ReInHerit
Redefining the Future of Cultural Heritage, through a disruptive model of sustainability

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Acronyms and abbreviations

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Contents:

Executive Summary

The overall objective of the Deliverable D3.4 is to prepare a consolidated report derived from research on current tools and methods of communication and collaboration between museums, heritage sites and audiences. The report will analyse and present conclusions based on the survey results and from the scientific communities working on advanced technologies such as Artificial Intelligence, Computer Vision, Multimedia and Telecommunication. This report describes the framework of the development process of innovative tools and practices that will disrupt the current status quo of museums – cultural heritage sites communication and collaboration. In addition, the consolidated report on ICT in Cultural Heritage Management presents Information and Communication Tools that allow to create personalized visits, allow user interaction and learning by doing or by gamification.

1. Introduction

The aim of this report is to report as a short booklet conclusions from the national surveys and from the scientific communities working on AI, computer vision, multimedia and telecommunications in the cultural heritage domain. A selection of state-of-the-art ICT tools for cultural heritage is reviewed, considering different types of applications such as AI, Computer Vision, IoT, A/R and V/R, immersivity, gamification, etc. For each type of application a number of use cases, where key technologies have been used, are presented.

In the first task of WP3 ReInHerit Toolkit (T3.1 National Surveys on current state of the art tools), national surveys were conducted to collect quantitative data on the digital capacities of heritage organizations across Europe, deliverable D3.1 reports an analysis of the surveys, and in this document the aspects related to user experience and digital tools are used to contextualise the technological solutions developed by the scientific community within visitor studies and the user experience surveys. The analysis of the results showed that visitors prefer to use their smartphones or tablets in a museum or heritage site, and visitors also prefer using QR codes or other codes rather than downloading mobile applications. Visitors are familiar with using new languages and digital tools to interact with the museum's collections, creating and sharing new stories, during, after and before the visit. Using digital tools allows cultural organisations to diversify their offerings, engaging people in more enriching and meaningful experiences that cover the needs of all audiences. This is particularly true for younger audiences who are considered digital natives and who already use digital tools, social networking services and text messaging as their main means of communication and learning.

The sections of D3.4 are: Sect.2 reports on advanced ICT technologies and their applications in different use cases related to cultural heritage; Sect. 3 relates such technologies with visitor studies and the user experience surveys (see D2.3 Questionnaires Report and D3.1); Sect. 4 briefly summarizes key aspects collected in the focus groups (see D2.4 Focus Groups Phase II Report); Sect. 5 analyzes how mobile apps and AI can improve the interaction with visitors. FInally, some recommendations are drawn in Sect. 6.

2. State of the Art of ICT Tools for Cultural Heritage

In this section we briefly review a selection of relevant open source and commercial solutions related to the tools considered in the questionnaires, as well as examples of applications and installations. The following subsections are associated with the categories used in the following chapter reporting the analysis of the results of the questionnaires. The selection includes representatives of the types of applications that are expected to be delivered within ReInHerit: examples of gamification, smart tourism/smart guide apps, tools for exhibitions and collection management, immersive experiences. It must be noted that the extremely vast majority of the examples reported below that exploits the most recent advances of AI and its applications, like CV, are experimental works and typically not deployed in small-medium museums and organizations. The apps developed in ReInHerit and distributed through the Digital Hub aim to reduce this technological gap.

2.1 AI and CV

Services we use everyday, from video and music streaming to buying products online, all use Artificial Intelligence (AI). When it comes to museums AI can be incorporated across the spectrum, from visitor experience to behind the scenes, and the technology can and has come in many forms.

Machine Learning technology could learn, categorize, and make predictions on data.

Deep Neural Networks (DNNs) are computing systems loosely modeled on the human brain. Their building blocks are filters that are used to extract the relevant features from the input, e.g. considering visual applications these filters are typically implemented using the convolution operations.

The deep in deep learning stands for the idea of successive layers of representations.
How many layers contribute to a model of the data is called the depth of the model.

Modern development of **AI-based systems** require the use of frameworks that ease the design, training and testing of models that implement the desired functionality, e.g. object detection and recognition in case of image analysis or text sentiment classification in case of natural language processing. The two main frameworks used nowadays are **open source: TensorFlow** is an open source deep learning framework created by Google and released in 2015 [Tensorflow-2015], and **PyTorch** is another open source framework developed by Facebook in 2017 [PyTorch-2017]. Both frameworks are widely used by companies, startups, and business firms, researchers and practitioners of AI to develop models and then deploy them. In particular Tensorflow allows to serve models using a REST client API that simplifies the use in web and mobile applications. This type of functionality was initially missing in PyTorch but recently it has been added through the TorchServe component. Typically AI systems request high computational capabilities that are available using hardware accelerators such as GPUs commonly installed in servers and workstations; however, mobile devices such as medium-high end smartphones and tablets have started to have mobile

GPUs and neural accelerators that allow to run neural networks also on this class of devices. To this end specialized versions of Tensorflow and PyTorch have been developed: PyTorch Mobile is a beta-level system that allows to deploy AI models on iOS and Android devices, while TensorFlow Lite is a more established version of TensorFlow that allows to optimize AI models for mobile devices and then executes them. TensorFlow has also an additional version, called TensorFlow JS that can be used in web browsers.

Computer VIsion is an enabling technology, since it is a powerful artificial sense to extract information from images: about places, objects, people.… It is possible to use it to automatically understand both contextual behaviors and situational conditions of people to provide the right information at the right time and place. COnsidering a museum setting it is possible to implement it using fixed external cameras, to understand what visitors observe or do and determine their degree of interest or mobile wearable cameras to augment the visitor experience providing the equivalent of multiple simultaneously active eyes.

Regarding the specific case of **Computer Vision**, the most popular open source solution is provided by the **OpenCV library** [OpenCV-2012]. OpenCV provides the tools needed to solve a very large number of different computer-vision problems. It contains a mix of low-level image-processing functions and high-level algorithms such as face detection, pedestrian detection, feature matching, and tracking. Nowadays many CV tasks are solved using AI-based models, such as Convolutional Neural Networks, but OpenCV is still extremely relevant for a large number of use cases where real-time vision, signal-based processing and the use engineered features is competitive, such as camera calibration, homography and A/R. The latest versions of the library include functionality to work with neural networks, so that it is not necessary to use TensorFlow or PyTorch and OpenCV can be deployed also on mobile devices using either iOS and Android. An alternative to OpenCV is **DLib** [King-2009], a toolkit that includes machine learning functionalities and a number of computer vision functionalities. Also DLib can be deployed on mobile devices.

Use cases: systems for user interactions

Using such tools it is possible to implement **systems for user interactions**. For example in [Baraldi-2015] has been presented a system that performs artwork recognition and gesture recognition using computer vision, allowing an interaction between visitors and artworks in an exhibition.

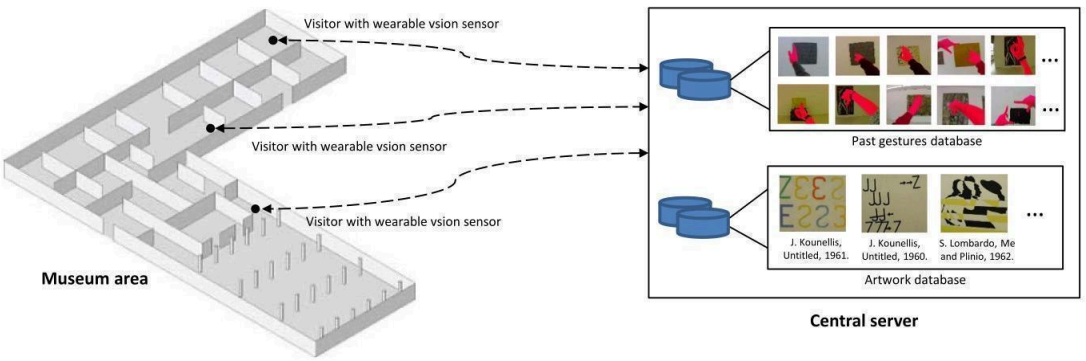

Fig. 1 - Schema of the system presented in [Baraldi-2015]: users have a wearable system that provides an ego-vision video stream processed by a central server that recognizes gestures and framed artworks.

A CV system based on neural networks for artwork recognition on mobile devices has been proposed in [Seidenari-2017]; the goal is to implement a smart audio guide that, using also machine learning techniques for audio event recognition and user movement, is able to engage with the user when it is more appropriate, e.g. when he's paying attention to an artwork and not when he is moving around or participating in a conversation.

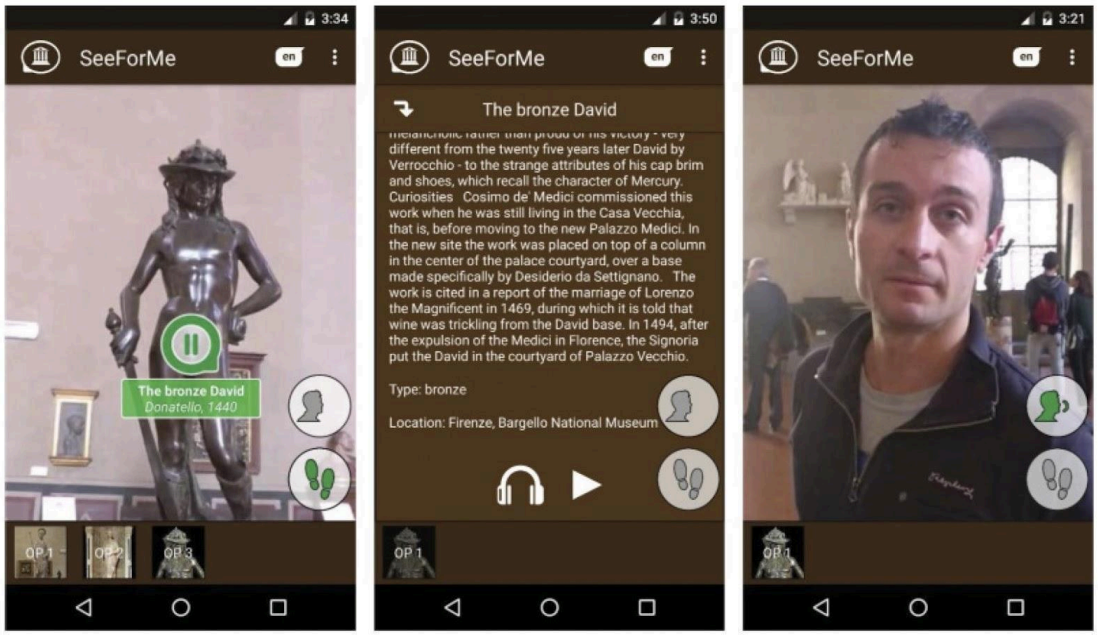

Fig. 2 - examples of interfaces of the system presented in [Seidenari-2017]: (Left) The user is listening to the description of the artwork, (center) the user is reviewing an item in the history, and (right) the user is speaking with someone not focusing on any artwork.

CV can help to manage digital collections, considering both high-quality archive materials and images from web and social media. Convolutional neural networks have been proposed in [DelChiaro-2019] to recognize artworks in collections of heterogeneous image sources. More recently multimodal neural networks like CLIP have greatly improved the results in this context [Baldrati-2022].

AI can be used also to revamp and restore iconographic materials such as postcards and movies. Deep neural networks have been proposed for colorization and restoration of B/W photos [Wan-2022a], and to restore and colorize films using a deep neural network [Wan-2022b], eliminating scratches exploiting temporal coherence of neighboring frames.

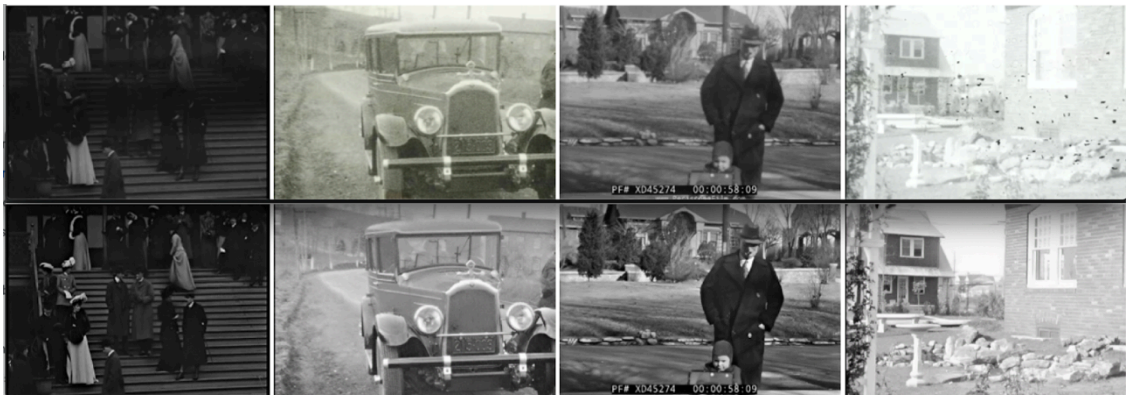

Fig. 3 - example of restoration of old films using the method proposed in [Wan-2022b]. Top row shows the input, bottom row the results of the restoration.

2.2 Smart Environments and IoT

Bluetooth beacons are hardware devices that transmit short messages (identifiers) using Bluetooth low energy (BLE) proximity sensing. The technology enables smartphones, tablets and other devices to perform actions when in close proximity to a beacon, which marks a point of interest. Using a number of beacons in the same environment is possible to triangulate the position of the receiver. Several protocols exist, among which the iBeacon proposed by Apple [Newman-2014] and Eddystone proposed by Google [Dasgupta-2016].

Li-Fi is a type of Wireless communication that is implemented using light transmission, from the visible spectrum to ultraviolet and infrared spectrums. Li-Fi devices can be used in a similar way to beacons, although they can transmit much more information apart from simply a position identifier.

Use cases: sensors for indoor navigation and proximity detection

Bluetooth beacons have been used in several works to provide services for **indoor navigation and proximity detection**. The smArt framework presented in [Ferracani-2015] uses beacons to localise and route visitors in a museum. Beacons have been used to evaluate artwork proximity detection in museums and historical landmarks in [Barsocchi-2021].

Fig. 4 - BLE beacon deployment (red arrow) and artwork visit, from [Barsocchi-2021].

In [Ng-2017] **BLE beacons** have been used to increase visitor engagement with artworks in a museum, through a Notify-and-Interact framework, implemented in a mobile app. The authors report that engagement based on this modality surpasses that of using QR codes.

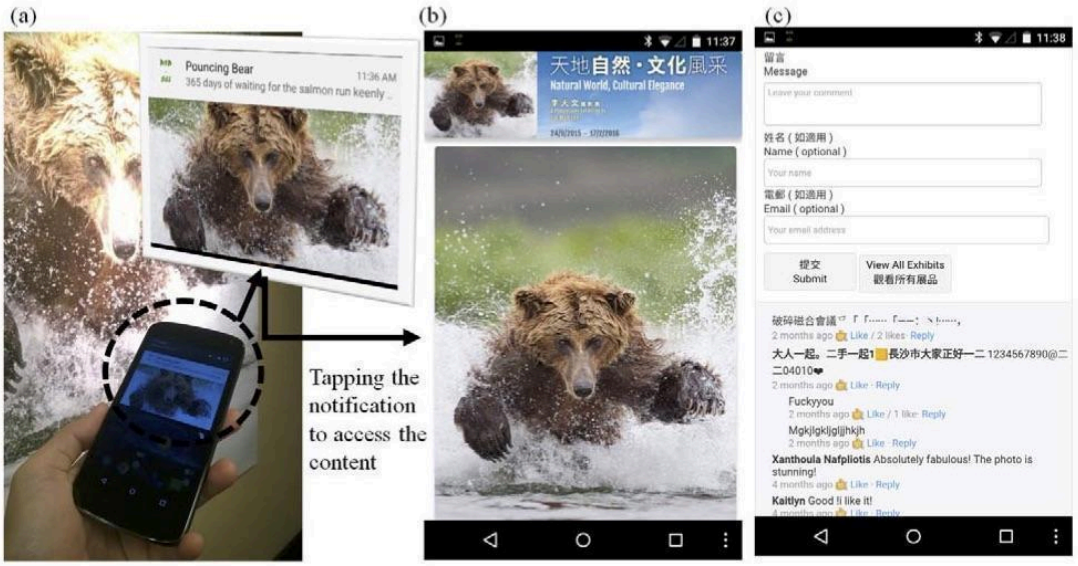

Fig. 5 - Interactive gallery application proposed in [Ng-2017]: (a) Notification, (b) Content, and (c) Comment section

A preliminary study on application of Li-fi technologies in CH and tourism has been presented in [Meucci-2021]. The authors have studied the feasibility of data transmission through the light reflected by artworks (wooden and marble sculptures).

2.3 IoT tools & app: gamification

Gamification is the use of game design elements outside the normal context of games, and it has become one of the primary tools for advanced communication and socialization with

users in a variety of sectors, among which cultural heritage. Computer vision techniques can help to increase the engagement of users in this context [Cesaria-2019].

Use cases

In the "Strike a pose" application developed within the ArtLens Exhibition [ArtLens], visitors are asked to imitate the pose of a sculpture, and they are provided with feedback relating to the accuracy of their pose. Visitors were able to share their poses and view others' poses, in addition to trying another pose. The visitor is shown an image of a sculpture in a unique pose and asked to imitate that physical position. A Kinect sensor measures how closely their pose matches the original and assigns a percentage to indicate how well the visitor embodied the sculpture's pose. The better the match, the higher the percentage achieved. The skeleton matching software uses a library of human-generated skeleton data captured via the Kinect data to quantify the match between the poses of a museum visitor and each sculpture. Visitors can email their image capture, see other visitors' images, and try another pose [Alexander 2013].

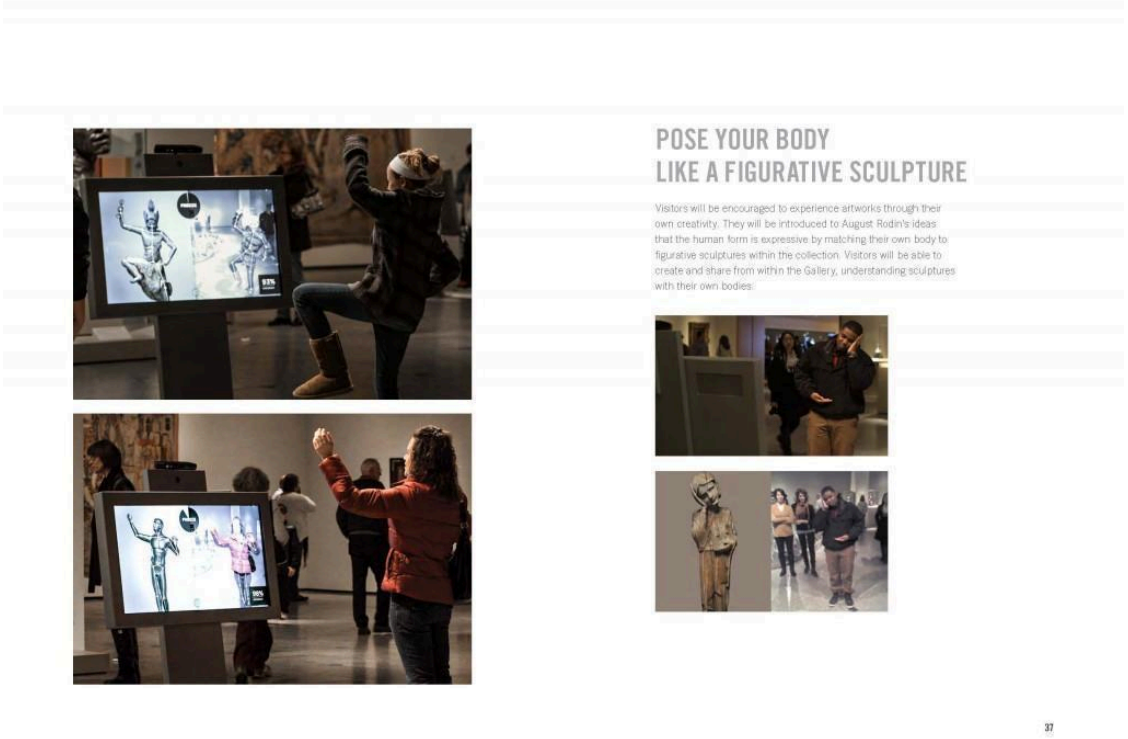

Fig. 6 - example of "Strike a pose" use Source Figure: https://mw2013.museumsandtheweb.com/paper/transforming-the-art-museum-experience-gallery-one-2/

The "Make a Face" app deals instead with faces: facial recognition and landmark detection is used to match visitors' facial expressions with one of artworks in the museum's collection. Visitors are shown a portrait to interpret the figure's emotion, then their facial expression is matched with another portrait. In real time, facial recognition software matches a visitor's facial expression to artworks within CMA's collection. The visitor's expression is captured and the system measures nodal points on the face, distance between eyes, shape of the cheekbones and other distinguishable features. These nodal points are then compared to

the nodal points computed from a database of 189 artwork pictures in order to find a match. The matched faces are collected into photo-booth-style strips that are then displayed on the Beacon near the gallery's entry. The visitor is also able to email their 'photo strip' to themselves and share with others [Alexander 2013]. Both "Strike a pose" and "Make a face" applications are provided as installations, given the difficulty in implementing such techniques on mobile devices at the time of their development.

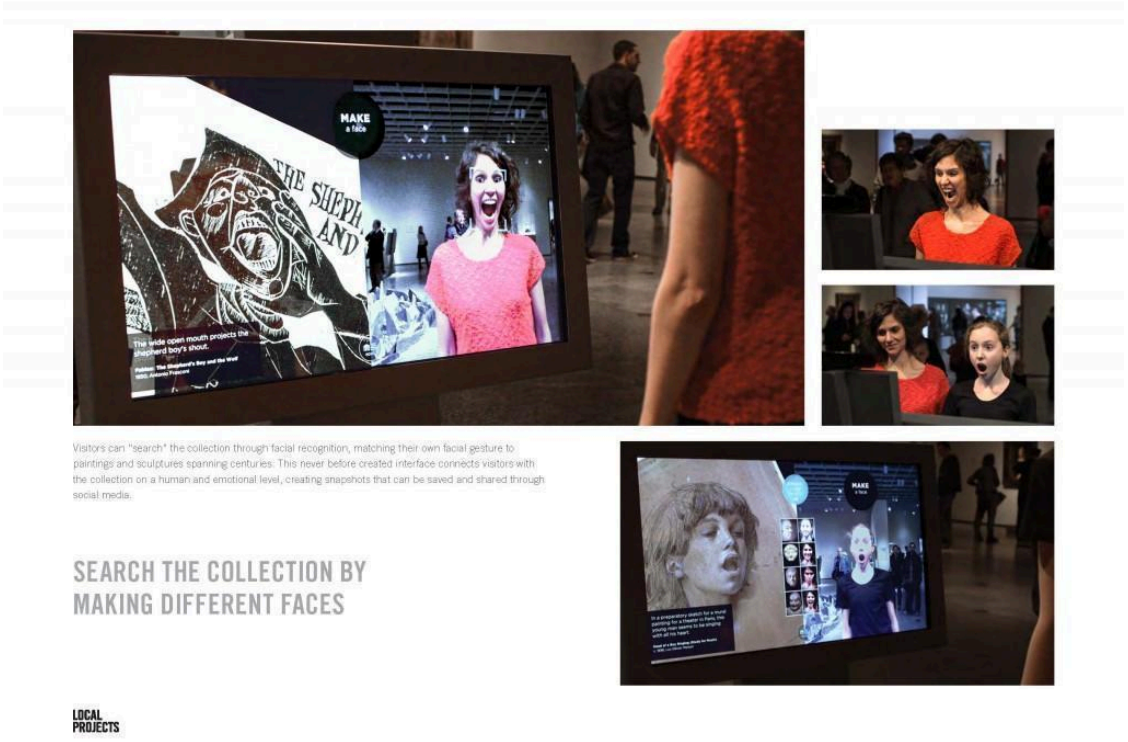

Fig. 7 Example of "Make a Face "use. Source Figure: https://mw2013.museumsandtheweb.com/paper/transforming-the-art-museum-experience-gallery-one-2/index.html

2.4 A/R and V/R

Augmented Reality (AR) technology has received a large amount of attention in the computing field, and major companies like Apple and Google have renewed their interest in developing new wearable devices for the whole spectrum of V/R, A/R and mixed reality experiences. These technologies can be used also within the context of the cultural heritage domain. Both iOS and Android provide A/R functionalities to develop A/R and mixed reality apps, namely ARKit by Apple and ARCore by GOogle, but several companies provide multi platform-frameworks that ease porting an application to different platforms, like Vuforia [Vuforia-SDK] and Wikitude.

Use cases

In [Hammady-2016] has been introduced a communication model that guides the development of A/R guidance systems in the Heritage domain, proposing a novel way to enhance the visitors' experience and learning by combining AR with games in museums.

A game on architectural heritage, using gamification for conveying information through the reanimation of an ancient city, has been proposed in [Varinlioglu-2019]. It is an immersive A/R game involving the portrayal of cultural heritage through mobile devices, combining rendering of 3D content with camera input and using GPS to localize objects on a larger scale and object recognition through computer vision for a smaller scale.

Fig. 8 - example of the A/R system presented in [Varinlioglu-2019]

2.5 Multisensory/Immersivity

Many Cultural Heritage applications exploit all the different levels of multimedia augmentations of experience, i.e. **augmented-reality**, **virtual-reality** and **mixed-reality**, thanks to the availability of numerous wearable devices and smartphones that provide the

hardware and software facilities to implement such systems. Typically such applications expand the visual experience. A thorough overview has been provided in [Bekele-2018].

Audio-augmented reality (AAR) can be used to promote v**isitor exploration and engagement in an exhibition** or location, since sound has been identified to have the potential to **give emotional power to exhibitions** [Bubaris-2014].

Use cases

Modern wearable devices like **smart glasses** allow the implementation of mobile augmented reality applications that provide hands-free functionalities and may be perceived as less cumbersome than other hand-held devices [Leue-2014]. These devices can be used in indoor environments, e.g. [Ragusa-2019] (more details in next section), or outdoor; e.g. in [Litvak-2020] they have been used to implement a smart guide in outdoor CH site. Smartphones are certainly more ubiquitous devices and less expensive, thus are more commonly used; [Plecher-2019] present the use of both mixed- and augmented-reality approaches for the exploration of ancient Greek artefacts.

Fig. 9 - Visualization of the 3D scanned statues within the walkable area in Olympia, from [Plecher-2019].

In [Chalmers-2017] two case studies related to multisensory experience are considered, one an Egyptian temple and the other regarding medieval pottery. The idea is to simulate through Real Virtuality [Chalmers-2009], i.e. implementing a Virtual Reality system with a high level of physical accuracy, environments so that it is possible to better experience the past.

In [Cliffe-2019] a system that **uses AAR** in response to **object tracking and recognition** has been proposed and tested in the context of exhibition in a National Science Museum and in an exhibition on opera and symphonic music. THe computer vision component is based on [Vuforia-SDK]

In [Sikora-2018] the authors investigate the use of an audio augmented reality (AAR) system to **recreate the soundscape** of a mediaeval archaeological site. The goal is to enhance a

tourist's archaeological experience, using a **smartphone app** that uses **location and orientation sensors** to determine how to mix different sounds at the appropriate intensity. This type of application can be considered also as a form of smart guide app, with a feedback similar to that of the system presented in [Seidenari-2017] (see above).

2.6 Exhibitions

AI and Computer Vision can help to improve the planning of an exhibition, evaluating how **visitors interact** with it; this technology can be applied also to cultural sites. The main computer vision problems that must be solved in this context are those of retrieval, i.e. searching for the most similar image of a known location in case it is needed to localize a visitor using a view taken from a wearable device, or person **detection** and **re-identification** if there is need to track the movements of the visitors within a specified area using environment cameras. Understanding how visitors move and interact can be used to deliver personalized content and targeted recommendations.

Use cases: localizing visitors and providing personalised contents

The authors of [Ragusa-2019] consider the problem of localizing visitors in a cultural site from egocentric (first-person) images, i.e. obtained from a wearable device; the idea is that localization information can be useful both to assist the user during his visit (e.g., by suggesting where to go and what to see next) and to provide behavioral information to the manager of the cultural site (e.g., how much time has been spent by visitors at a given location? What has been liked most?). The authors have released a dataset that can help future researchers in the field, as well as the AI models used to recognize the locations of the site. It is interesting to note that one of the device used to capture the images of the dataset is a Microsoft HoloLens, that can be used also for A/R applications. The dataset has been expanded to include object recognition and retrieval tasks in [Ragusa-2020].

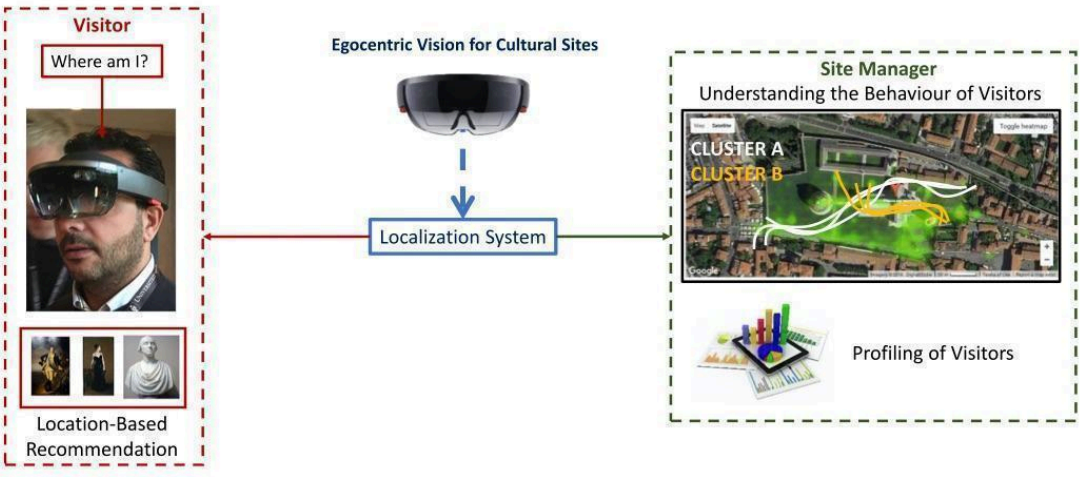

Fig. 10 - diagram of a system presented in [Ragusa-2019] which uses egocentric visitor localization to provide assistance to the user and augment his visit (left) and to provide useful information to the site manager (right).

Observation of visitors through cameras, tracking how they move within a museum hall and how much time they spend to view an artwork has been used in the Menmosyne system installed in the Bargello Museum of Florence [Karaman-2016, Baecchi-2019] to build a list of

the artworks of interest for each visitor. These preferred artworks are then used to deliver personalised content and targeted recommendation of other items of interest on an interactive table exploiting user re-identification.

Fig. 11 - The tabletop of the Mnemosyne system [Karaman-2016, Baecchi-2019] installed in the "Sala di Donatello" of the Bargello museum.

2.7 Marketing and feedback

AI and Machine Learning techniques can be used as marketing tools, e.g. providing personalised recommendations to visitors, either as a way to provide a better experience and education to the users and as a way to improve a tourist experience. A thorough review of recommenders in CH domain is provided in [Pavlidis-2019]

Computer Vision can be used to analyze in an unobtrusive way the engagement and satisfaction of visitors through analysis of their behaviors and emotions.

Use cases

[Hong-2017] presents a novel recommender system that discovers and exploits social affinity between users based on artwork features and user experience.

In [Gonzalez-Rodriguez-2020] the authors have shown that tools for facial expression recognition can be successfully used as alternatives to self-administered questionnaires for the measurement of customer satisfaction, evaluating this approach in a heritage site using a commercial tool.

2.8 Conclusions

This selection of applications and technologies, was used in the design of the questionnaires and the analysis of their results, comprise the types of applications initially planned in the ReInHerit proposal and drives the development of the apps of WP3. The advances in AI allow the creation of new versions of many of these applications that are capable of running on **mobile devices**, instead of fixed installations or on servers that require a client-server paradigm for their implementation, thus democratizing the access to such tools. Moreover, developing these new apps following an **open source** approach along with documentation on the digital hub of ReInHerit, allows small organizations with limited resources to re-implement them. As noted in the focus groups the lack of open source solutions is one of the main issues, since it leads to maintenance problems and to the lack of reuse of applications by different organizations.

3. Focus on the User-Experience - Primary and Secondary Research by ReInHerit

The aim of this section is to contextualize the above technological solutions within visitor studies and the user experience surveys (see D2.3 Questionnaires Report) conducted by ReInHerit in order to make informed decisions in selecting the most appropriate technologies for communicating and collaborating with various audiences. User Experience survey (WP2) results show that visitors prefer to use their smartphones or tablets in a museum or heritage site. In general, visitors prefer a smart interaction using QR codes or other codes rather than downloading a mobile application. Interactive surfaces, multi-touch tables, immersive rooms and responsive environments are more interesting for young and middle-aged visitors. The classic audio guides seem to be very useful for older visitors because interactive surfaces and/or immersive rooms are rather difficult to use. When considering ways to improve audience engagement and develop memorable and usable tools, it is also relevant to analyze the deep motivations behind visitors' preferences, in order to implement sustainable museum solutions that meet the needs of different audiences, especially young people.

This emerging vision involves an interactive and participatory approach to cultural heritage for different audiences (with various ages, many interests, and diverse visiting styles). Visitors are familiar with using new languages and digital tools to interact with the museum’s collections, creating and sharing new stories, before, during, and after the visit. If these audiences are emotionally involved, the contents become unforgettable and memorable. Digital technology -combined with effective scenography- offers a great opportunity to expand the modes of visitor engagements, creating an emotional relationship between collections, museum and visitors.

The collected contemporary literature emphasizes the importance of engaging diverse audiences in dynamic experiences, developing solutions in which the visitor's essential motivation is to learn, discover, experience, and consume the tangible and intangible cultural attractions/products of a tourist destination. It is important to create new forms for

engaging different types of audiences, with a focus on local communities. Using a range of digital tools can motivate diverse audiences to experience, enjoy, and participate. Tools based on participatory storytelling, user personalization and headset devices, mobile technologies, and smart applications for game-based learning in immersive environments are therefore important for fostering engagement.

A primary need is to use digital tools to diversify the cultural offerings, engaging people in more enriching and meaningful experiences that cover the needs of all audiences. Especially the younger audiences, who are considered digital natives and use digital tools, social networking services and text messaging as their main means of communication and learning, are an important target audience for these tools. It is important to promote dialogue between young people and CH organisations in order to determine their specific needs as well as to better understand how they define CH, how they experience it, how they want to engage with it, and what is important to them. This can help to renew their current view of CH and to establish a new relationship based on collaborative and strong interaction, fostering innovation.

For instance, digital natives consume fast, in visual formats, and choose their content. It is important to better understand them and to consider solutions for audience development and engagement of different types of audiences, with a focus on local communities and through different digital tools and instruments capable of involving and motivating diverse audiences in experiencing, enjoying, participating. This helps promoting a dialogue and relationship between users, organisations, museum collections and heritage sites, based on strong and collaborative interaction.

Therefore, it is important to introduce games and digital tools (Augmented/Virtual/Mixed reality, Gesture Technology/Non-touch Interactives, Mobile Technologies, ICT CV/AI tools, etc.) in CH organisations to attract younger audiences. Young museum visitors (18- 29 as well as 30-44) are more likely to use digital tools in a museum environment. Younger people in general have a strong tendency to be interested in technology related experiences and in gamification approaches. Although the young audience segment seems to be one of the most desirable target groups for CH professionals, it is equally important to maintain and increase the visitor base of CH organisations across all age groups (e.g., 65+). As such engaging existing or new audiences of all ages should be the starting point in the process of audience development. As evidenced by the visitors' survey conducted by the ReInHerit project, young audiences are the most likely to be interested in using digital tools, however it is equally significant to ponder how we can market these tools to all age groups.

The ReInHerit survey helped to identify key needs and requirements for the development of a set of digital tools (prototypes, apps and relevant training) for museum professionals and museum visitors, looking at a sustainable design and management in line with the ReInherit goals. Digital tools will be developed and based on the insights and recommendations of the National Survey conducted with cultural heritage professionals and visitors and considering the needs highlighted during the interviews and Focus Groups conducted with experts and professionals. Conclusions of the Survey for Cultural Heritage Professionals and Museum and CHS Visitors (D2.6 p. 25), indicate the following recommendations regarding the audiences and the type of institutions interested in the Digital Tools to be offered in the Digital Hub. Younger respondents are more likely to use digital tools, including games, exhibitions and

immersive experiences, and the use of QR codes in a museum or cultural heritage sites. Small and medium-sized organizations need digital tools along with support and technical guidance.

Diversify Audience

The Focus Groups results indicate that a primary need is using digital tools to diversify the cultural offerings, engaging people in more enriching and meaningful experiences that cover the needs of all audiences. Especially younger audiences who are considered digital natives and who use digital tools, social networking services and text messaging as their main means of communication and learning. Young museum visitors are more likely to use digital tools in a museum environment and therefore would be more positively inclined towards the digital engagement activities and the solutions offered by the ReInHerit Toolkit. They use digital tools to interact with the museum's collections, creating and sharing new stories, before, during, and after the visit. Social media sharing and new technologies can also play an important role in attracting younger audiences, promoting social inclusion, creating more narratives via participative storytelling. Cultural Heritage institutions need to expand their target audience and attract younger visitors, making museums and CH sites as more appealing and emotional places. It is important to develop solutions for audience development and engagement of different types of audiences, with a focus on local communities and through different digital tools and instruments capable of involving and motivating diverse audiences in experiencing heritage. According to the focus groups conducted with professionals and experts it is important to develop the tools so that museum experts and developers can dialogue with visitors. Hackatons and design-thinking workshops need to be organized, inviting communities into the creation process and understanding their needs, defining the problem, devising solutions, and testing prototypes. The goal is to provide not just a tool, but a development process, inviting communities into the creation process and understanding their needs, defining the problem, devising solutions, and testing prototypes. Tools are to be designed, developed, tested together through interdisciplinary Design Thinking workshops. In addition, visitors and professionals can interact with the digital platform, sharing a set of useful practices for museum professionals and in connection with national and international networks, in order to explore new trends on people-centered museums and sustainability with an interdisciplinary perspective.

Digital technology makes cultural tourism more competitive. It is important to diversify cultural tourism products by creating new experiences, services and cultural products with the application of new information and communication technologies (ICT) for the development of intelligent tourism and by establishing synergies with other CH organisations and sites to create cultural routes, creative tourism experience, etc.

3.1 Visitors and Digital Tools

In this subsection, we present an overview of the survey results for the visitors through descriptive statistics, which, as already mentioned, is usually the first step and an important part of any statistical analysis of either categorical or continuous data. The total number of participants is 1746. Of course, this does not mean that we had 1746 responses for each one of the questions in the survey because a small proportion of participants skipped parts of the questionnaire. We now provide contingency tables on the frequency and the percentages of the different levels in four categorical variables in the data set; the age, the educational level, the employment status, and the country of origin of the participants.

Table 1: Descriptive Statistics for the age of the participants in the survey for the visitors

Age category	Counts	Percentages
18-29	317	19.32%
30-44	615	37.48%
45-64	639	38.94%
65+	70	4.26%

Table 2: Descriptive Statistics for the educational level of the participants in the survey for the visitors

Level of Education	Counts	Percentages
Primary (compulsory) education	10	0.61%
Secondary Education	222	13.59%
Bachelor's degree	385	23.58%

Master's degree	796	48.74%
Ph.D.	220	13.48%

We notice from Table 1 that only 4% of the respondents are over 65 years old, while Table 2 makes it clear that only a very small proportion of the participants (0.61%) have received education only up to the primary (compulsory) level.

Table 3: Descriptive Statistics for the type of the organization

Employment status	Counts	Percentages
Secondary school student	9	0.55%
University student	208	12.72%
Unemployed	79	4.83%
Self-employed	238	14.56%
Employee	991	60.61%
Pensioner	65	3.98%
Other	45	2.75%

Table 3 indicates that the vast majority of the visitors (60.61%) that took part in the survey are employees of an organization. Only 0.55% of the participants are secondary school students, these being among the individuals whose highest educational level is primary (compulsory) education (see Table 3). The category ``Other'' includes some responses related to Academia, such as "University Professor", "Lecturer at the University", as well as some answers in the native language of each of the participants, such as Greek, Italian, Spanish.

Table 4: Descriptive Statistics for the country of origin of the participants

Location of organization	Counts	Percentages
Andorra	3	0.17%
Austria	246	14.32%
Belgium	8	0.47%
Bulgaria	12	0.70%
Croatia	23	1.34%
Cyprus	112	6.52%
Denmark	1	0.06%
Finland	189	11.01%
France	14	0.81%
Georgia	4	0.23%
Germany	21	1.22%
Greece	184	10.71%

Hungary	3	0.17%
Ireland	5	0.29%
Italy	358	20.84%
Kosovo	1	0.06%
Latvia	6	0.35%
Luxembourg	1	0.06%
Netherlands	3	0.17%
North Macedonia	4	0.23%
Norway	3	0.17%
Portugal	5	0.29%
Romania	28	1.63%
Russia	1	0.06%
Serbia	3	0.17%
Slovakia	2	0.12%
Slovenia	1	0.06%
Spain	412	23.98%

Sweden	9	0.52%
Switzerland	1	0.06%
Ukraine	4	0.23%
United Kingdom	19	1.11%
Other	32	1.86%

Table 4 provides an overview of the responses concerning the country of origin of each one of the participants. At this stage of the initial analysis, we provide the frequencies (counts) and the percentages for all the possible options in the questionnaire. The vast majority of the museum visitors (around 43%) are from either Spain or Italy. In contrast, there are many countries with a very low percentage of participation. The option "Other" includes mainly non-European countries, such as Argentina, Puerto Rico, Brazil, and Mexico.

In Tables 1-4, the initial exploratory data analysis based on descriptive statistics has indicated, among others, that there are many categories with only a very small fraction of the responses, leading to extremely low percentages. In addition, some categories could be merged for the better understanding and presentation of subsequent analysis. Therefore, from now on, and until the end of the current section:

- The categories [``30-44'' and ``45-64'' of the variable] Age have been merged. The three new categories are ``Young users'', ``Medium-age users'', and ``Old users''. The reason for merging the age category to the three main groups was to have a better visibility of the young audiences since the age between 30 – 44 use advanced technologies and they are very well educated about the main use of Artificial Intelligence Applications. Also the merge of the age group is a way to avoid biasness in the research study.
- Concerning the variable "Level of Education", the categories "Primary (compulsory) Education" and "Secondary education" have been merged. The same holds for the categories "Master's degree" and "Ph.D.".
- For the "Employment status" variable, the options "Other" and "Secondary school student" have been removed, whereas the categories "Employee" and "Self-employed" have been merged.
- With respect to the home country of the participants, for the rest of the analysis, we have kept only the top 6 countries in terms of their percentage. It can be seen from Table 9 that these are Spain, Italy, Austria, Finland, Greece, and Cyprus.

In Figure 12, we provide a graphical representation of the results after the new categorization described above has been applied to our data.

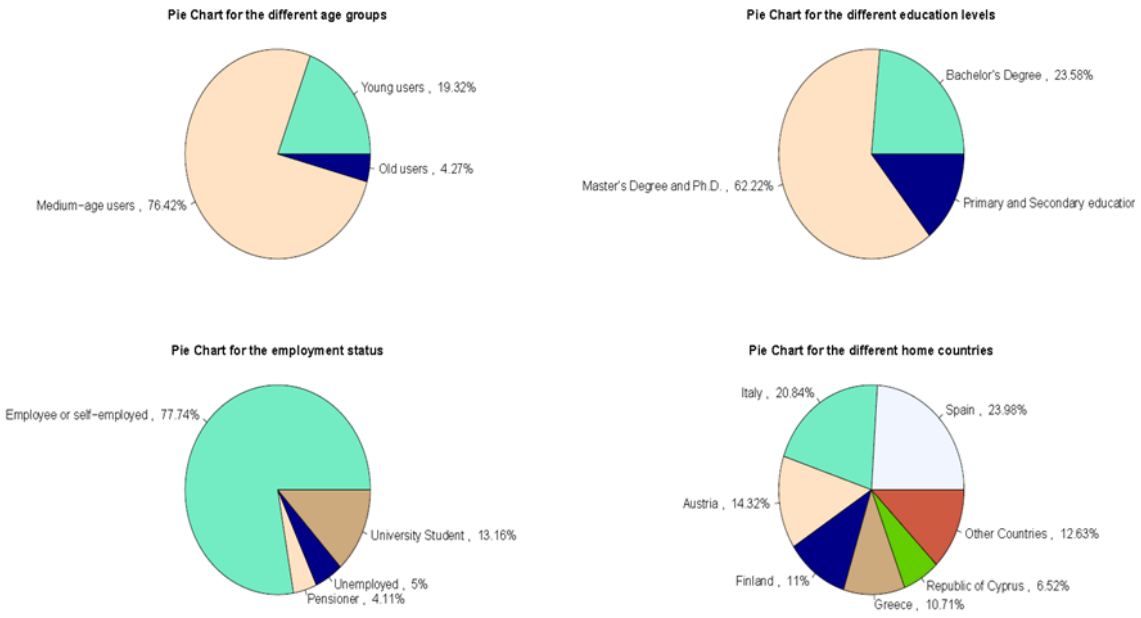

Fig. 12: Graphical representation of the percentages after the new categorization of the variables has taken place.

Visitor preferences on devices

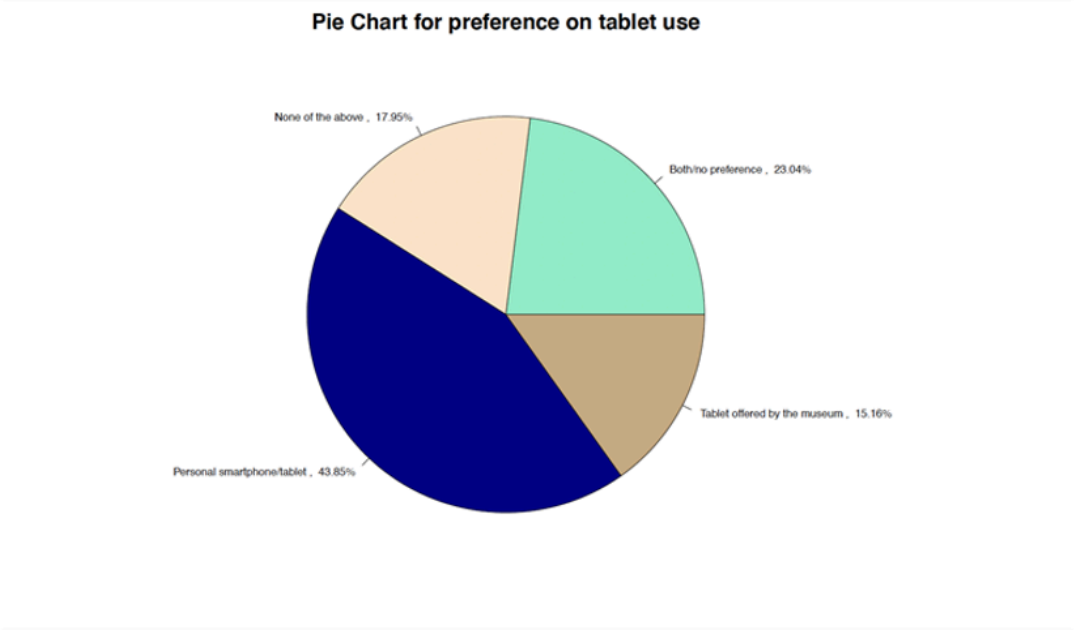

Fig. 13: Pie chart of what devices people prefer to use during a visit to a museum or a cultural heritage site.

Figure 13 makes it clear that people, in general, prefer to use their smartphones or tablet during their visit to a museum or cultural heritage site. In Figure 14, we observe that as the participants' age group increases, the preference for using personal smartphones or tablets decreases, and older visitors seem to either prefer tablets offered by the museum or use none of the two options at a much higher percentage than the one for younger visitors. From Figure 15, we deduce that there is a uniform preference for the use of personal smartphones or tablets across all different education levels, while in Figure 16 we observe that "Pensioner" is the only group of which the top categories are "Tablet offered by the museum" and "None of the above". This is related to (and to an extent anticipated from) Figure 14, where a similar result holds for older people since the vast majority of the participants that are pensioners are also in the "Old users" age group.

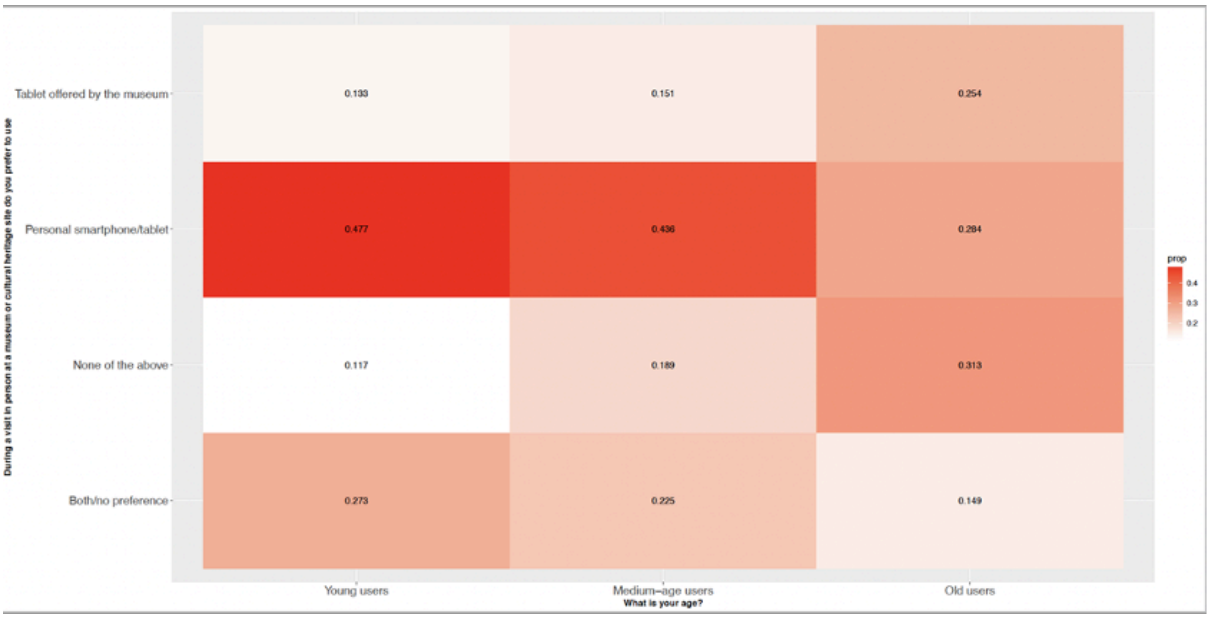

Fig. 14: Covariation plot between the variables "Preferred device to use during a visit" and "Age".

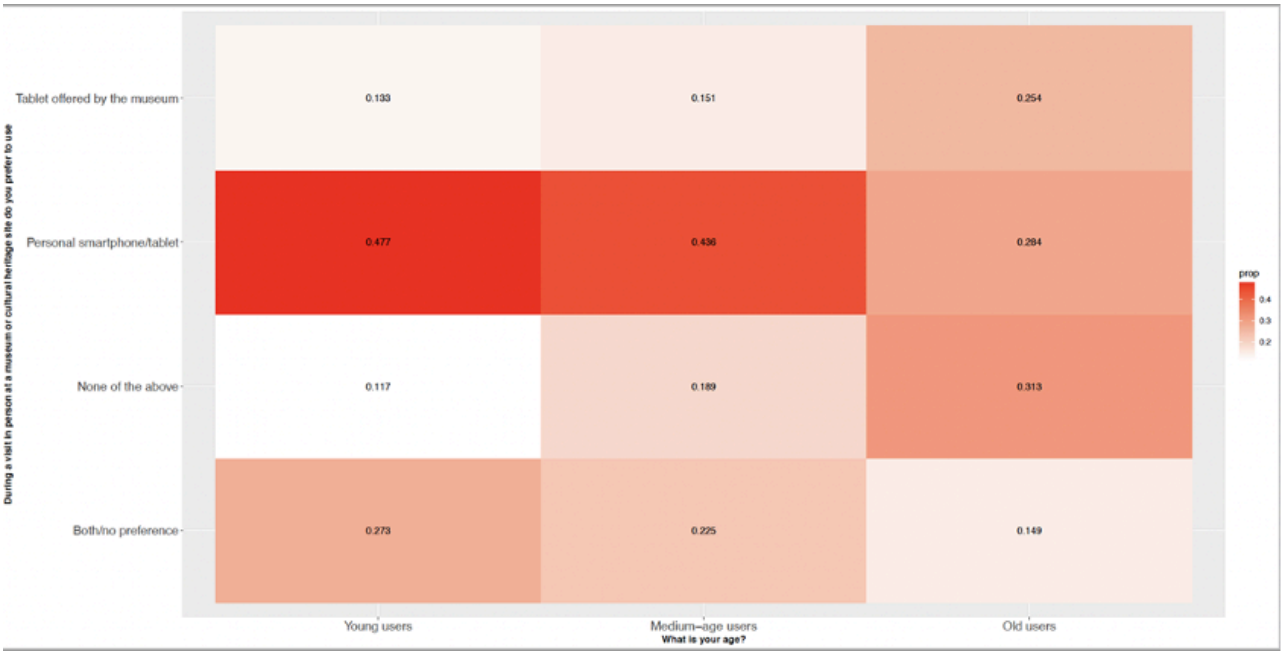

Fig. 15: Covariation plot between the variables "Preferred device to use during a visit" and "Level of Education".

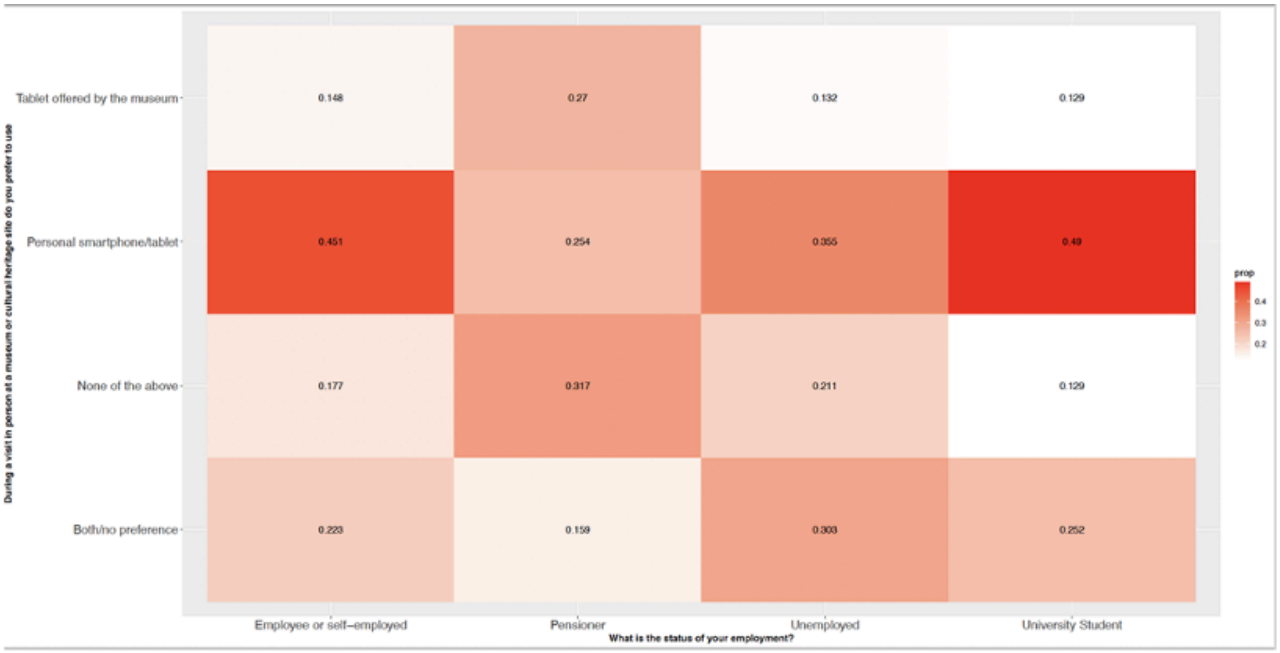

Fig. 16: Covariation plot between the variables "Preferred device to use during a visit" and "Employment Status".

Visitor preferences on Apps and Codes

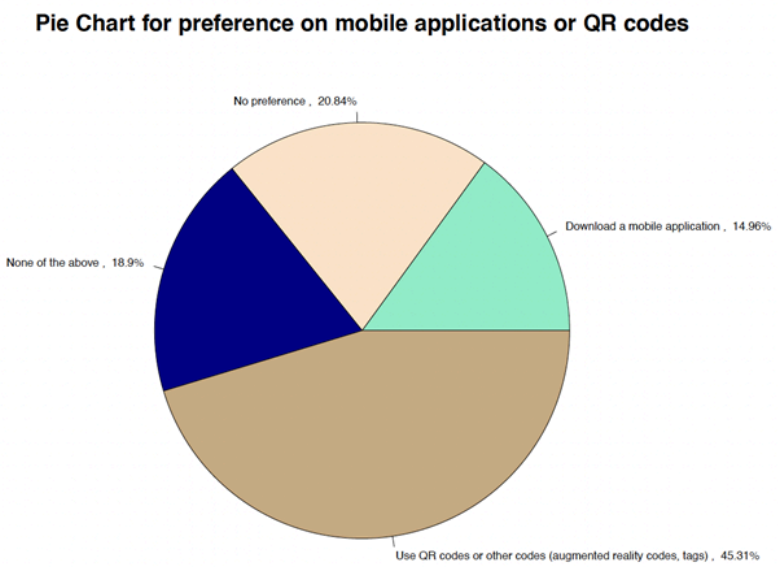

Fig. 17: Pie chart of visitor's preferences between QR codes and mobile applications during a visit to a museum or a cultural heritage site.

Figure 17 makes it clear that people, in general, prefer to use QR codes or other codes (augmented reality codes and tags) instead of downloading a mobile application during their visit to a museum or cultural heritage site. Furthermore, from the heat map in Figure 18, we deduce that concerning the preference for using QR codes, there is a strong inversely proportional relationship to the age group, meaning that the younger the person, the more likely that they prefer using QR codes rather than downloading an App on their mobile device. Figure 19 indicates that there is a uniform strong preference for QR codes across all different educational levels, while Figure 20 shows that the only category that seems to have a significantly lower (compared to the rest of the groups) preference for QR codes is “Pensioner”. This is related to Figure 18 and the respective low preference percentage for “Old users”.

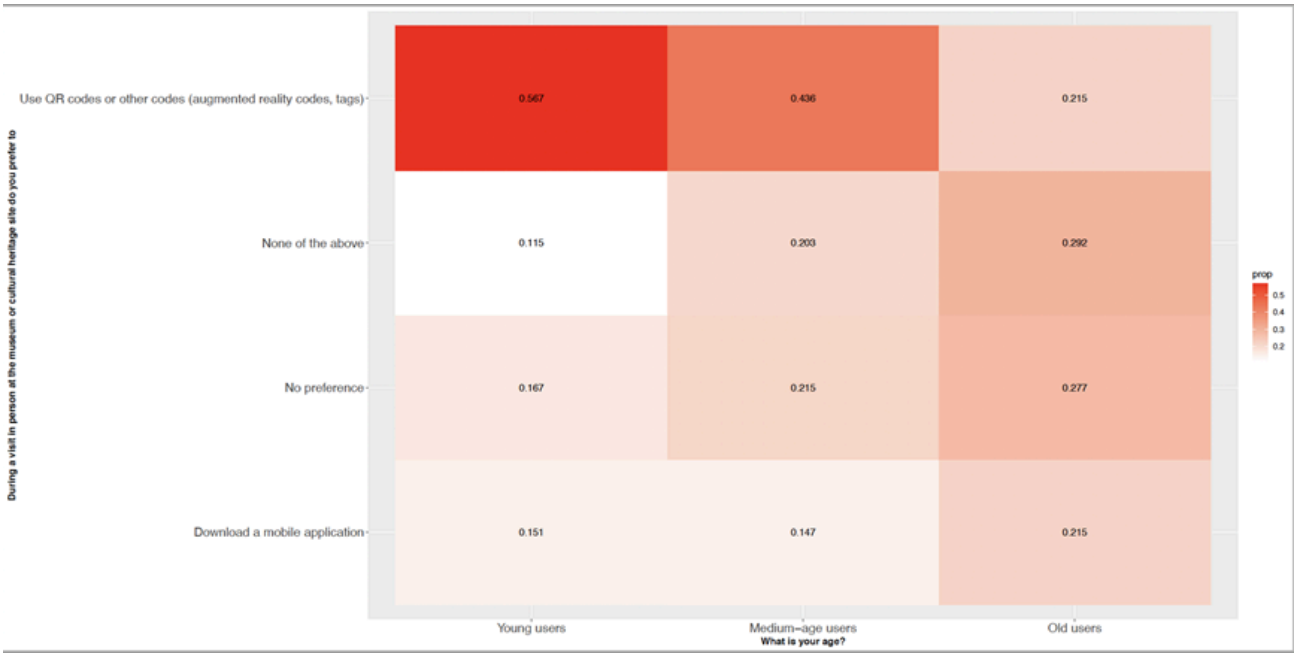

Fig. 18: Covariation plot between the variables ``Preference during a visit'' and ``Age''.

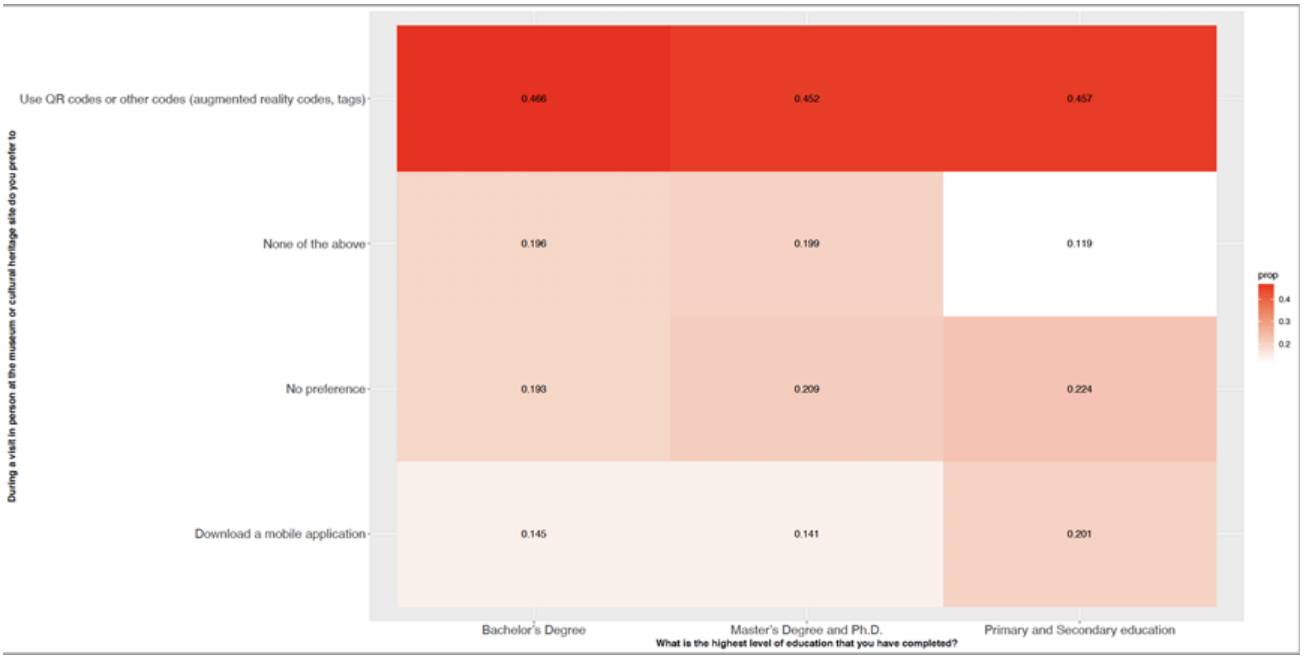

Fig. 19: Covariation plot between the variables ``Preference during a visit'' and ``Level of Education''.

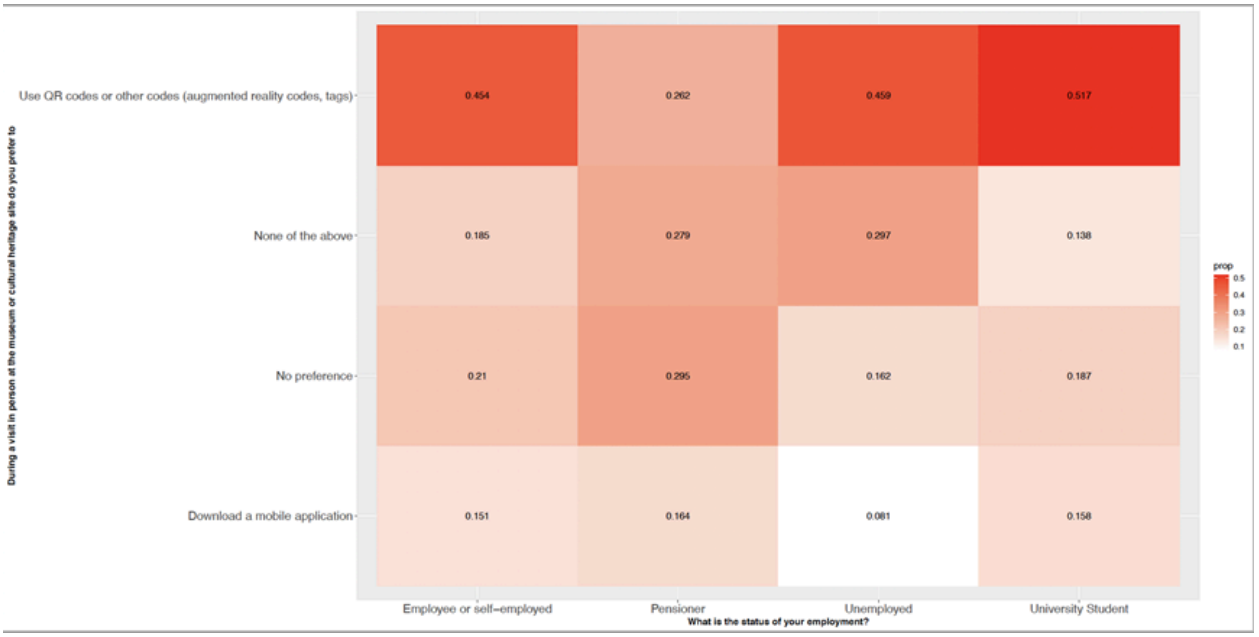

Fig. 20: Covariation plot between the variables ``Preference during a visit'' and ``Employment Status''.

Reasons for not using mobile applications

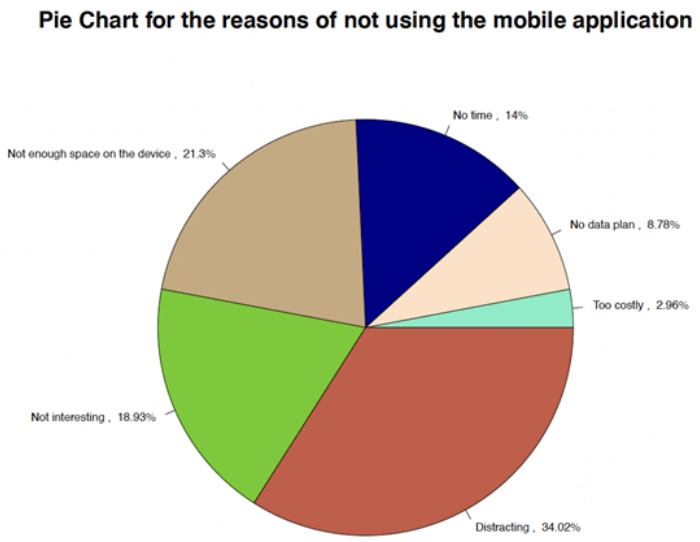

Fig. 21 Pie chart of the possible reasons for not using a mobile application during a visit to a museum or a cultural heritage site.

The main reason for people not using mobile applications during their visit to a museum or cultural heritage site is that they find it distracting. To be more precise, it is worth mentioning that more than 50% of the respondents have found mobile applications either distracting or uninteresting. When we covariate these responses with the age factor, we observe (Figure 22) that the “Distracting” option becomes more and more apparent when we move from younger to older users. In addition, younger users have higher percentages of the “Not enough space on the device” option compared to other age groups. This is justified by the existing literature on teenagers' approach during a visit to a museum or cultural heritage site. It has been shown that younger people are not willing to download museum applications because they do not want to waste memory on their smartphones. [Gaia, Boiano, Borda - 2019].

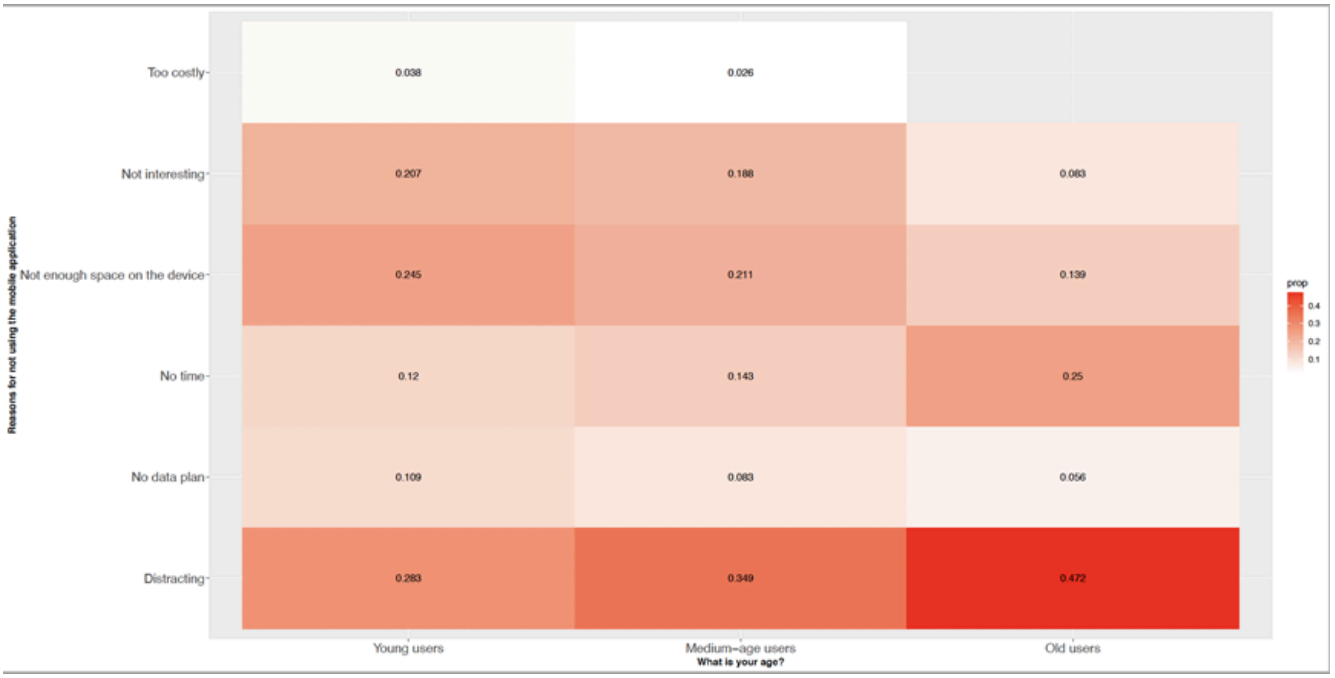

Fig. 22: Covariation plot between the variables ``Reasons for not using a mobile application'' and ``Age''.

Figure 23 shows that uniformly across all the different educational levels, the most common response for not using mobile applications during a journey at a museum is because they find it distracting. In Figure 24, there is a much higher percentage of “Distracting” for pensioners compared to the other employment statuses. This is related to Figure 22 and the respective very high percentage for “Old users”.

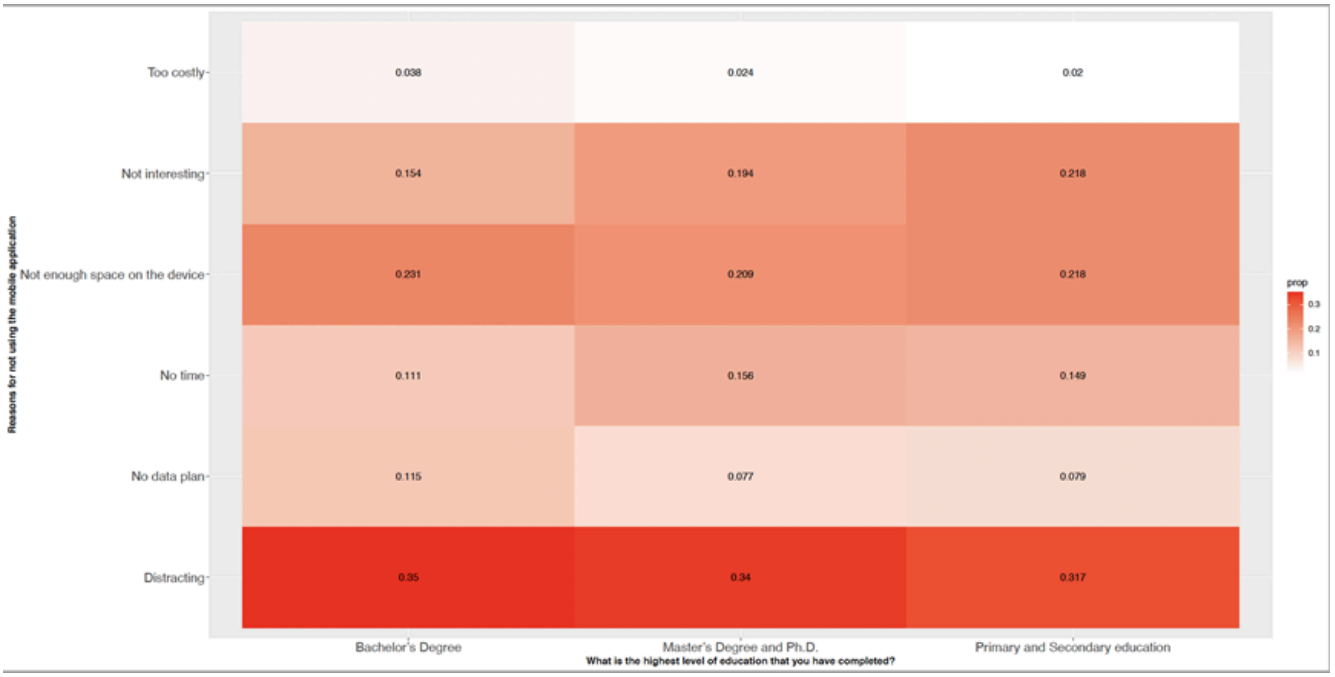

Fig. 23: Covariation plot between the variables "Reasons for not using a mobile application" and "Level of Education".

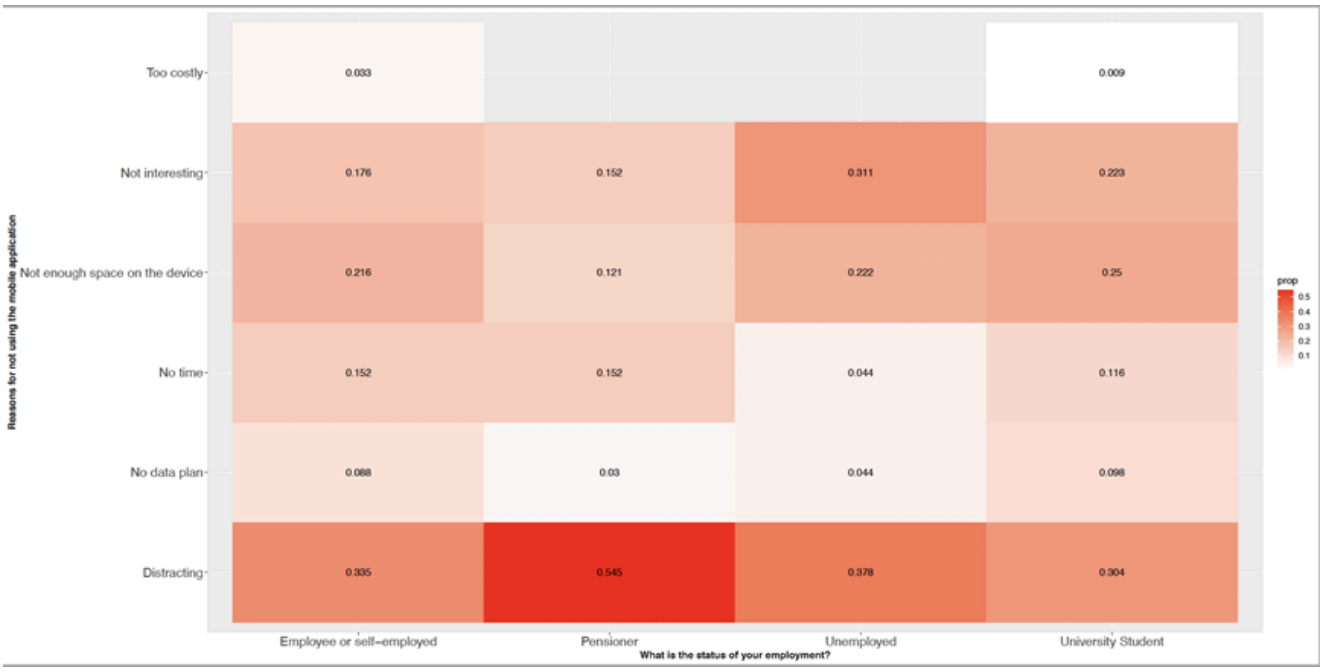

Fig. 24: Covariation plot between the variables "Reasons for not using a mobile application" and "Employment status".

Digital tools that help improve the visit experience

Figure 25 shows that there is not a single digital tool that stands out as either the most or the least helpful. Figure 26 shows that there is a slight preference for young and middle-aged visitors on interactive surfaces, multi-touch tables, immersive rooms, and responsive environments. In contrast, classic audio guides seem to be very helpful to older visitors, something expected because older users may find interactive surfaces and/or immersive rooms quite difficult to use.

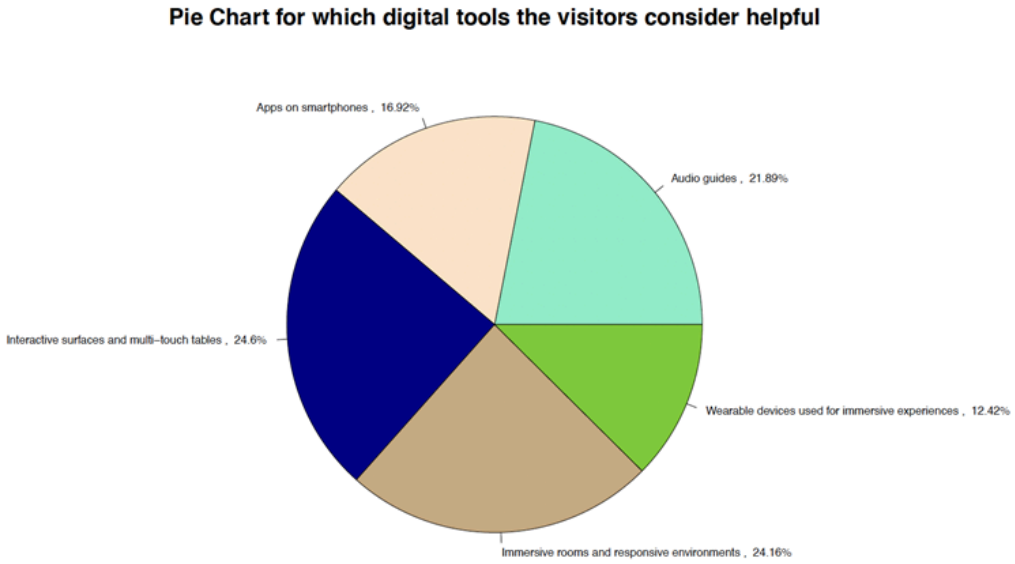

Fig. 25: Pie chart of which digital tools help improve the visit experience.

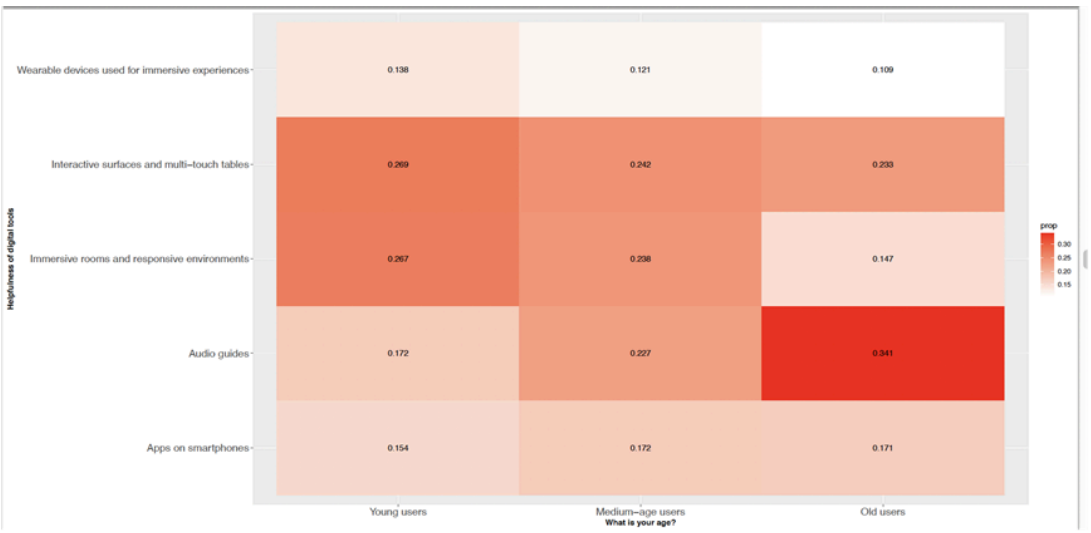

Fig. 26 : Covariation plot between the variables ``Helpful digital tools'' and ``Age''.

Figures 27, 28, and 29 present the pie charts on visitors' interest in direct interaction with the exhibits, digital games, and mobile applications, respectively, during their last visit. We conclude that, in general, there is a significant amount of interest in interacting with exhibits during the visit and an average interest in both digital games and mobile applications.

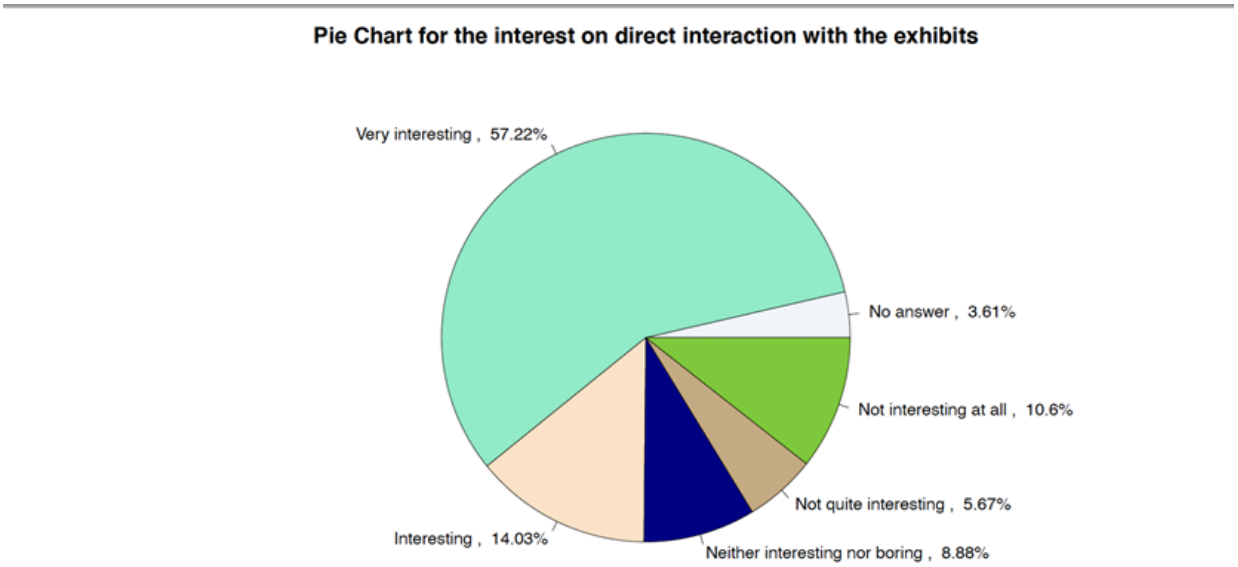

Fig. 27: Pie chart of how interesting the direct interaction with the exhibits was during the last visit.

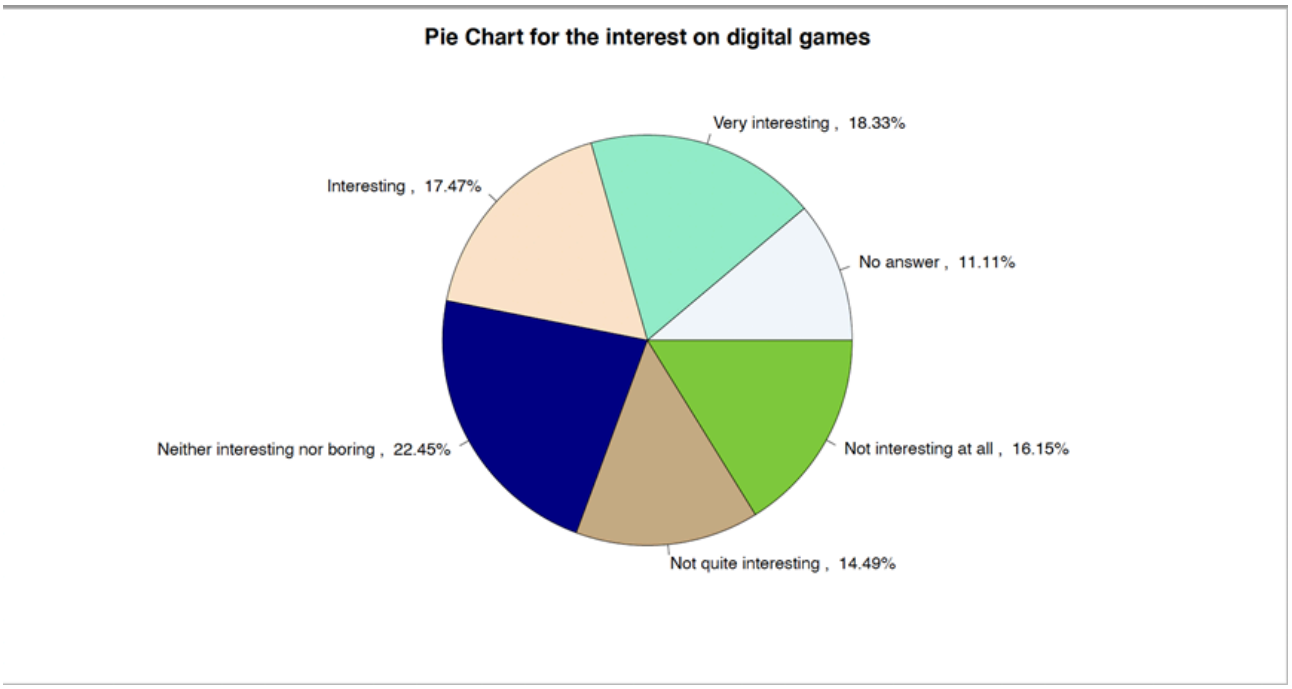

Fig. 28: Pie chart of how interesting digital games were during the last visit.

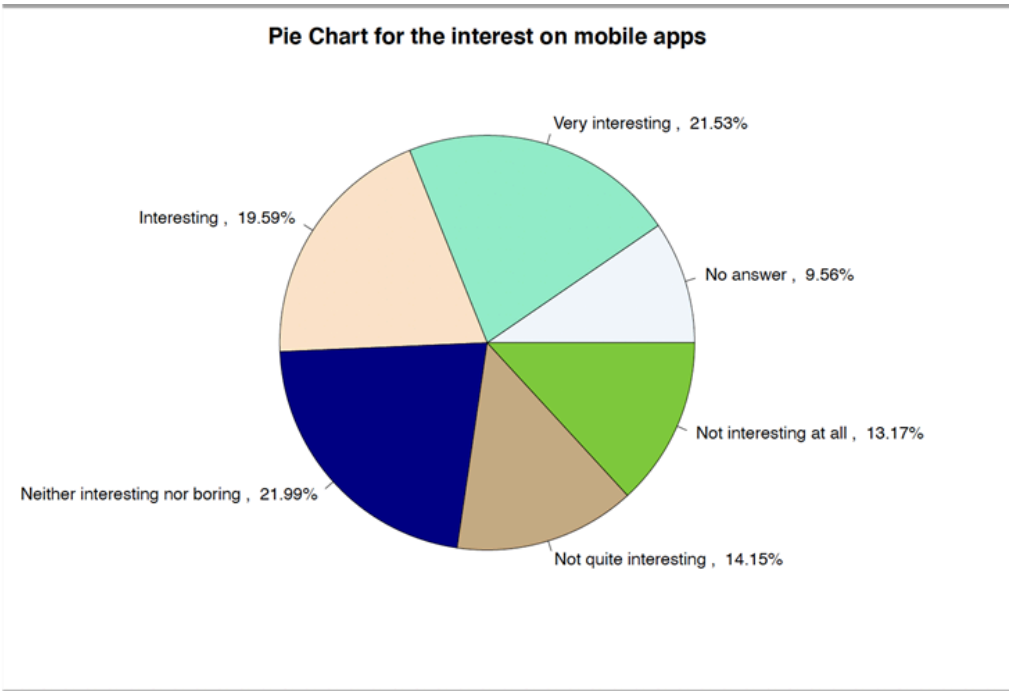

Fig. 29: Pie chart of how interesting the use of mobile applications was during the last visit.

Figure 30 indicates a uniform behaviour across all different age groups in the sense that the vast majority of visitors of all age groups find direct interaction with exhibits very interesting. With respect to digital games, Figure 31 exhibits that a substantial part of "Old users" does not find them interesting; this is not the case with the other two age groups. In Figure 32, we observe that the vast majority of younger respondents find mobile applications either "interesting" or "very interesting". In contrast, adults over 65 (the category of "Old users") remain in a neutral position (they find mobile applications neither interesting nor boring). Such results highlight that users (mainly at a younger age) are possibly and potentially interested in the use of digital games and mobile applications during their visit to a museum or a cultural heritage site. Whether they do download or use them depends primarily on the type of the application (or of the digital game) offered and the added benefits.

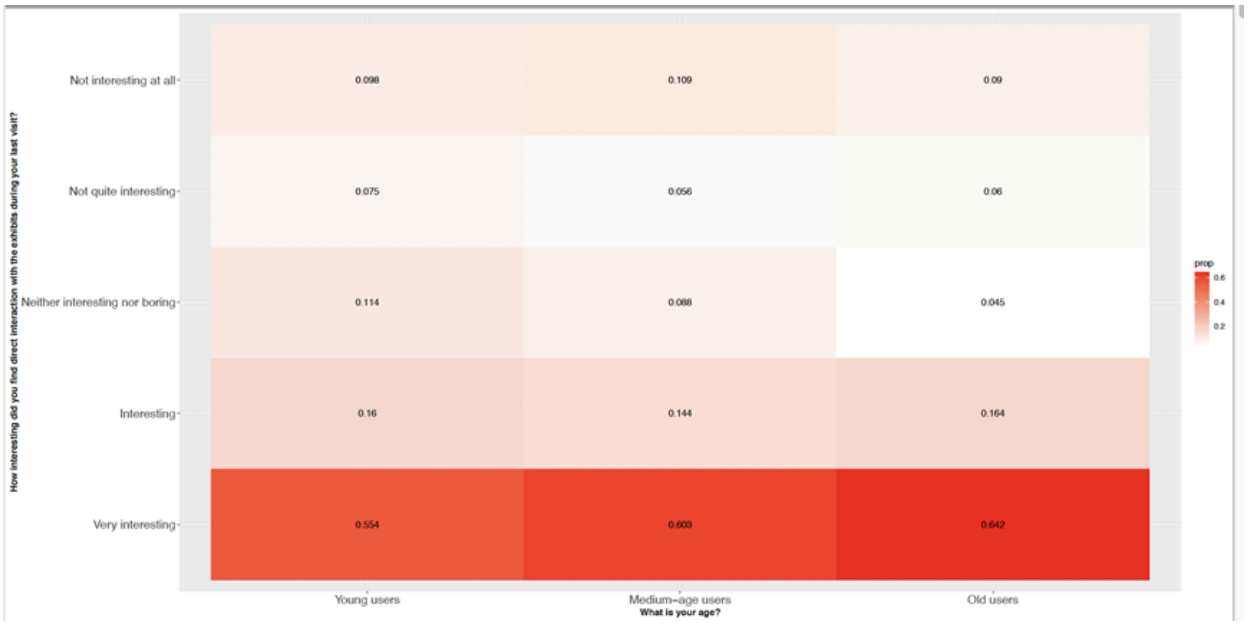

Fig. 30: Covariation plot between the variables "Interest in direct interaction with exhibits" and "Age".

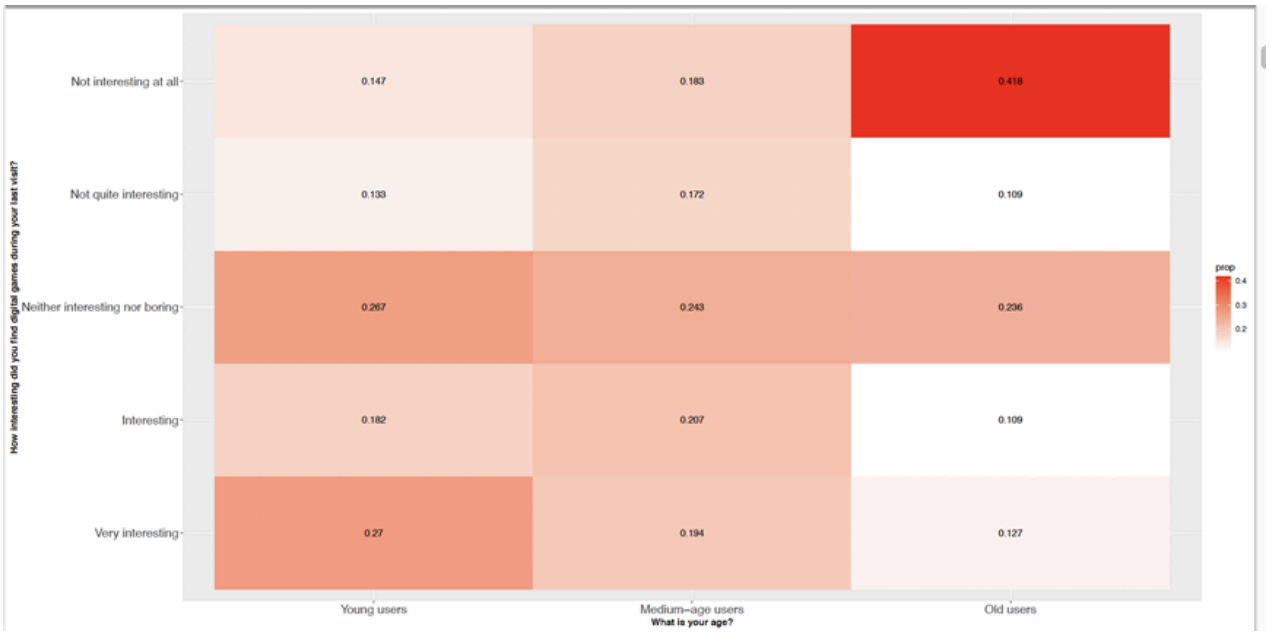

Fig. 31: Covariation plot between the variables "Interest in digital games" and "Age".

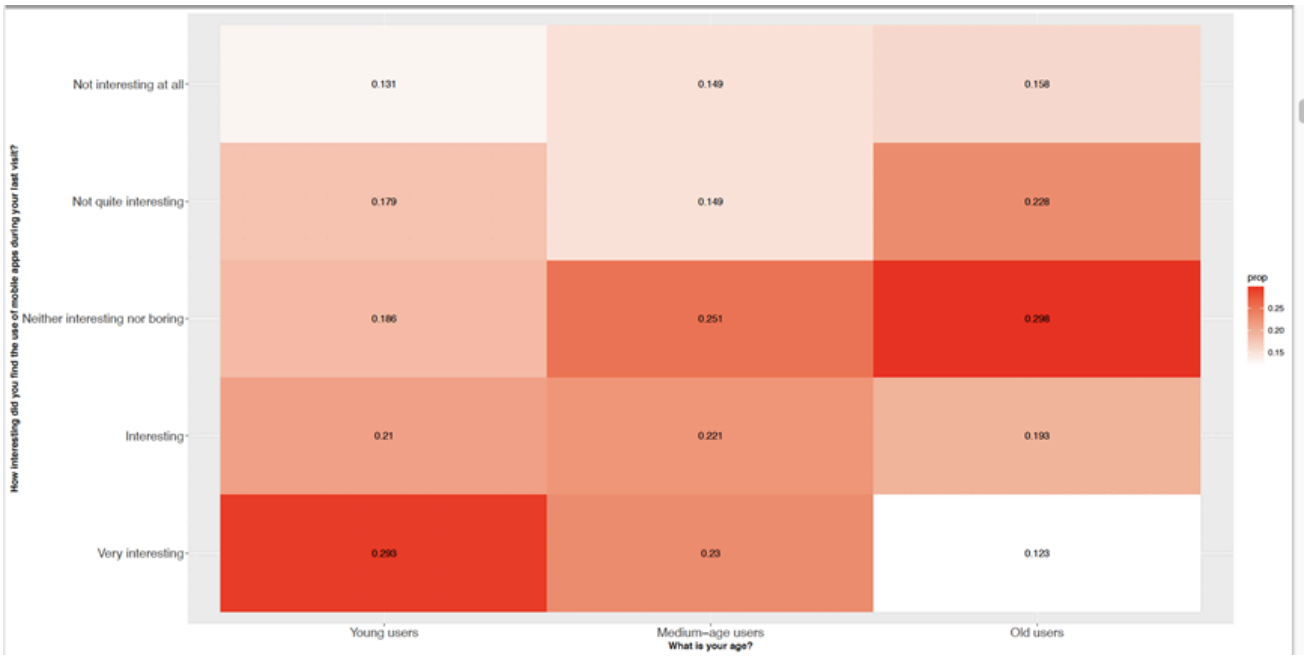

Fig. 32: Covariation plot between the variables "Interest in mobile applications" and "Age".

4. Focus Groups on Digital Tools with Experts

Additional qualitative data on digital tools was collected from academic and scientific staff at institutions and companies active in information technology used in cultural heritage. This allowed gathering information about the tools available and the ways in which they can be applied to museums/heritage sites. This data was collected in the focus group stage of the primary research (see D2.4 Focus Groups Phase II Report). The ReInHerit focus groups conducted with museum and archaeological site professionals, academic researchers, public authority/NGO officials, and ICT professionals identified motivations, technical barriers and enabling factors to support the process of designing digital tools in museums and CH sites. Through the co-creation process of the focus groups, heritage and ICT professionals described their requirements for digital tools and these have been formulated into three key parameters of digital management in small-and medium-sized museums/heritage sites.

The three parameters are: digital strategy (see diagram below), multinational and multidisciplinary collaboration and digital literacy training. Their core premise of reusing, educating and sharing forms the cornerstone of a sustainable digital heritage management.

5. AI for Smart Interaction

AI and VR combined are useful to know interests of visitors and personalize narratives and interaction according to their preferences. The results indicate that visitors prefer to use their smartphones or tablets in a museum or heritage site. In general users, especially the

younger visitors, prefer *quick and smart interaction* with digital tools, using QR-Codes and do not download mobile apps and generally they want to be engaged and motivated in their use by first understanding the benefits, features and value added. These are the main bottlenecks identified for actively engage users in cultural heritage using digital tools:

- User/Human Centered Approach
- New points of view and perspectives about collections
- Interactive and Memorable Experiences
- Phygital Experiences
- Emotional Engagement for Learning Motivation
- Storytelling and Social Media Sharing
- Users Generated Narratives and Contents

The possibilities for using digital tools in museums are varied and numerous and the recent studies indicate that in order to be up–to–date and give visitors a memorable and unique experience, museums are including usage of digital technologies in their exhibitions. In 21st Century museums all visitors actively participate, involving them into dialogue and using museums' collections creatively. Mobile today could be wearable or portable devices, smartphones or tablets, mobile or desktop websites, "*bring your own device*" (BYOD model) mobile experiences or traditional on–site device distribution [Goldberg, 2013]. Research conducted on the use of Mobile Technologies in Museum Exhibitions indicate that visitors prefer technology that is quick to use and provides continuous and dynamic interaction, especially on mobile/web applications or Quick Response (QR) code and sensors because they allow a high degree of personalization of the museum experience. Mobile digital tools are preferred for the following aspects: *Versatility* - they can be used for anything (games, business productivity applications, multimedia applications, time management, etc.); *Interaction* – they can be used to get feedback from visitors or to connect them with each other through social media; *Individuality and customization* - visitors can create their own highlights, with the ability to search, group, and filter every object; *Analytics* - tracking can be added to discover user actions; *Comparison* - the mobile platform can give the visitor the ability to compare items, thus providing valuable content; *User-generated content* - collected content, in the form of comments, thoughts or responses, could provide the museum with a valuable research tool [Medić - Pavlović 2014]. For mobile technologies, the common advice is to keep it simple. Too much text, actions needed or too many possibilities could confuse the user and discourage him/her to continue to use it. It is important to give visitors the opportunity to engage with other visitors, the museum community or employees, sharing experiences and stories.

Innovative technologies have the potential to renew the experience a visitor can have with a museum, expanding this experience. A better experience can alter the way visitors perceive the museum's exhibits, bringing benefits for both the museum and visitors. Best mobile apps

are dynamic, allowing a series of interactions with users that are not always available on personal computers, since they are executed on compact physical devices. Smartphones are used individually and are not shared by the public, mobile apps can play an important role in pandemic e post-pandemic Museums [Cuseum, 2020 ; Spencer, 2020]. Audio Guides can be transmitted by wi-fi directly to the visitor's smartphone, QRCodes can be used to enable devices, and digital maps can help the user to navigate the museum's spaces, all solutions that make the visit safer. Smartphones and tablets are the two top types of technology used, because most visitors bring their own devices when visiting the museums. [Shah and Ghazali, 2018]. Mobile apps can enhance learning if they can provide an active learning environment that goes beyond swipe and tabs, that engages the learner in its process, and that is meaningful and socially interactive.

Evaluations of mobile applications in in museums and cultural sites highlight that the potential of mobile devices to improve visitors' experience in a museum setting was characterized in the following ways: allowing a customized experience; diversifying sources of content; accessibility; expanding the role of a visitor, as a curator, researcher, or content provider; stimulating further exploration and discoveries in the exhibition; enabling a personal expanded meaning experience; enabling experiences that go beyond the walls of the museum; catalyzing social interactions; extending the visitors' observational capabilities; increasing interactivity with exhibits [Barbosa, Saboya, Bevilaqua 2021]. Regarding the user interface design for mobile apps in museums, recent studies identify the need for a design that is easy to use and does not interfere with the physical experience. Apps should be designed to enhance rather than oversteer; design to engage rather than simply guide to a place; design to enchant; encourage curiosity rather than content consumption; combine playfulness with local interest; design for memorable experiences. An effective digital toolkit strategy aims to enhance and extend user experiences by analyzing and trying to understand what are the desirable aspects, the benefits in using and the emotional and triggering effects of user engagement.

Based also on the well known "Contextual Mode" of learning proposed by Falk and Dierking [Falk, Dierking 2012], the more multisensory, interactive and participatory the museum experience is, the more it will have a lasting impact on the visitor and thus enhance his or her learning on the subject. Visitors do not enter the museum as a blank canvas, but their visit is guided by their own motivations, emotions, interests, and prior knowledge. This background has a huge influence on the experience the visitor gets from the stay, also on the memory they will have of it, and on recommendations to other users and friends. Digital tools can be used to enhance the museum experience, triggering a multisensory experience, or enhancing social interaction during the visitor's journey, improving the personal, physical, and social aspects of the museum experience. Digital technologies are useful in enabling personal connection, personalizing the visit according to the user's needs, enhancing playful and social interaction, and sharing personal experiences. Digital and mobile applications

based on CV/AI can be used to interact with the performance environment in a playful approach, based on gamification and learning-by-doing techniques, so that the audience have the opportunity to select objects to interact with them, taking advantage of the "wow" effect to encourage deeper study of the artwork's content during and after visits. Visitors have the possibility to connect selected objects to their visit experiences, creating narrative and user-generated content to share via social media.

6. Recommendations

Visitor studies have a long history in museums, and draw now on well-developed methodologies comprising questionnaires, interviews, and observation methods to evaluate visitors' experiences in the galleries. Visitor research is now conducted also through the support of specialised agencies (e.g. Morris Hargreaves McIntyre, with their Culture Segments framework[1]; the Audience Agency, with its Audience Spectrum framework[2]; or Dexibit, which also uses big data and AI to predict visitors behaviour). All these agencies have developed visitor segmentation and prediction tools, which allow inferring from questionnaires and – in the case of Dexibit[3] – analytics, patterns of cultural consumption. Attempts to create broader benchmarks have been deemed not granular and precise enough to satisfy the needs of individual institutions (Arvanitis et al. 2016).

To a certain extent, these methods can also be used to evaluate visitors' reactions to digital interactive and apps in the galleries: through surveys and short interviews or focus groups it is possible to test the success of digital engagement activities happening in the museum space. There are, however, few benchmarks to allow comparison and planning of new digital in-gallery tools: evaluations in this field tend to be conducted for research purposes, testing specific case studies, with limited research on their broader applicability. In this sense, there are not clear benchmarks that allow comparing different organisations' digital offer and plan for new tools.

As noted in [Cappa-2020], visitors can contribute to generate new knowledge, through their behaviour, that can be exploited by museum managers to improve the cultural offerings of their institutions to generate major economic and/or social impacts. Instead of obtaining such information with traditional questionnaires it is possible to use visitor-sensing techniques based on digital technologies to collect visitors' ideas, preferences, and feedback. The acquired data can be used to improve path design and the organisation of artwork in exhibitions, and to shape a more satisfying museum experience for visitors.

[1] https://web.archive.org/web/20210731023718/https://mhminsight.com/articles/mhm-relationships-2907
[2] https://www.theaudienceagency.org/news/audience-spectrum-updates
[3] https://dexibit.com/

Sensing techniques can exploit, for example, computer vision to estimate the attention of the visitors in a museum (e.g. as in [Bartoli-2016] and [Centorrino-2021]) or exploit digital devices, e.g. through instrumentation and logging of smart guides it is possible to collect information regarding the artworks that have attracted the interest of the visitors, as cookies and web page tracking allows to collect information on the behaviour of users of web sites.

Digital technologies can thus help to reconfiguring the customer value proposition [Russo-Spena-2022] (i.e. what is being offered) and reshape its delivery to improve the visitor experience, exploiting the BYOD (Bring Your Own Device) model as a sensing network and integrating different channels (e.g. from social networks to chatbots) to collect additional data on behaviours and interests.

Online audiences are yet little researched. On the one hand, museums and CH organisations monitor platform analytics (e.g. website analytics, often drawing on Google Analytics and marketing tools[4], or in-platform analytics for Facebook pages, Twitter, and Instagram Business accounts). On the other hand, few researchers have attempted to go beyond these quantitative approaches to develop data-driven analyses or qualitative insights on audience engagements with CH organisations online content (Arias 2018; Budge 2020; Villaespesa 2015; Zuanni 2017b, 2017a). However, these research projects have focused on single case-studies, and methods difficult to replicate on a broader scale across different institutions.

Regarding the visitors' experience, in general they prefer to use their own smartphones or tablet in a museum or cultural heritage site. Young visitors prefer to use personal smartphones or tablets. Older visitors seem to either prefer tablets offered by the museum or none of the two options

Museum visitors, in general, prefer to use QR codes or other codes (augmented reality codes and tags) instead of downloading a mobile application in a museum or cultural heritage site. Most young visitors prefer using QR codes rather than downloading an App on their mobile device. There is uniform strong preference for QR codes across all different educational levels. Old users seem to have a significantly lower (compared to the rest of the groups) preference for QR codes.

The main reason for people not using mobile applications during a visit to a museum or cultural heritage site is that they find it distracting or uninteresting. Distraction is the main reason for older users and it is a uniform response across all different levels of education. Younger users don't download museum apps also because they don't want to waste memory on their smartphones and devices.

[4] https://marketingplatform.google.com/about/

No single digital tool stands out as the most or least useful.

- **Interactive surfaces**, **multi-touch tables**, i**mmersive rooms** and **responsive environments** are a little more interesting for young and middle-aged visitors
- **Classic audio guide**s seem to be very useful for older visitors because interactive surfaces and/or immersive rooms are rather difficult to use.
- In general, users are very interested in i**nteracting with the exhibits** during the visit and they have an average interest in both digital games and mobile applications. Visitors of all age groups find **direct interaction** with the exhibits very interesting. Older users are less interested in digital games and they remain in a neutral position regarding mobile apps (neither interesting nor boring). Differently, **young visitors** find **mobile applications** interesting or very interesting, depending on the **type of application** (or digital game) offered and its **added benefits.**

Considering the technical aspects of the use cases reported in Sect. 2 it can be observed that in many cases the performance of the presented systems can be greatly improved employing the most recent advancements in AI and its applications, like Computer Vision. Often, systems that require high-end desktops can be implemented on mobile devices, and in many cases such applications can be even implemented as web-based applications, that do not require to download native applications, thus addressing one of the concerns of users, observed in the surveys (see Sect. 3), that is the preference of not downloading apps. The most recent advances in neural networks and the integration of hardware accelerators for AI applications even in mid-level mobile devices make it possible to bring advanced applications and more compelling interactions to a large number of users.
On the other hand the vast majority of applications and use cases reported in Sect. 2 are more academic exercises or have been used for a more or less limited period in some institution as experiments, rather than becoming commonly used tools. Sometimes this has been caused by the requirements of special hardware (e.g. desktop GPUs) that make it difficult to deploy applications on end-user devices, but in many other cases the problem lies in the fact that applications are not available as open source tools or are not sufficiently documented to allow their maintenance and evolution; these latter causes have been particularly noted as critical points in the focus groups of phase II.
These considerations lead then to identify a set of main guidelines that drive the development of the ReInHerit toolkit:

- employ modern AI technologies that can be implemented also on mobile devices, e.g. use low- latency and low-computation solutions to develop AI-based apps that can be executed on smartphone GPUs and neural networks accelerators; an additional benefit of this approach is to reduce the cost of deployment and maintenance of the developed systems;
- develop a set of reusable components that can be used as building blocks of sets of applications, along with sample apps that show how to compose them;

- use an open source approach, to let also small and medium sized cultural organisations to develop their own applications or adapt the same applications of the ReInHerit toolkit;
- develop a training curriculum to teach the basics of modern AI technologies, to provide high-level information for managers and designers, as well as providing more detailed and technical oriented information for developers to understand the technical possibilities and performances of systems developed for mobile devices.

6.1 Implications of using AI

As explained in Section 6 of the D3.2 Toolkit Strategy, when working with Generative AI tools for user engagement in museum and educational contexts by motivating learning, it is essential to evaluate the implications of using AI in general, and paying particular attention to the generative models, taking into account expert recommendations and references. The development of these artificial intelligence applications involved extensive training on large data sets. Ensuring that the final training data is ethically sourced, unbiased, and free of discriminatory content is crucial to maintain the ethical integrity of AI tools. Regarding this aspect the Ethics Annexes of the applications developed for the ReInHerit toolkit report the model cards of the models used and describe how the dataset used were collected. Regarding this aspect the Ethics Annexes of the applications developed for the ReInHerit toolkit report the model cards of the models used and describe how the dataset used were collected. Some of the pre-trained models used to develop the applications, do not fully disclose how the data used to train them was obtained, notably the FaceMesh network used in Face-fit, but the authors analyze the fairness of the model w.r.t. different visual attributes.

Toolkit Strategy underscores the ethical and operational considerations related to the use of AI, particularly AI chatbots like ChatGPT, in museum contexts, emphasising the importance of ethical conduct, transparency, and compliance with relevant regulations.

- **Ethical Implications and Algorithm Biases:** It is imperative not to overlook ethical implications and potential biases in AI-generated content. Evaluating the ethical impact and potential biases of AI-generated content is necessary to avoid unintended consequences.
- **Correct Terminology for ChatGPT**: Using the correct terminology to represent ChatGPT accurately is essential to avoid misunderstanding its role and contribution in any generated content.
- **Copyright Issues:** Although ChatGPT is an artificial intelligence language model developed by OpenAI, it is essential to clarify its role and contribution in any content it generates, particularly concerning copyright.

- **Legitimacy and Scope of AI Use:** Understanding the legitimacy and scope of AI use in museum contexts is crucial to ensure appropriate implementation.
- **Transparency in Training Data**: Transparency about the data used to train ChatGPT is necessary to assess its reliability and potential biases.
- **Ethical Implications and Data Privacy:** Given the absence of appropriate regulations, ethical implications and data privacy issues must be considered, especially concerning the ethical impact and potential bias of AI-generated content.

GenAI technologies are still evolving rapidly and are likely to have a profound **impact on education and research,** even in non-formal settings such as **museums**. Therefore, their long-term implications for education, research and cultural institutions require immediate attention and thorough review, as outlined by the latest **UNESCO Guidance** [UNESCO 2023].

This includes the resolution of concerns regarding the **ethics of AI chatbots**, compliance of user privacy policies, training data and the scientific accuracy of chatbot results. Regarding the ethics of AI chatbots, interactions with museum visitors raise concerns about the processing of personal data. Ethical standards regarding user privacy, data tracking, profiling and compliance with data protection laws and regulations are essential. Before collecting personal data, users' consent must be obtained and the chatbot must be transparent about the use of data, while ensuring safe and appropriate data storage and anonymisation.

The main controversies on generative AI and its implications for education are summarised by Guidance,[5] focusing on **generative AI in education and research** discussing various ethical concerns and risks associated with generative AI systems.

The UNESCO 2023 Guidance outlines the importance of regulating generative AI to address controversies and maximise its potential benefits in education[6]. The document proposes a series of **seven steps** for governmental agencies to regulate generative AI and ensure its ethical, safe, equitable, and meaningful application, including in education.

The Guidance emphasises the need for a comprehensive**, human-centred approach** to regulate generative AI for educational purposes. These seven steps provide a roadmap for governments to navigate the complexities of AI regulation and ensure responsible and beneficial use in the field of education, also in the CH management sector.

Regarding AI initiatives and related ethical concerns and biases during their lifecycle, the **“AI+Museum Network”** has created an **“AI Ethics Worksheet**” as part of a Toolkit that aims to identify and address the following issues at each stage.[7]

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[5] [UNESCO 2023] (pp. 14-17)

[6] [UNESCO 2023] (pp. 18-20)

[7] Elena Villaespesa, Oonagh Murphy, “AI: A Museum Planning Toolkit” - The Museums + AI Network - Goldsmiths, University of London New Cross London SE14 6NW (pag. 13) https://themuseumsai.network/toolkit/ . These issues have been discussed during Museums+AI Workshop” described in Section 3.4.1 “Co-creation and Ethical Use of AI Tools” - D3.8 - Toolkit Phase II.

- **Data input: Collection & clean up:** - it is essential to assess potential pre-existing biases in the original dataset and identify any missing data. The data must be thoroughly cleaned and prepared to ensure its quality and reliability. Furthermore, it is crucial to confirm the acquisition of informed consent for data containing personal information and to implement measures to ensure and comply with legal requirements on data privacy.
- **Data training:** it is important to assess the suitability of museum collections as training data sets and whether the available data are sufficient. Furthermore, we should evaluate the advantages and disadvantages of using machines for training artificial intelligence models.
- **Testing/Model development:** in the testing/development phase of the model, considerations include identifying potential biases arising from the algorithms, assessing the ethical implications of using third-party artificial intelligence platforms for model development and ensuring transparency in the development process rather than a 'black box'.
- **Application:** in the Application phase, we need to understand how the use of a 'black box' model might impact curatorial practice and consider both the intended and unintended consequences of applying this model.
- **Data Output:** with regard to data output, the potential for data bias must be addressed, ensure that the process is documented and explained to users, and consider future and potential applications of this data.
- **Evaluation**: in the Evaluation phase, the focus is on assessing the success of the AI initiative, understanding its impact on the visitor experience, evaluating how it contributes to and expands collection data, and ensuring compliance with the ethical codes of various museum associations.

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