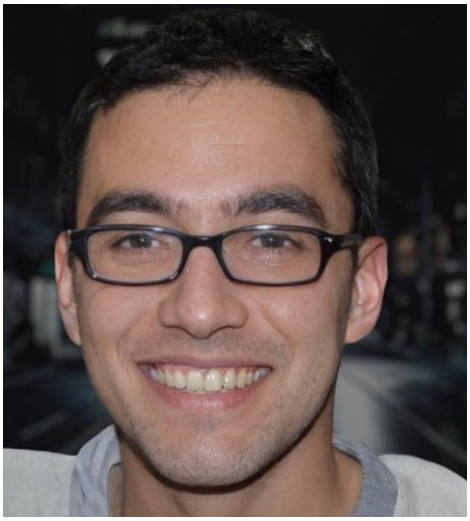

Figure 10: Portrait of Alexis Panagiotopoulos. AI-Generated, This Person Does Not Exist 2022

Table 1: Description of Alexis Panagiotopoulos

Name	Alexis Panagiotopoulos
User Group	Visitors with low vision
Age	19
Place of Birth	Voula, Greece
Disability	Loss of central vision

Quote	“You truly know something when you can explain it in your own words.”
Museum Experience	Avoids visiting museums because he gets overwhelmed and feels like an outsider.
Technology Experience	Advanced use of technology and accessibility features, struggles with complex visual interfaces.
Relationship with Informatics and Telecommunications	Has shown an interest in technology since a young age, aspires to do research in Natural Language Processing.

3.3.2. Low Dexterity Visitor

Figure 11: Portrait of Areti Christidi. AI Generated, This Person Does Not Exist 2022

Table 2: Description of Areti Christidi

Name	Areti Christidi
User Group	Visitors with limited dexterity
Age	51
Place of Birth	Thessaloniki, Greece
Disability	Rheumatoid arthritis
Quote	“General knowledge for various topics sparks interesting conversations and makes the world more interesting.”
Museum Experience	Visits museums often, always with a guide, appreciates the general knowledge she gains.
Technology Experience	Limited use of computers due to the discomfort caused by operating keyboard and mouse. Occasional, basic

	phone usage, finds it difficult to use smaller screens and buttons.
Relationship with Informatics and Telecommunications	Admires assistive technology for its effect on our daily lives.

3.4. User Scenarios

In this section, we will present user scenarios for the personas mentioned in 3.3. representing each user group, to offer a detailed understanding of how different users will interact with the application. The scenarios will encompass a range of tasks and activities, highlighting the various features and functions of the app, and demonstrating how the app will assist the users in achieving their goals.

3.4.1. Low Vision Scenario

Alexis has been assigned to do a presentation for the course History of Informatics and Telecommunications regarding punched cards and their debut in business. He has gathered some theoretical content online but is struggling to paint a picture of how the punching worked. He learns that the MI&T hosts some relevant exhibits and decides to visit, even though he generally avoids museums due to his visual impairment.

Upon arrival, he finds a braille sign explaining that there is an NFC tag to scan, which downloads the application of the museum and that earphones are recommended. Once installed, he is instructed to scan the “Example Tag,” where he practices using the supported gestures within the app, navigating through an exhibit’s page, and capturing a recording as a souvenir.

When he reaches the museum’s relevant section, Alexis scans the “punched cards” exhibit tag to get audio guidance as he touches the cards and the punching equipment to understand how they operated. He listens to an audio description of the artifact, which enhances his understanding of the exhibit and its context. He pauses the guide and rewinds whenever he has trouble processing the information.

To recall his visit and reflect on his observations later, he proceeds to record and save his audio souvenir, where he captures his personal reflections, along with the sounds produced by the equipment, a prerecorded summary of the exhibit and key points he plans to make in his presentation.

3.4.2. Limited Dexterity Scenario

Areti is in Athens with her daughter to explore university options, and they have planned to visit the MI&T to learn about the department's history and facilities. Areti faces limitations in physically interacting with exhibits that require delicate movements.

Upon arrival, Areti is given a lanyard to attach to her device to minimize the strain that the grip causes her. She then scans the NFC tag at the entrance of the museum that triggers the application installation on her mobile phone. She proceeds to practice using the app's interface in the training mode to familiarize herself with the guide’s functionalities. To overcome her physical challenges, she takes advantage of the simple gestures provided by the application and places the phone in front of the NFC tags. Autoplay allows her to listen to the audio descriptions of the exhibits without compromising immersion.

Areti captures photos and videos of the exhibits, which she saves to later share with her husband, who was unable to join the trip due to work obligations. By the end of their visit, she has gathered plenty of information on the Department of Informatics and Telecommunications, its history, and its facilities, which render her able to aid her daughter in their decision-making process.

3.5. Requirement Analysis

Following the description of the user groups and the respective personas, we conducted a requirement analysis by examining the information gathered, drawing conclusions about their needs, translating them to requirements and, eventually, specifications for the user interface [28].

In this chapter, we will outline the design requirements and specifications for the museum's digital interface, taking into account the needs of the aforementioned personas, Areti and Alexis. These requirements are essential to the creation of an interface that is intuitive and accessible, successfully accommodates visitors' needs and provides seamless guidance that allows them to achieve their goals. The user interface specifications that are derived from these requirements aim to contribute to the design of an interface that renders the visitors' experience educational and immersive for all visitors with minimal distractions and limitations.

Table 3: Requirement 'Seamless Guidance'

Title	Seamless Guidance.
Description	To be able to access additional material with minimal interaction with the phone screen.
Explanation	Even though mobile phones are an affordable and convenient means to enrich the material given by the museum, visitors often lose focus and find themselves "absorbed by the device" when they constantly need to perform actions that require attention to their screen [4]. Hence the need to be able to follow the museum guidance without sacrificing immersion in the exhibits. In order to prevent uninformative interactions and avoid squandering visitors' time or effort, in the case of visitors with disabilities, the interface may treat the mobile phone as an object that triggers guidance-related actions.
User Group(s)	Visitors with low vision, Visitors with limited dexterity.
Specification(s)	- Installation of NFC tags on each exhibit. - NFC tag reading implementation within the app.

Table 4: Requirement 'Intuitive Gestures'

Title	Intuitive Gestures.

Description	To execute actions within the app without depending on precise movements or voice commands, which could be difficult to achieve in a museum environment.
Explanation	To make the exhibit accessible to everyone, regardless of their level of technological proficiency or any disabilities they may have, the interface should include ways of navigating that are intuitive and easy to use. Both user groups may have difficulty selecting components within the app, and so there is a need for alternative ways of navigating, intuitive gestures. They must not require precise motions nor rely on timing because tapping on the screen with small intervals (i.e. for double tap) or extended periods of time (i.e. for tap and hold) can be challenging to people with fine motor limitations. According to Motti et al., 2013, older users with low manual dexterity or touchscreen users with no prior smartphone experience seem to take longer to select a target while tapping [29]. Aside from tapping, dragging interactions have been suggested for motor-impaired users and older users with tremor due to the additional stability caused by the continuous contact with the screen [30].
User Group(s)	Visitors with low vision, Visitors with limited dexterity.
Specification(s)	App-specific gesture implementation for guidance-related actions: - NFC Tap. - Tap anywhere on the screen, regardless of number of fingers or duration. - Drag and slide (left or right).

Table 5: Requirement 'Haptic Feedback'

Title	Haptic Feedback.
Description	To receive feedback after executing a gesture within the app, to ensure that the action has been successfully completed.
Explanation	Haptic feedback can provide a tactile response, such as a vibration or a buzz, to let the user know that their action has been registered and improve their interaction with the touchscreen [31]. This is important for visitors with low vision who may not be able to rely on visual cues alone, and for visitors with limited dexterity who may not be able to perform precise movements or rely on timing-based interactions [32]. The feedback should be clear

	and easily distinguishable, without being too strong or overwhelming.
User Group(s)	Visitors with low vision, Visitors with limited dexterity.
Specification(s)	Vibration for successful completion of an action.

Table 6: Requirement 'Descriptive and Comprehensible Audio'

Title	Descriptive and Comprehensible Audio.
Description	To understand the exhibit's content and follow the app's instructions as clearly as possible through audio.
Explanation	Visitors with low vision may struggle to perceive visual elements within the exhibit, making audio crucial to their experience. Descriptive audio content can provide a comprehensive understanding of visual elements, enabling individuals with low vision to access information that might otherwise be unavailable to them. As such, the app should provide deeply descriptive audio that accurately describes the exhibit's images, as well as clear audio instructions for navigating the app.
User Group(s)	Visitors with low vision.
Specification(s)	- Audio description that provides detailed and accurate descriptions of exhibit images. - Clear and concise audio instructions for navigating the app. - Audio tracks that are free of distortion or other background noise.

Table 7: Requirement 'Clear and Accessible Typography'

Title	Clear and Accessible Typography.
Description	To recognize text and outlines to the extent they are physically capable.
Explanation	While audio instructions will be provided (Requirement 6), the design should be inclusive and provide clear, legible text that is easy to read in order to accommodate visitors with low vision to recognize as much content as they can. The typography should thus comply with Legibility Standards that make text accessible to low vision users according to Web Content Accessibility Guidelines, also known as WCAG [33]. Specifically, the color contrast between text and background should be at least 4.5:1,

	and the font size should be a minimum of 14 point for bold and 18 point for regular text. It is also important to choose a typeface with easily recognizable letters that avoid confusing similar shapes, such as lowercase “l” and uppercase “i” or the number 1, and uppercase and lowercase “c”, “o”, and “e” which often have narrow apertures [34]. A font that we deemed satisfies most of the above is Atkinson Hypereligible, created for the Braille Institute with the goal to improve legibility and readability for people with visual impairments by making each letterform visually distinct [35].
User Group(s)	Visitors with low vision.
Specification(s)	- 4.5:1 color contrast between text and background. - Use of typeface created for accessibility. - Icons that are crucial to conveying a message should also follow the 4.5:1 minimum contrast ratio and be larger. - Font size of at least 18 point throughout the application.

Table 8: Requirement ‘Tutorial Exhibit’

Title	Tutorial Exhibit.
Description	To learn and try out supported gestures without consequences.
Explanation	To make the app as accessible and user-friendly as possible, a tutorial exhibit should be included to teach visitors how to use the app's features and gestures. This will help visitors feel more comfortable and confident in their use of the app and reduce frustration due to missed information or disrupting other visitors in the museum. The tutorial exhibit should provide clear instructions and a safe space for visitors to experiment with app gestures before using them in the main exhibit. It should be designed to not interfere with the flow of other visitors in the museum and not cause unnecessary congestion.
User Group(s)	Visitors with low vision, Visitors with limited dexterity.
Specification(s)	A tutorial exhibit that will be located in an easily accessible area of the museum and provide clear step-by-step instructions.

3.6. Prototypes

Building upon the requirements and specifications outlined in the previous section, series of high-fidelity prototypes for the museum's digital interface has been created. These prototypes represent an iterative design process that considers the needs of the target user groups and aims to provide an intuitive and accessible interface. The following paragraphs consist of screens that visitors may encounter during installation, as well as the main screens, including the welcome and home screen. Additionally, they feature exhibit audio description screens and souvenir screens, with varying modes and interfaces.

The high-fidelity prototypes serve as a comprehensive representation of the proposed digital interface and have undergone multiple iterations in the attempt to seek balance amongst functionality, accessibility, and aesthetic appeal. A previous set of prototypes will be showcased below alongside with the various reasons their design was reconsidered in order to explore how they eventually lead to the final state.

3.6.1. Museum Entrance

As the visitors enter the Museum of Informatics and Telecommunications, they find an NFC tag with a Braille inscription, Figure 12, which initiates the installation of the application to their devices, as well as any additional equipment that they may require for their tour, such as earphones and lanyards for those who do not wish to grip their phones or have their hands occupied with a cane.

Figure 12: Download App NFC Tag

After the guide is successfully downloaded, visitors may be presented with initial screens, Figures 13 and 14, that prompt them to take specific actions, such as enabling NFC on their device and wearing earphones, before proceeding.

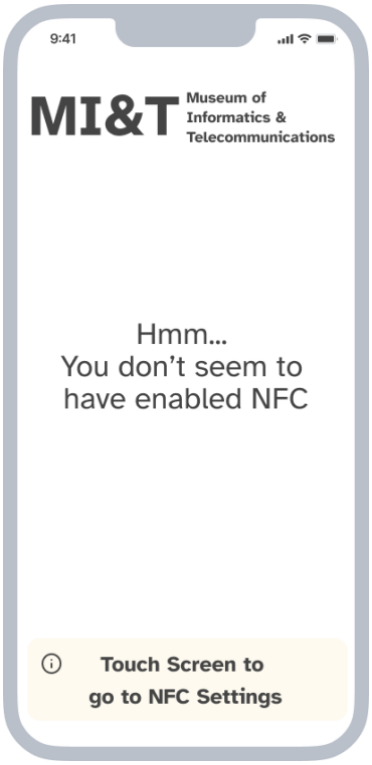

Figure 13: Enable NFC Screen

Figure 14: Wear Earphones Screen

Once these requirements are fulfilled, the Welcome screen, Figure 15, provides an audio overview of the application and directs the users to the Tutorial Exhibit to familiarize themselves with the supported gestures.

Figure 15: Welcome Screen

The Tutorial Exhibit is a "placeholder" exhibit that allows visitors to practice navigating within the guide. It contains all the screens of the paragraphs below, just like any other exhibit within the museum.

When the tutorial phase is done, the Home Screen, Figure 16, appears and simply exists to remind the users that wherever they see a tag, they may scan it to enhance their experience.

Figure 16: Home Screen

3.6.2. Exhibit Audio Description Screens

Each exhibit's information screen is triggered by contactless interaction with an NFC tag, Figure 17, placed on a flat surface by the exhibit accompanied by Braille text.

Figure 17: Audio Description Tag

The Exhibit Audio Description consists of two states; the "Playing" and the "Paused" state, Figure 18. Automatically, the application enters the "Playing" state once initiated and contains both text and audio instructions to accomplish basic audio controls with minimal interaction with the device's screen. This way they may Touch anywhere in their Screen,

regardless of its duration or the number of touch points used, to pause or resume the audio content. They may also start over from the beginning by rescanning the tag.

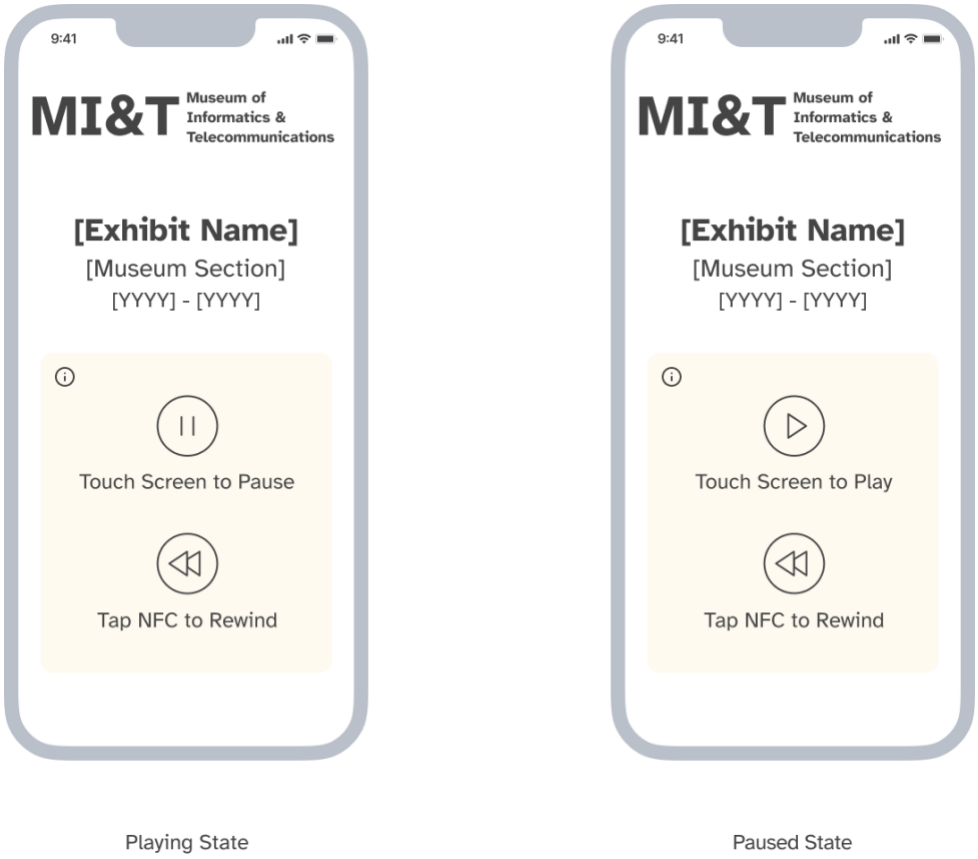

Figure 18: Exhibit Audio Description Screens

3.6.3. Digital Souvenir Screens

The museum exhibits come with basic information that visitors can enrich with their own perspective and save on their devices. This feature is referred to as the "Digital Souvenir" in this thesis and is composed of three modes: "Photo", "Video", and "Voice Memo". These modes offer visitors with varying needs and preferences the opportunity to express themselves creatively within the museum without adding complexity to their interaction with the guide. Visitors can switch between modes of the carousel menu by swiping the screen from either side. This is a commonly used interaction in the default camera applications of Android and iOS devices.

To initiate the “Digital Souvenir” for an exhibit, they may tap the NFC tag placed by the “Audio Description” one, Figure 19.

Figure 19: Digital Souvenir NFC Tag

First, permission to access the device's storage is required to automatically save the media captured, as shown in Figure 20.

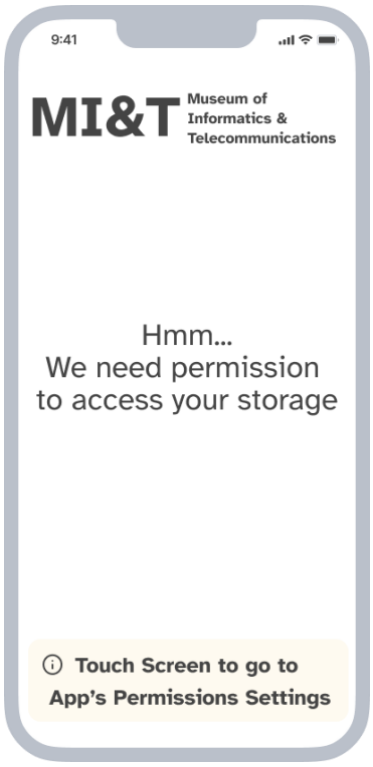

Figure 20: Storage Permission Screen

The "Photo" mode, Figure 21, allows visitors to take a single picture by touching their screen. Once the photo is captured, it will be saved to their device's gallery. On the top of the camera is a text AR overlay with the museum's name, the exhibit's name and its basic information, the museum section, and the operational period.

Figure 21: Photo Souvenir Screen

Accordingly, the "Video" mode, Figure 22, enables visitors to record a video of the exhibit that they scanned with the "souvenir" tag. They initiate recording with a tap and finish it with another tap. Once recorded, the video is saved to their device's gallery. Similar to the "Photo" mode, the video is embellished with an AR camera filter featuring the MI&T logo and the exhibit's primary information.

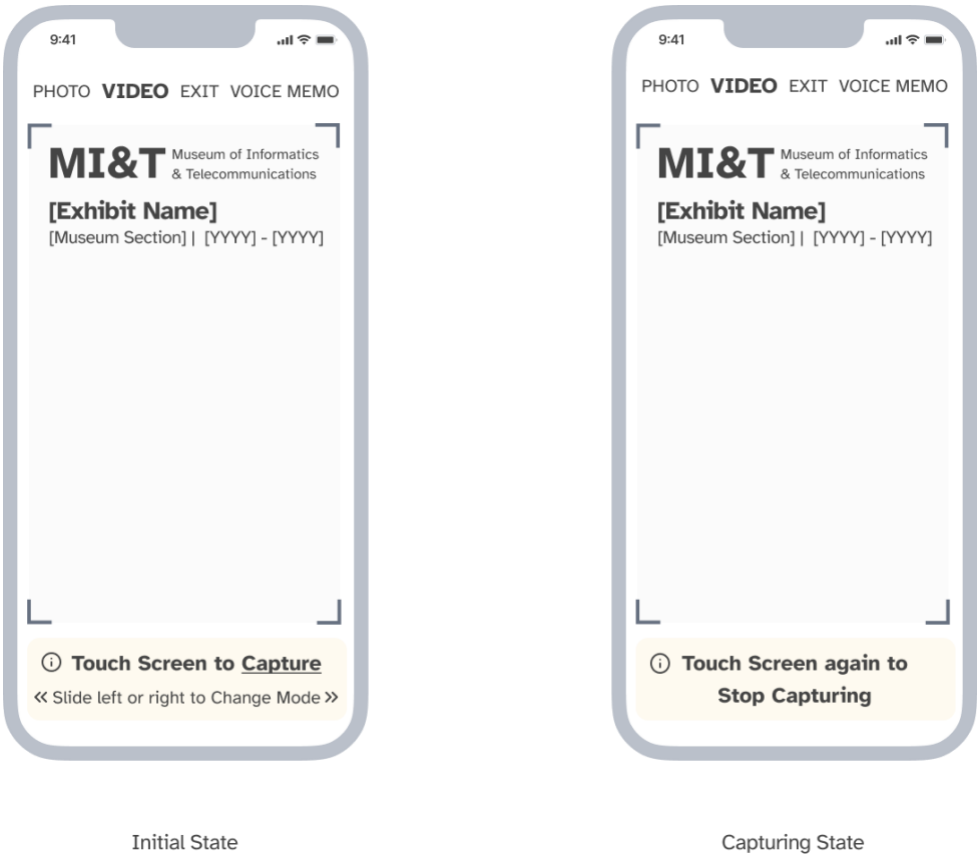

Figure 22: Video Souvenir Screens

The “Voice Memo” mode, Figure 23, is an alternative to the prior “Digital Souvenir” types for visitors who may prefer to express their thoughts and observations verbally. To initiate recording, visitors simply tap on the screen and begin speaking. The recording ends with another tap and is automatically saved to their device's gallery. Similar to the “Photo” and “Video” modes, the "Voice Memo" mode features a pre-recorded voiceover that announces the name of the museum and the exhibit's basic information. This allows visitors to focus solely on their thoughts and ideas without worrying about providing additional context.

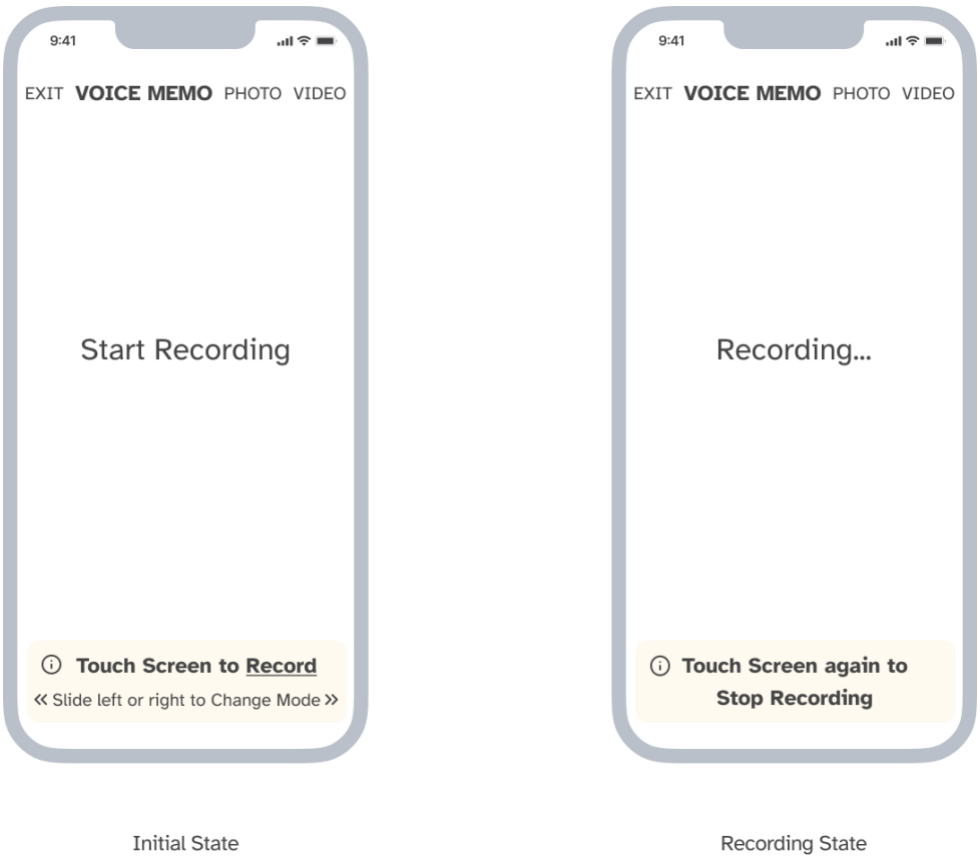

Figure 23: Voice Recording Souvenir Screens

To return to the “Home Screen” and continue exploring the rest of the exhibits, the visitors slide until they reach the “Exit” option, Figure 24, and touch the screen to confirm their action.

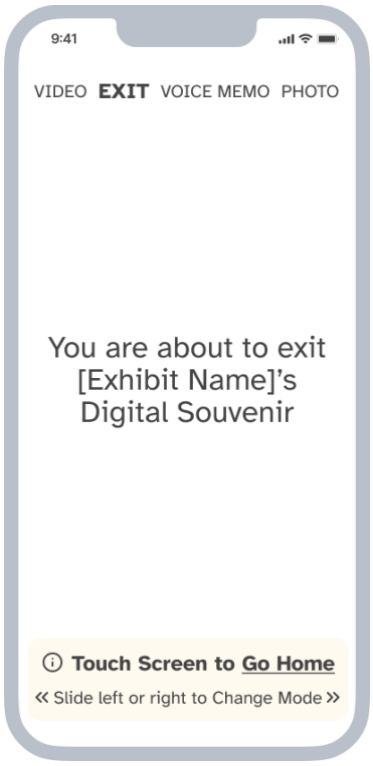

Figure 24: Exit Digital Souvenir Screen

4. CONCLUSIONS AND FUTURE WORK

In this thesis, we have explored the design of a museum guide application that provides an intuitive user interface, minimizes distractions, and maximizes engagement for all visitors, including those with accessibility barriers.

The analysis of related apps and their respective studies highlighted the importance of designing accessible and frictionless applications that enhance, rather than detract from, the museum experience. Through the development of user personas, we identified the needs and preferences of various user groups. We then used this information, along with findings from research on accessibility principles and natural interfaces, to gather requirements and specifications that would reflect said needs. It was deduced that the incorporation of NFC tags and intuitive gestures, along with haptic feedback, typography compliant with legibility standards, and descriptive audio, can contribute to rendering the interface seamless and inclusive. The resulting high-fidelity prototypes featured a simplistic interface that prioritizes limiting non-informative screen time and leverages Near Field Communication to trigger app workflows, allowing visitors to seamlessly engage with the museum's exhibits.

While this research offers valuable insights into the design of museum guide applications, it has limitations.

Future research should challenge the effectiveness of our design proposal by conducting usability testing with a broad range of visitors, including those with disabilities or limited familiarity with technology. By doing so, we expect to gain insights into the application’s intuitiveness, accessibility, and disruption from the cultural setting. This evaluation should be both quantitative, through first-click testing, completion rates and heatmaps, and qualitative, through interviews and the think-aloud protocol. Given that the actions within the app are triggered by the user’s interaction with physical tags, it is essential for the usability tests to be done in person and, ideally, within the museum setting.

Following user testing, the development of the mobile application is expected. It should be implemented using a framework supporting NFC tag reading and accessibility features, namely React Native, which offers both an NFC library [36] and comprehensive Accessibility documentation [37] for both iOS and Android assistive technologies. The audio recordings should be stored in a data store and associated with unique identifiers to ensure the data is independent, modifiable, and not relying on the application’s updates. This will allow the app to quickly retrieve and play the audio file of the correct exhibit based on the ID attached to the NFC tag tapped. Once developed, it must be deployed and made available for download by visitors.

In future redesigns of the application, we would encourage enriching its functionality while maintaining the principles regarding disruption and accessibility tackled in this study. For instance, visitors could be given the option to review their souvenirs prior to saving them and store them within the app instead of directly to their devices. Additionally, the feature to move to a specific time in an audio recording could be helpful for those who benefit from replaying specific audio clips, i.e., in the case of a university assignment or frequent loss of focus.

Regarding accessibility, it is important to provide more personalized settings for visitors with disabilities, as their needs can range drastically. Such options could be adjustable haptic feedback, font sizes, contrast levels and audio speed. As reported by the research on the Warhol Museum's app, Out Loud [11], users with screen readers installed on their phones may struggle to perform tasks which may be straightforward to the average user due to the app overriding or ignoring the screen reader’s default gestures. For screen reader users, a single tap on the screen may translate to reading the selected item aloud,

making this functionality disruptive to the current design. Thus, we plan to adjust the application's functionality when a screen reader is detected, replacing single taps with gestures that screen reader users are accustomed to and utilizing OS-specific features such as “Magic Touch” [12]. This will ensure that visually impaired visitors can access the same content as sighted visitors without feeling excluded or disadvantaged.

ABBREVIATIONS - ACRONYMS

MI&T	Museum of Informatics and Telecommunications
NKUA	National and Kapodistrian University of Athens
DIT	Department of Informatics and Telecommunications
BYOD	Bring Your Own Device
WCAG	Web Content and Accessibility Guidelines
GUI	Graphical User Interface
NFC	Near Field Communication
RFID	Radio-frequency Identification
AR	Augmented Reality

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