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# Augmented Reality in Portuguese Museums: A Grounded Theory Study on the Museum Professionals' Perspectives

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**Abstract:** Augmented Reality (AR) is increasingly present in several fields, including the museological space, where the challenges of presenting objects interactively and attractively are constant, especially with the sociocultural changes of recent decades. Although there are numerous studies on AR in museums, the perspective of museum professionals on the technology still needs to be explored. Thus, in this study, we use a qualitative design and conduct in-depth interviews with professionals from 10 Portuguese museums involved in creating or applying AR within these environments. Applying the grounded theory, the researchers propose a framework to understand Portuguese museum professionals' practices, perceptions, and experiences with AR in museum environments. The findings allow the creation of a theoretical framework divided into four levels, namely the perceptions of museum professionals on the role and use of AR, the understanding of departments, museum teams, and digital strategies, the perceived challenges, limitations, and advantages in the use of augmented reality technologies, and the future perspectives of AR in museums. The theory resulting from this study may also contribute suggestions for the design and implementation of AR in museums, which both museum professionals and designers can use.

**Keywords:** augmented reality; AR; museum; museology; museum professionals; Portuguese museums; AR museum experiences



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## 1. Introduction

As we know, the contemplative attitude is strictly related to the museum concept. However, this pattern has changed with the emergence of new interaction paradigms and technologies. The museum can now provide innovative methodologies and new ways of viewing and contemplating the exhibited works. With society increasingly dependent on technology, the museological sector does not remain unscathed. The accelerated pace drives proficient and agile changes by incorporating new forms of communication and stimulating greater collaboration and knowledge sharing about museum collections [1].

Museums have undergone changes and transformations in recent decades, motivated, above all, by the need to adapt to current society, one of their most significant challenges being the form of communication between the institution and the public, reinforcing "a distancing from the centrality of objects in towards an emphasis on promoting experience" [2] (pp. 99–100). In this way, museums are no longer just identified by their resources but also are evaluated by their programs, capacity for loyalty, diversity of products, attraction to the public, and quality of services [3].

The museum's visiting experience now focuses on bringing visitors closer to what is on display. The visitor is now seen as an active element who interprets the exhibitions as he moves along his route. However, the visitor often remains passive in the interaction with the exhibitions that he only sees. Thus, institutions have sought to create more profound levels of interaction to transform the visitors into participants who can interact through the senses and create a dialogue with what is on display [4], hence the requirement to use new technologies that meet the new generation of visitors/participants' needs. One of the

technologies that has gained prominence in recent years in the museum environment is augmented reality (AR). Through the superimposition of virtual objects in the real environment, AR technology adds new layers of information to traditional museum exhibitions, transforming the museological environment. By providing a re-reading of the traditional museum experience, with an increase in the perception of details that would be invisible at first glance, AR systems expand the visitor experience, interactively presenting information, and elevating the museological narrative and interactivity of the museum [2].

Currently, most AR museum applications aim to provide interactive experiences that offer responses to the different perspectives of the visitor, acting as a bridge between the museological discourse and the visitor [5]. By helping to navigate the environment [6], complementing pre-existing information from the exhibitions [7], providing access to inaccessible objects [8], reconstructing the past [9], or even generating opportunities for social experiences and content generated by users [10,11], several small or large museums have already used AR systems to bring dynamism and movement to their collections, draw public attention, and engage new visitors [12–14].

However, despite the high expectations of technology within the museological environment, its use in these spaces still needs further exploration and reflection, mainly regarding holistic approaches that involve visitors, developers, designers, and museum professionals in creating these experiences. Many studies have already explored the use of AR in museums from the perspective of user experience design [15–17]. The results of these studies suggest similar aspects of using AR in museums like the increased interest in the visualized artifact, the greater immersion and interactivity between the visitor and exhibited artifact, the self-collection of information from the exhibition, the generation of curiosity and attraction of visitors, and the maintenance of the public by providing a new look at the artworks. Other studies focus on the more technical aspects of AR [18,19]. Although AR is considered an added value for the museological space, it still needs to improve its technical problems and overcome implementation difficulties, those among which stand out being the instabilities of internet connections and problems with tracking points, mainly when using multiple targets.

Nevertheless, few investigations examine the perspectives and experiences of museum professionals with AR more deeply. Among these, we only identified the report prepared during the implementation of the Let's Explore and Smartify projects at Watts Gallery–Artists' Village. This report [20] aimed to develop supportive guidelines with recommendations for AR practice that can be used by the museum team, volunteers, or gatekeepers. Another study [21] sought, through six semi-structured interviews with museum employees and app developers, to understand the impact of AR beyond the museum context, first studying the application of this technology by institutions and asking how this tool would improve the user experience and the quality of information delivery effectively. In another study [22], although the focus is on museum professionals, the theme is VR, not AR. The authors tried to understand the advantages and challenges perceived in the use of VR within museums and encourage the in-depth analysis and critical evaluation of the use of this technology in these spaces, providing suggestions for VR projects in the future by acting as a kind of roadmap to be applied by museum professionals and VR designers.

Emerging technologies such as VR and AR have caused a reinvention in museum concepts and experiences, bringing unprecedented design challenges for designers, developers, and museum professionals [23]. However, as we can see, few examples of research address the correlation between AR and museum professionals. Research has thus left aside the study of museum professionals whose responsibility is exposing objects and creating narratives within the museum. These professionals are also the only observers able to critically analyze the interaction of visitors with AR experiences and the flow of exhibitions offered by museums.

Thus, the present study seeks to fill this gap, exploring and describing the perspectives, aspirations, and perceptions of museum professionals who have had contact with

AR technology. This work resulted in an analysis and critical evaluation of what these professionals think and expect from this technology within the museological space.

## 2. Materials and Methods

### 2.1. Objectives and Research Questions

Since this study's objective is to investigate the perceptions of museum professionals about the use of AR in museum environments, our investigation focused on four central research questions:

1. How are museums currently using AR technology in their spaces? What are their roles and uses?
2. Which museum departments deal with emerging technologies like AR? How are the teams and strategies?
3. What advantages, challenges, and limitations do museum professionals face with AR technology?
4. What do museum professionals expect about the future of AR in the museum environment?

### 2.2. Methodology

This work aims to analyze the experiences and perceptions of museum professionals, and develop theoretical propositions about how these professionals evaluate the use of AR within these spaces. In order to respond to these objectives and the research questions already defined, we chose to work with the grounded theory methodology. On the one hand, we believe that this is the most appropriate method for an approach to exploring the perceptions and views of museum professionals about AR since, thanks to the appreciation and attention given to the data, the method guarantees that the perspectives of these professionals are duly registered and valued during the study. In this way, as the data are generated, categories are also created, from which an underlying pattern is discovered that gives rise to the determination of a theory [24]. Another predominant factor for choosing grounded theory was the lack of research involving the topic addressed, since most studies that discuss AR in the museum do not analyze this particular angle. One of the first indications for an investigator to apply this methodology is when the reports of the phenomena under investigation do not provide a general image of the process and the results, having poorly written or non-existent theories [25] as commonplace, such as in our case.

A grounded theory process has the following key elements: (1) systematic data collection, (2) constant comparison of qualitative analysis, and (3) theory generation [26]. It should be noted that the core of the process takes place through constant comparison, in which the researcher must first compare the interviews (or other data), code them, and identify their categories [27]. Thus, the process has systematic steps, which range from the selection and generation of information categories (open coding), going through the identification of connections and inter-relationships between categories (selective coding), and the final stage, in which the researcher defines, based on the analyses, a main category, from which he will build the theoretical model, also presenting the relationship with the other conceived categories (theoretical codification) [28]. This methodology then aims to build new theories through essential elements, such as concepts, categories, and properties. Then, the researcher establishes an area of interest and collects data to address the research questions, allowing relevant ideas to develop rather than starting with preconceived theories and hypotheses. As the data are generated, categories are created, thus discovering an underlying pattern in which, finally, the theory is determined [29].

Therefore, the chosen methodology aimed to understand the experiences of museum professionals, identify themes, difficulties, and similar aspects arising from each experience, and assimilate the possibilities and difficulties of the path of AR within the museological environment.

### 2.3. Sampling and Participants

In this case, we define the sampling based on two specific criteria: (1) working in a museum in Portugal; and (2) having had contact with an AR experience within the museological space in which he/she works. Participants in this research were approached and recruited after an extensive search on the current uses of AR in museums. This research resulted in a list of twelve museums across Portuguese territory with AR experiences in their permanent exhibitions, or that hosted AR experiences in temporary exhibitions.

The twelve museums received invitations via e-mail to participate in our research. The invitations offered a brief scope of the study, inviting museum professionals to collaborate with the investigation, highlighting the importance of the topic today, and ensuring the confidentiality of the reported data.

In addition to museum details, the generated list included the names of the curators or other museum professionals responsible for the technologies or exhibitions. When we found such details, invitations were sent personally to these professionals. When this information was unavailable, we contacted the museum directly, asking to be directed to the appropriate team member.

An important aspect is that due to the expansion and worsening of the COVID-19 pandemic, during the first contact phases until the actual interviews of this work, two of the museums ended up not responding to the contact (despite numerous attempts), as they were temporarily closed. Thus, this research reached the final sample of ten professionals working in ten different Portuguese museums. Given the particularities of grounded theory, its main sampling characteristic comes from focusing on theory generation rather than representativeness. As such, selecting participating organizations and individuals is more representative of the research than the problem under investigation. Grounded theory's essence is the generation of sufficient data for a comprehensive image of the observed phenomena's patterns, concepts, categories, and properties [25]. Since we recruited suitable participants for this research, directly involved in the investigation problem, and there is no need for statistical representation in a qualitative investigation, we considered our sample satisfactory.

The ten participating museums were Óbidos Museum (Óbidos), the Portuguese Communications Foundation (Lisbon), the Colonial War Museum (Vila Nova de Famalicão), the Money Museum (Lisbon), the Pharmacy Museum (Lisbon), the RTP Museum (Lisbon), Loulé Municipal Museum (Loulé), the Water Museum (Lisbon), the Côa Parque Foundation (Vila Nova de Foz Côa), and the Wine and Vine Museum (Bucelas).

Regarding the participants' profiles, they were of a male majority (6 male and 4 female) and aged between 25 and 67 years old. A master's degree was the education of most participants (6). They also held various positions, such as curators, scientific directors, communication directors, museum directors, and museum technicians. Concerning the time of experience in the profession, we found a wide variation, ranging from 6 months to 21 years of experience in the museological sector.

We conducted the interviews through remote conference programs such as Zoom, Microsoft Teams, and Google Meet.

### 2.4. Data Collection and Analysis

Similar to the study of VR by Shehade and Lambert [22], we sought to gather data in this research that could clarify and deepen our understanding of the use of AR in museums from the perspectives of their professionals. In order to fulfill the proposed objectives, it would be necessary for our subjects to answer the proposed questions, describing their experience and perceptions. For this purpose, we applied a semi-structured interview method with museum professionals. In constructing the interview guide, we were concerned with formulating objective questions to avoid a plurality of interpretations [30], as well as maintaining the definition of the objectives of the interview with only necessary questions [31]. Aligned with the research questions, the interrogations of the interview

sought to explore three major points: the interviewee, the museum, and AR. We grouped the questions in the interview guide.

The first set of questions, “about the museum professional”, dealt with questions about demographic aspects (such as gender, age, academic background, position, and service time). This set of questions was intended to provide us with a quantitative profile of our sample of museum professionals.

The second moment of the conversation, called “about the museum”, focused on the discussion of the technical aspects of the museum as a means of obtaining data such as the theme, size, and typology of the institution, in addition to the average audience and mission of the institution from the point of view of the museum professional. This second moment provided parameters for analyzing and comparing the different museums studied in this paper. Subsequently, questions directly related to AR and the museum professional began. With a list of thirteen questions, we tried to trace the participants’ relationships with AR technology, gathering details of the carried out experience and their perceptions about the difficulties and benefits of the technology. In the end, we questioned professionals about their expectations for the future of AR in museums. One last question also invited the participant to add any additional comments they wanted to address or that they thought needed to be properly explained during the interview.

All data collection for this study took place in two distinct phases. The first part was held between February 2021 and June 2021, and the second between July 2021 and November 2021, with an average duration of 30 to 60 min per interview. The confidentiality and anonymity of responses were guaranteed, with the recognition of the potentially sensitive nature of the information provided.

After collecting the data, we explored, analyzed, transformed, and synthesized the information, applying processes that offered meaning to what was collected [32]. Thus, we gathered all the materials, processing them through data transcription to the electronic medium for later analysis. We performed this transcription manually, and any term or specificity that could identify the participant was removed.

In the next phase, the collected data were repeatedly read to search for recurrent ideas, events, and behaviors to identify the coding categories that would classify and organize the data [33]. We used a coding system to organize the data and facilitate their analysis. This system was based on finding frequent repetitions of words and phrases, among other elements, which defined significant sections that represented the coding categories, classifying and grouping them into topics that were inter-related [34].

Based on the responses received, we applied a coding process that would help compare different categories of data, coded within the three steps of the grounded theory constructivism approach: open coding, selective coding, and theoretical coding [24]. Open coding identifies and compares codes, selective coding explores the relationships between categories, and theoretical coding applies appropriate codes and achieves a consolidated framework for general grounded theory, corresponding to the final coding stage [35].

Thus, in our data analysis, we followed a holistic approach through the indexing and specific categorization of the collected data. We used open coding to raise the initial research themes, represented by keywords for each category of the questions we wanted to explore. The second and third stages of coding provided the refinement of the previously detected codes and the identification of their inter-relationships.

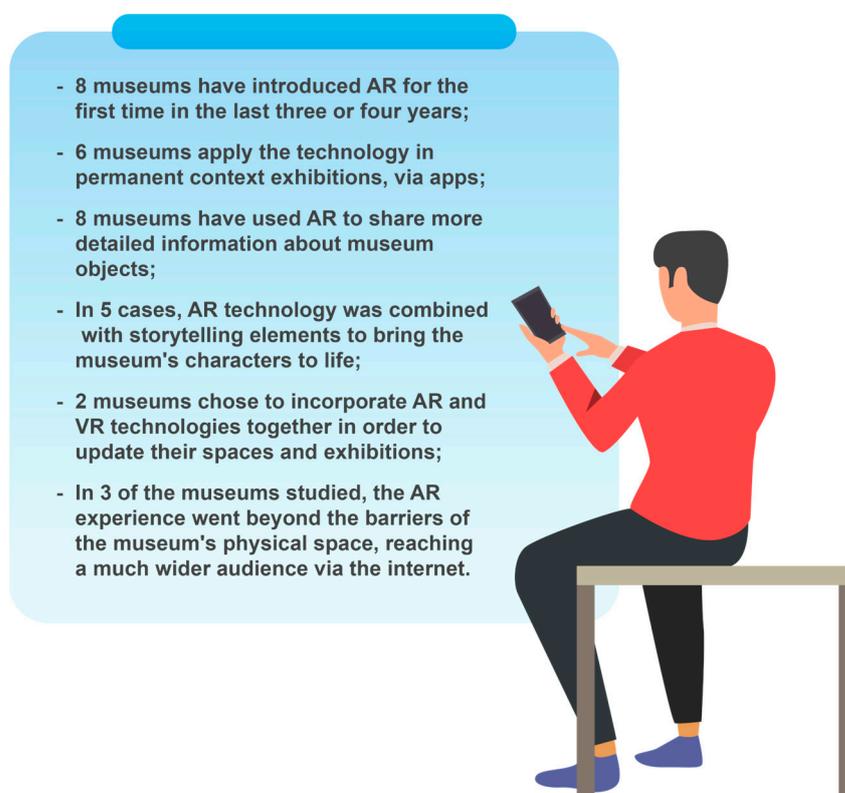
This codification process allowed the emergence of four categories, namely Perceptions of Museum Professionals on the Role and Uses of Augmented Reality; Departments, Museum Teams and Digital Strategies; Perceived Advantages, Challenges, and Limitations in the Use of Augmented Reality Technologies; Direction and Future Perspectives on AR in the museum environment. These categories allowed the participant’s responses to be categorized according to pre-defined criteria. The present study followed an analytical model that included classifying the essential elements of the theme according to specific categories. Concentrating the results on convergence points allowed for identifying several common patterns in their responses [35].

### 3. Results

#### 3.1. Perceptions of Museum Professionals on the Role and Uses of Augmented Reality (Research Question 1)

##### 3.1.1. Uses of Augmented Reality

The first point of our analysis focused on surveying and observing how participating museums used technology within their spaces. Figure 1 summarizes our discoveries. In most of the analyzed cases (eight museums), AR was introduced in the museum for the first time in the last three or four years, with the majority pointing to 2019 as a turning point. Only two participating museums had incorporated technology into their spaces for over six years. Six of the museums interviewed applied technology in permanent context exhibitions, mostly through applications that could be downloaded directly to the visitor's smartphone or through tablets available at the institution, and most of the time offering both alternatives to visitors. Despite the few devices available in museums, which made it impossible for many visitors to use the technology, respondents pointed out that this was the most viable option, since an AR application can be heavy and take a long time to be downloaded.



**Figure 1.** Summary of the reported uses of AR, according to the interviewees.

In most cases portrayed (eight museums), AR technology was used to share more profound and detailed information about museum objects. The animated reconstructions and three-dimensional models helped the visitor to discover the context and use of particular pieces, "helping to understand better the histories of the objects that are part of the museum" (Interviewee 9). This type of reconstruction opens a window to the past of the museum itself by presenting monuments and ancient objects in entire working order, which might not have been possible without the help of technology, one of its added values being "the ease of reading and interpretation that AR brings to all its visitors, in order to explain and contextualize the museum's collection" (Interviewee 1). AR was also used to restore damaged pieces or pieces severely degraded over time, restoring their original appearance. AR facilitated visitors' interpretation and understanding of these pieces by reconstructing the objects entirely. Previously, visitors had difficulty viewing them in their

completeness, making “interpretation much easier” (Interviewee 5) “interactively and dynamically” (Interviewee 4).

In addition to promoting a greater understanding of artworks and artifacts, museums use AR as a method of interaction between museums and visitors. AR makes it possible for the visitor, through its virtual contents, to explore the space in a new way, even “virtually wearing pieces from the exhibition” (Interviewee 3). AR allows the expansion of the museum’s own rules and physical limits. Technology helps to build surprising environments, with “the possibility of rotating, manipulating and expanding, through mobile devices, the objects on display” (Interviewee 2). AR offers a new poetic layer to a museum’s collection, displaying it from different angles and thus enhancing the distribution of the contents immediately and dynamically.

In five cases, AR technology was combined with storytelling elements to bring museum characters to life. This medium allows visitors to know the facts of a particular period through stories told in the first person. The characters convey aspects of the time and events experienced by them, giving meaning to figures that were previously only illustrative in the museum. As interviewee 5 comments,

*“AR was adopted to value and enrich history, heritage, and memory, offering visitors first-class innovative exhibition programs and superlative, unique, and unforgettable experiences. Its use provides the visitor with an elevated aesthetic experience that enhances the appreciation of art, transmitting to the visitor an authentic knowledge about that period.”*

Two analyzed museums chose to jointly incorporate AR and VR technologies into their environments to update their current spaces and exhibitions, replacing some of the old methods employed and “enriching the museological offer available” (Interviewee 7). Technologies were also implemented to improve and fix weak aspects perceived by professionals. One of the interviewees commented that due to the lack of information on the museum’s wall, those who participated in non-guided tours noticed little of the content on display. Thus, technologies were used to level the information on a guided and non-guided tour.

*“With the resources of interactive technologies, we challenge our visitors to make discoveries and seek answers. Now our visitors have a new approach to museum information. With an easier reading and a greater knowledge of the history presented, we started to honor the movement of the fight for the museum preservation.” (Interviewee 10)*

For three museums that participated in this study, the AR experience went beyond the museum’s physical space barriers, reaching a much wider audience through the Internet. The combination of interactive technologies gave access to part of the museological heritage without leaving the home. Many museums have begun experimenting with the virtual world, creating digital museums and exhibitions. With the COVID-19 pandemic, museums found in digital spaces a way to remain “open” to the public, transporting part of their collection to sites where they could be visited at any time and in any place. More than replacing real museums, virtual museums emerged as a method of complementing the visit, allowing the institution to become closer to its visitors on more platforms. The positive point of AR projects lies in the combination of two distinct and complementary approaches, a virtual approach, and a face-to-face approach, as interviewee 7 points out:

*“The museum allows visitors to experience the AR project on its space, more immersively and in large dimensions, or on a smaller scale elsewhere, through the institution’s website and app. Making the visit more attractive and allowing visitors to get in touch with these new technological aspects.”*

### 3.1.2. Augmented Reality Role

One of the objectives of this study was to explore the respondents’ perceptions of the role of AR within museums. Figure 2 synthesizes the reported roles of AR. We highlight that the majority of respondents (six out of ten) underlined that AR is a tool that offers greater

engagement with the public, “leading to a better dialogue between museum and visitor” (Interviewee 1). By providing new formats for interpreting the museological collection and allowing the visitor to be involved in the process, technology makes us rethink how visitors experience the museum and paves the way for new interactions between people and artifacts, going far beyond the simple visualization of objects.



**Figure 2.** The reported roles of AR, as perceived by the interviewees.

It was essential to understand why museums chose to incorporate AR. An AR environment enables the visitor to experience new ways of understanding/experiencing history, as well as the reconstruction and the transmission of collective memory and identity. Developing AR systems involves encouraging users to interact with the environment in specific ways since, in an AR experience, visitors are free to move around in the physical space around them. Nevertheless, these interactions determine how the story is told and how far it progresses. In most of the cases analyzed (seven museums), the use of AR appeared to be strongly connected to the educational sector of the museum, as Interviewee 8 says:

*“Always educate, but as we are a non-formal space, it has to do with this more playful part, with entertainment, but, yes, the main objective is to educate, or at least to make people aware of the subject.”*

If the experience is conveniently mediated, AR enhances the learning and retention of relevant information on museum themes. In this sense, technology emerges as a tool to reach another layer of visitor sensitivity, allowing the visualization of the collection through different perspectives and a new understanding of the exhibition, providing high-level programs with unique and unforgettable experiences, as observed by Interviewee 9:

*“I think it is a job that requires much multidisciplinary and is undoubtedly a way to make the museum more accessible and interesting to all audiences. By introducing new layers of information, we can add value to what the visitor can see. This consequence of AR is one of its great assets because it contextualizes and highlights details.”*

In addition to improving the experience, AR technology can contribute to attracting new audiences. In line with what Interviewee 6 reveals, an AR application came to remedy a goal: “increase the number of visitors.” AR was intentionally adopted by most of the participating museums (six institutions) to attract young audiences to the institution, partic-

ularly the “digitally literate.” Respondents noted that younger visitors are the most prone and open to new ideas, such as applying interactive methods with AR in the museum environment. In this sense, technology was seen as an “added value for the museum” (Interviewee 1), which is in line with the literature review, since technology is more appealing and easily implemented within this age group, mainly thanks to the more remarkable skill handling the technological devices necessary for experimentation [36].

Adopting an AR-complementary nature concerning the museum’s collection is also highlighted. The objective is that AR does not harm the narrative and interpretation of the exhibition, avoiding overlapping with the museum’s collection but assuming a complementary role. In order to “adapt to the needs of different visitors, museums need to find tools that serve other audiences, using technologies such as AR to interpret the collection and not as a way of competing for the attention of the objects in display” (Interviewee 3).

Despite the different roles that AR can play within the museum, the technology is not intended to replace the specialized knowledge of museum professionals but should enhance their activity. Thus, technology must be treated as an instrument of museology, and its application must be duly justified and designed beforehand, as Interviewee 5 emphasizes: “AR must be treated as an instrument within museology, and not a method, The use of AR within the museum should not be mandatory, it must be justified.” AR use must be aligned with other tools to create a complete experience for the visitor, contributing to advertising the museum and personalizing the exhibition’s contents, and helping to understand the public that frequents the space. Interviewee 5 complements this idea:

*“On our side, we are offering content and knowledge. On the other side, we have people who come to visit us. Visitors find it difficult to understand our work, but we also need help understanding what they expect from their visit to the museum. Because there is no typical visitor, there are different types and expectations. The complexity is that having a speech adapted to all visitors. AR is a tool that can solve this difficulty by opening up possibilities for our contents, transforming the classic method of museology, where the content is very fixed, into a new approach adaptable to the public.”*

Therefore, understanding the role and needs of this technology is essential for implementing adequate and effective AR projects.

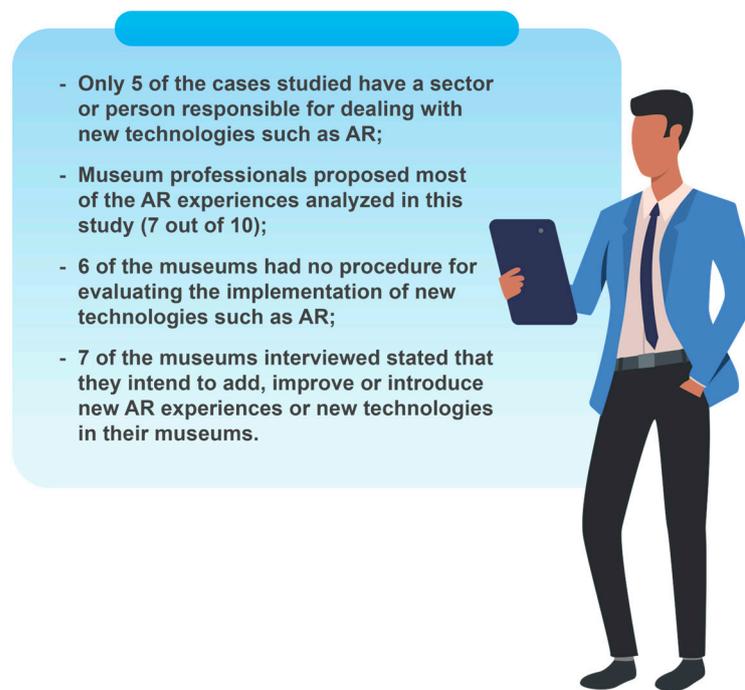
### 3.2. Departments, Museum Teams and Digital Strategies (Research Question 2)

To better understand the challenges imposed by AR in museums, we have to analyze which sectors deal with the technology, investigating the strategies used and the existing museological plans for adding new emerging technologies. This analysis allows us to determine what changes museums need in order to implement AR more smoothly and effectively in their spaces (Figure 3).

In only five cases studied, there is a sector or person responsible for dealing with new media technologies such as AR. Of these five, only one museum has a specialist in new technologies, while the other two use outside multimedia and technology companies for advice. In the last two cases, the AR experiences are supervised by the institution’s Department of Communication, requiring these professionals to have a multidisciplinary role, which ranges from implementing this type of exhibition to maintaining and updating the entity’s social media, among other tasks.

However, despite the lack of specialized departments in new technologies, museum professionals proposed most of the AR experiences analyzed in this study (seven out of ten). These professionals assume different positions, such as curators, commissioners, members of educational services, directors, and museologists, among others. All of this demonstrates institutions’ growing interest in finding new ways to meet emerging demands and adapt to current sociocultural changes. Museums are looking for innovative solutions such as AR to better display and communicate their tangible and intangible heritage while engaging visitors in an educational and leisure experience. As Interviewee 7 states:

*“We are aware of the importance of ancient traditions and concerns associated with new technologies in a cultural context, and, for the same reason, we believe in technologies such as AR and VR. Because these techniques are not substitutes but create additional layers of information that make the learning process more engaging and efficient, with this in mind, technology can complement existing traditions and concepts, offering a new interactive way of learning. We hope that more museums and exhibitions will be able to take advantage of these opportunities.”*



**Figure 3.** Summary of the different sectors and departments of the museum analyzed that deal with new technologies.

Since the introduction of the analyzed AR experiences resulting from the collaboration between different departments, teams, and external companies, it is essential to investigate how this process took place and the difficulties that museums face in implementing the technology in their spaces. Since the production of AR experiences still needs guidelines to be followed, and countless obstacles are faced between the data collection stage and the installation of technology in the museum, one of the most used methods focuses on user-centered design practices [37].

Another interesting aspect that we observed is the non-evaluation of new technologies. Six of the museums studied did not have any evaluation procedure. At the same time, the rest divide their evaluation procedures between interviews and questionnaires made with visitors, carried out by the museum itself (three cases) or by external companies responsible for AR technology (one case). In many of the investigated cases, these tools are used together with other data collected at the museum, such as museum visit questionnaires, ending up not giving the actual dimension of the impact of AR technology within the museum space.

Although many museums have tried to adapt by introducing more rigorous assessment procedures, implementing these procedures has been complicated mainly because of the need for different types of technology and more resources to implement such procedures. Thus, most evaluations are only carried out “in a punctual way” (Interviewee 2), making it difficult to measure the impacts of such technologies on the museological experience as a whole. Another challenge recognized in the literature concerns a form of evaluation that only partially measures the effectiveness of the experience. Commonly, these experiences are tested and evaluated regarding their usability and pre-defined in-

ternal objectives. Most currently proposed evaluations focus on specific aspects of the experience, such as the perception of learning of the mediated visit or the validation of the technology in response to specific concerns, without bothering to conduct more in-depth research with the visitors [38]. The construction of an in-depth evaluation process then allows the analysis of the technology from new perspectives, enabling the construction of more accurate and better-targeted experiences for the museum and its visitors.

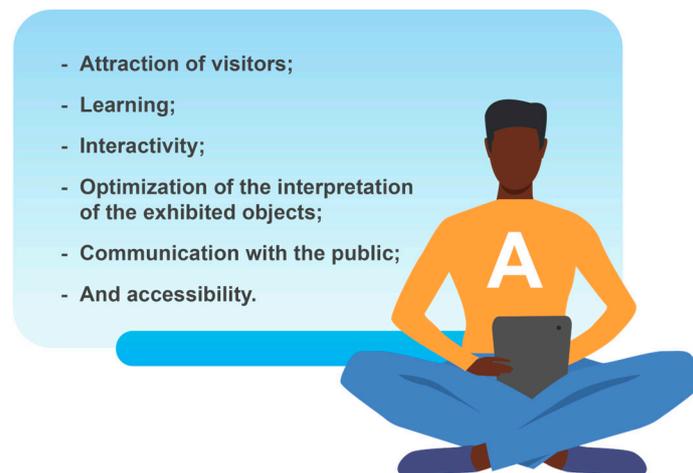
For this reason, building AR experiences continues to be an obstacle to be continually overcome by museum professionals. In this way, more and more museums are betting on intersectoral and cross-skill collaboration to explore new ways of improving by revisiting and expanding the traditionalism of the presentation of collections and information. Struggling to cope with current needs, institutions plan to use emerging technologies. Seven of the interviewed museums declared that they intended to add, improve, or introduce new experiences with AR or new technologies in their spaces, demonstrating a growing interest in updates and new media for exposing content and attracting new audiences, as Interviewee 8 reveals:

*“Since we started using this AR exhibition in the museum, about fifteen other museums have been interested in who did the work. I think one way to improve is to use AR in the room that explains the production and apply it in the other rooms that involve the historical process.”*

### 3.3. Perceived Advantages and Challenges in the Use of Augmented Reality Technologies (Research Question 3)

#### 3.3.1. Advantages

In this section, we investigate the perceived advantages of using AR within the museological environment by the interviewed professionals (Figure 4). Based on participants' responses, we identified six categories of benefits. They are the attraction of visitors, learning, interactivity, optimization of the interpretation of the exhibited objects, communication with the public, and accessibility.



**Figure 4.** List of advantages perceived by the interviewees.

Most respondents (six out of ten) highlighted attracting visitors as one of the main benefits of AR. Museums are no longer competing with each other; they are battling for public attention with other spaces and attractions. At the same time, visitors are becoming more demanding and interested in a unique visiting experience adapted to their needs. Museums have used technologies to align their audience's expectations with everyday digital experiences. With AR, museums find a way to keep up to date and be relevant in the current cultural market: “reinventing and reimagining itself for a new, more contemporary and technological reality” (Interviewee 6).

AR is a way to face this new range of challenges, offering more excellent attractiveness to new visitors, especially younger ones. As Interviewee 7 points out, “The objective we defined since the beginning was to present to our visitors (...) experiences in AR and VR, making the visit more attractive and allowing them to have contact with these new media”. At the same time, AR can be applied to improve the experience of recurring museum visitors, transforming their view of the institution, and promoting new visits. As Interviewee 8 indicated:

*“I think the visitors are the same, but they are curious about AR because it is something new many people probably do not know. For example, I had never seen anything about AR, it is an innovation for our museum, and this has already been shared on our social networks, generating more visitors.”*

Another advantage perceived by five of the interviewees concerns the contribution of AR to learning. Museums are environments that create unique learning opportunities, focusing on a constructivist model rather than the passive transmission of information. Technology helps the general education objectives of the institution, making teaching more effective and introducing new concepts and themes by “establishing a bridge between the present and the past” (Interviewee 3). AR provides a new way of educating by offering an additional layer of information to its visitors and awakening the imagination by providing a new look at the museum’s artifacts and their respective histories; “AR intends to transmit valuable knowledge about the history, heritage, and memory, all in one place. Valuing and enriching the cultural past of the museum” (Interviewee 1).

The third advantage, emphasized by three interviewees, is the contribution of AR to the museum’s interactivity process. Since the early 2000s, this technology has been the object of experimentation in cultural institutions, promising to transform the traditional way of interacting between visitors and collections. “In this sense, AR technology contributes to public participation by making content available immediately and dynamically” (Interviewee 2). AR allows visitors to interact with the exhibitions and objects on display through digital devices, so the traditional visiting experience is wholly modified. Visitors, who until now were passive spectators of static exhibitions, became active users of a museum experience with interactive interfaces [39]. So, “it is no longer about simply appreciating and contemplating artifacts, now it is about interacting with them. The visitor wants to live a new form of experience, involving the digital and the past” (Interviewee 9).

Four of the studied museums emphasized optimizing the interpretation of the exhibited artifacts as one of the advantages of AR. Given that technology, through the superimposition of virtual information on the museological collection, guarantees the construction of new digital narratives, visitors now have access to information that would not be possible to access regularly, using the object’s context to improve the associated story. The experience perceived by the visitor is now “mediated by the narrative created and supported by technology” (Interviewee 3). AR favors the interpretation and reading of the different pieces of the museum by presenting virtual recreations, which help to contextualize the use and function of the exhibited artifacts. Technology allows for an interactive, dynamic, and more appealing experience. As Interviewee 4 states:

*“It allows access to another level of visitors’ sensitivity, with the advantage of presenting the museum’s collections from different perspectives that could not be done in any other way. It is not just a museum space. It is a place designed to transmit to visitors real knowledge about that period, told by those who lived through it.”*

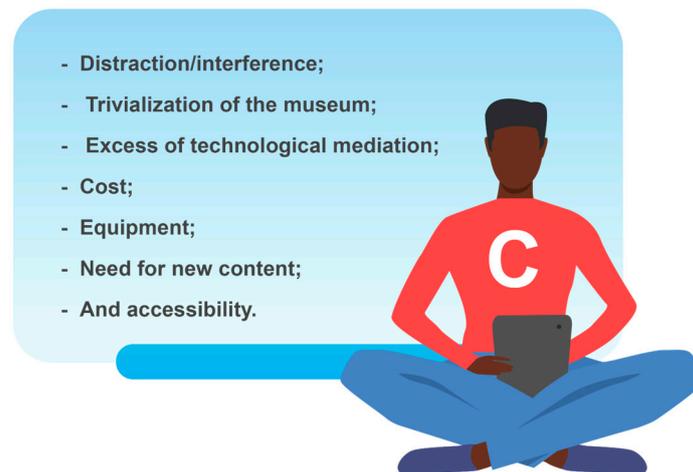
The increase in participatory and interactive exhibitions within the museological space demonstrates that these spaces have sought a closer relationship between the collection and the visitor. At the same time, they allow artifacts to continue to occupy a prominent place within the exhibition discourse. Thus, one of the advantages that two interviewees identified in using AR concerns the increased communication with visitors. Through the virtual contents linked to the collection of artifacts or through storytelling, AR technology moves away from the conventional model of interpreting the collection through texts, increasing

the relationship between museum and visitor by generating “better communication with the visitors, more interactive, (...) that goes beyond the ludic content and helps understand the message” (Interviewee 10). AR and its interaction methods offer dynamic means of presenting information, emphasizing its potential to enrich the communication between object and visitor, encouraging and involving him in exploring content. AR enables “new ways of communicating while keeping the museum intact” (Interviewee 6). An interactive AR experience changes its content according to the visitor’s participation. Museums should develop strategies that encourage visitors to make specific decisions and actions that integrate with the environment while letting the visitor engage with the exhibition and choose their path [40]. “Strengthening its communication and its relationship with the public” (Interviewee 1).

Finally, three interviewees pointed to accessibility as a perceived advantage of using AR in museums. By extending the visitor experience beyond the physical limitations of the museum, accessibility in AR experiences benefits engagement, the user experience, and the ability to adapt to diverse publics. “This resource . . . personalizes the exhibition’s contents, as it helps to understand the various audiences that attend the museum” (Interviewee 2). In addition, the presence of museums in a virtual space offers greater accessibility to the museum collection. Visitors with different characteristics can have virtual cultural experiences from their homes through digital space, “Enhancing the attraction and loyalty of audiences, making an important contribution in bringing the museum and citizens closer together, in addition to its re-affirmation as a reference entity” (Interviewee 7).

### 3.3.2. Challenges and Limitations

In addition to the advantages of AR, our aim included exploring the challenges and limitations faced by museum professionals in implementing AR technology in their museum environments (Figure 5). A total of seven categories of challenges and limitations were identified based on the interviewees’ responses: distraction/interference, trivialization of the museum, excess of technological mediation, cost, equipment, need for new content, and accessibility.



**Figure 5.** List of challenges perceived by the interviewees.

One of the main challenges emphasized by the interviewees (six museums) is related to the issue of technology distraction and interference within the museum. Considering all the elements that compose the exhibition language, AR is a tool that directly affects the exhibition narrative and should be designed to complement and assist in the communication between the public and the artifact. Sometimes, technology can end up over-shadowing the museum’s collections and contents, distracting the visitor from the artifacts and pre-conceived narratives for the experience, as questioned by Interviewee 7: “The challenges

and limitations stem from the very dynamics of technological evolution. How to add something without creating noise?”.

AR is a multidimensional construction in which technology and human actions are integral vectors. The interaction between the real world and the digital content changes the perception of reality [40]. Thus, technology can also be an intrusive element, negatively interfering with the visit to the museum and “affecting other visitors at the same time in their visiting experience” (Interviewee 6). In addition, adopting visitors’ devices to access AR systems, a common practice in museums that adopt AR technology, exposes visitors to notifications from other applications, consequently disturbing their attention to the museological route. As Interviewee 9 puts it, “One of my main concerns is the abusive use of the cell phone inside and the ‘noise’ that it causes during the visit”.

Another limiting aspect pointed out by three of the professionals interviewed concerns the trivialization of the museum. Emerging technologies such as AR often attract new audiences to the museum, fragmenting the traditional exhibition experience. Despite bringing new audiences, sometimes “they trivialize the museum and its content, which becomes just a means of accessing technology” (Interviewee 4). On the other hand, visitors create queues to access all the content available through the new AR exhibitions; “groups of people try to visualize an object through the cell phone screen causing congestion in the spaces, and giving rise to interrupted or obscured views, which can cause flaws in the perception of the experience” (Interviewee 3).

Four interviewees also highlighted the excess of technological mediation as one of the problems faced in the adoption of AR in the museum. Interviewee 7 asks, “How can we manage to mediate and take advantage of the enormous potential of AR without underestimating the importance of contact with the physical pieces of the museum?” Several studies have shown that people spend more time with museum objects when AR is involved, but this finding may result from the effect of technological novelty. Once this effect ends, the technology may cease to be seen as a uniquely engaging and helpful interaction [41].

In addition, as AR can increase the amount of information made available, museums need to be careful not to offer too much information since “the increase in time with each museum object can mean greater fatigue” (Interviewee 2). The digital world has infinite potential to store content, but restrictions such as time, resources, and attention require well-defined limits so as to not overload the visitor [38]. As highlighted by Interviewee 5,

*“It is important not to overload the visitor’s attention. Studies prove that AR should be integrated into an environment designed for this purpose and not as an excerpt from existing environments that were not created for this interaction. We also know that there should not be an excess of devices and AR in the museum environment. Their presence must be considered so as not to distort the museum’s experience, exhausting the visitor who is overloaded with information and disoriented.”*

Another limitation that three interviewees indicated concerns the cost of producing AR experiences at the museum. Creating a meaningful AR experience requires time, various material resources, and specialized technical knowledge. These resources are usually unavailable in museums, making implementing AR in these spaces difficult. “It is necessary to think carefully about the tools to be added and the technological logistics to be implemented so that these resources are not misused” (Interviewee 3).

In addition to the actual implementation of AR in the museum, technology comes with expenses such as training the museum staff, maintenance, and updating requirements, since technology requires constant updates that accompany the development of mobile devices and improvements in their software. As interviewee 8 describes,

*“We have only had AR for a short time, but probably a year from now, we will say the experience is completely obsolete, and we already need to do something else. (. . .) this technological advance opens up many possibilities we will encounter sooner or later.”*

Another practical concern registered by the interviewees (four out of ten) was the equipment issue. Typically, most visitors use their smartphones to experience AR in the museum. Which, despite facilitating access to technology, also brings some problems such as “the fact that not all people have devices that allow the reading of AR, limited by their processing power, memory or device storage, which prevents the execution and integration of AR during the experience” (Interviewee 1).

In addition to these problems, other equipment-related setbacks were found. Among them is the high battery consumption, since AR applications consume large amounts of energy. This condition limits the time the visitor spends with the technology and, consequently, in the exhibition. A second aspect highlighted was the issue of the museum's internet. Many visitors want to avoid spending their data packages to access the experience, so museums need to increase their free Wi-Fi offers. Internet instability inside museums is another point to be considered since many museums need help to offer good Wi-Fi connections, either because of the high cost of the infrastructure or the need for preservation that does not allow for further interventions in that space. The size of the application to be downloaded and the number of devices available in the museum are also problems to be taken into account, as emphasized by Interviewee 8:

*“Then the issue, in our case, was the size of the application. In order to have all the tools we need, the application has become too heavy, and people cannot download it quickly. We must evolve so visitors can access AR easily from their mobile phones. (. . .) In addition, because we only have 4 tablets, it is very difficult for all visitors to be able to use them, taking greater advantage when they are on individual visits or in groups of two people.”*

Another interviewee also highlighted the visual discomfort caused in the space by the visibility of technology; “the issue of technology is still obvious. For example, we have an exhibition in a room with two projectors, however, these projectors are huge, and they end up appearing very in the exhibition. I believe that what is missing is technology being more subtle” (Interviewee 10).

Still, concerning the previous questions, two interviewees highlighted the need for new content as one of the problems of AR. Over time, the quality of the equipment and content produced evolves. For this reason, the museum must update the available offers, which requires the creation of new experiences and new content to be experienced by the visitor, generating new costs related to labor, exhibition resources, equipment, and so on. “Visitors come and go, and when they return, they expect to see new things. (. . .) Although we managed to reach the initial goal, everything can be improved. We still miss a more immersive experience” (Interviewee 10).

Although specific properties of accessibility are among the identified advantages, some of its characteristics represent a series of limitations for museums (emphasized by two interviewees). AR may not be friendly to visitors unfamiliar with the technology, causing difficulties in handling its applications, such as their installation, the necessary steps for use, and correct framing of the object, among others. As interviewee 8 emphasizes, “One of the difficulties faced was the familiarity of some people with technology: the senior public is not used to using social networks and mobile phones.” The use of the visitor's own devices requires a responsive app. Smaller screens generate a cluster of minimal information that can be difficult to comprehend and create a barrier to interpreting the experience [38].

Finally, as AR is still considered an emerging technology, this paradigm contributes to a feeling of fragility among the museum public. While most visitors may be eager to experience it, some still need to be convinced of its proper role and space within the institution, representing an obstacle to overcome. Museum professionals indicate that they need to find a balance between the needs of different visitors.

### 3.4. Future Direction and Perspectives (Research Question 4)

In this section, we collect museum professionals' needs and future perspectives. These needs and perspectives may guide the future of AR design in museums, leading us to a

series of suggestions to be considered in constructing new AR experiences in the museum space (Figure 6).



**Figure 6.** Summary of the directions and perspectives the interviewees expect from the future.

As demonstrated by our research, several concerns exist regarding the development of AR projects in museums. Museum professionals are constantly concerned that using AR in exhibitions could harm the museum experience while trying to balance the contents offered with the offer of new technology. These professionals face other challenges of a practical nature, such as improving visitors' AR experiences and smoothing the technology barrier, so in the future, many of them expect improvements in the technical aspects of technology and their respective museological processes in order to facilitate the implementation of emerging technologies in these spaces. Among the expected improvements are the "training of technical staff" (Interviewee 4), "work methodologies and proposals" (Interviewee 2), "financial support" (Interviewee 1), and "greater development of its technology (cost/benefit)" (Interviewee 3).

AR is used to flexibly enhance the museum visitor's experience, presenting creative forms of content, such as images, sounds and movement, through the overlap between the real and the virtual. Therefore, any integration must be designed under the general mission of the museum, and the technology adopted must be integrated within a global strategy and a conscious museological approach to preserve the institution's collection [41]. Available technologies should be applied based on what they can offer and where they are best used. As Interviewee 5 recognizes, "AR is essential for the dissemination of heritage, which now requires new platforms. It is also constituted as a new way of guaranteeing the iconographic preservation of the collection".

In addition, emerging technologies such as AR are sometimes applied as an attraction for the museum to the public by offering the opportunity to experience the space through technology, consequently proposing new formats for their visit. However, depending on the future of AR in museums, this novelty effect may eventually fade [42]. In this way, AR experiences become even more dependent on the quality of all aspects of the exhibition, its meaning, narrative, interface, and proposed contents. As Interviewee 10 points out:

*“The future is the visitor to forget that it is AR, to overcome technology and think that this is a ‘normal’ exhibition in the museum, for AR to be part of museology methods, people forget the playful side to enjoy the informative experience.”*

It is highlighted here that the point should be different from which technology is effective, but which technology best meets the specific needs of that space in the best possible way. By using AR, museum professionals can influence visitor engagement and preferences, which are reflected in their behavior patterns, content navigation, visitor satisfaction, and experience. It is essential to consider which features have the most significant impact on visitors. These characteristics may vary according to age, place of origin, or education, as well as the visitor’s life habits concerning the use of technology [33]. With that in mind, it is essential to precisely define the aspects with the greatest impact and how they affect the perception of its users. As reflected by Interviewee 9:

*“AR will become an integral part of museums, constituting an undeniable added value for them. The question arises to generate the necessary balances so that physical reality and augmented reality become part of a whole that does not tend to subordinate physical reality. It will be necessary to create experiences that meet visitors’ expectations, improving their experiences while respecting the values and collections that define each museological institution.”*

As for the future, most interviewees agree that museums will need to adapt and incorporate new technologies since the new generation of visitors will increasingly seek digital experiences in these spaces; “it will be a way to bring together and motivate young people, researchers and the general public” (Interviewee 6). Placing new challenges (such as those mentioned above) at an organizational and practical level may require greater investment from the institution, which Interviewee 1 adds to:

*“The future demands a greater connection with the digital area, mainly because the new generations see it as an indispensable accessory in their daily lives. However, we cannot neglect other audiences. We have to strike a balance.”*

In addition to investing in new technologies and electronic devices, museums must outline strategies and procedures regarding their infrastructure, staff training, and evaluation strategies for effectively implementing new technologies in their spaces. Likewise, Interviewee 4 explains that AR technology “will be here to stay if the implementation costs decrease.” As evidenced in the literature and interviews, a lack of funds can inhibit the greater access to and use of technology in museum environments. In order to obtain the necessary financial resources, the museum professionals highlighted the formation of partnerships as an alternative to the problem, being a path for the necessary training of museum professionals, to which Interviewee 5 adds

*“It is imperative to link the industry to museum centers, cultural agents, archives, and libraries. Only this way is it possible to create functionalities that allow achieving a common objective that all of us must maintain: to tell the past, understand the present, and project the future.”*

Some participants also hope that future challenges related to costs and equipment can be better solved with the establishment of technology. As more and more museums establish themselves in the digital space, increasing their digitized collections, virtual content production may become more accessible and less expensive. As extended reality technologies make strides toward their massive use, most of their problems must be corrected [43]. Therefore, museums must keep up with technological advances and update their approaches according to what works best in their environments, focusing on their ability to tell stories and involve the visitor. Interviewee 7 adds

*“As it is an innovative technology, not only for our museum, it streamlines and tells the museum’s history differently. AR makes an important contribution to increasing the public’s interest in our museum environment when it complements it. AR allows visitors*

*to see in detail and gives a future reading to the heritage, stories, facts, and past events disclosed in the museum."*

AR or any other technology will only sometimes be the best choice for a given museum since technology does not necessarily add a positive or negative value. It is the quality of the contents and the design of the interface that add meaning. AR "may play a role in valuing spaces and the experience of the visit, but never as a primary tool. It will be an added value for museums" (Interviewee 3). Consequently, museums cannot expect the technology to achieve technical robustness or their visitors to be impressed with new experiences just because of new technology. Instead, museums should invest time and effort in technologies that benefit their visitors. As Interviewee 8 states,

*"... the person is never satisfied, and it seems that no matter how much you do, you are never well. On the other hand, this technological advance opens up many possibilities that we will face sooner or later, and it is always a question of balance between acting and reacting. At this moment, AR is a key technology, but we do not know for how long."*

In the current context of deep mediatization, where technological means of communication saturate social domains [44], museums play an essential role in helping society to explore and understand its culture and history credibly. These spaces are facing the emergence of various technologies, which have impacted their exhibitions and forever transformed the museological environment, such as photography, video, internet, mobile, AR, and VR. Museums have reinvented themselves to adapt to everyday life's cultural and social changes. They ceased to be institutions focused on artifacts to focus on the visitor, replacing the unilateral and contemplative visit with interactive experiences using technological devices which allow the overlapping of digital information with the immersion and incorporation of the visitor in their museological narratives, thus transforming the paradigm of museum visiting.

So that museums can create new exhibition formats, reinforce their cultural, aesthetic, or historical meanings, generate deep reflections and understandings about their collection, and create more attractive, informative, and fun presentations through AR technology, a project that is well thought out and implemented is essential. It is confirmed that the conscious alignment between the design, mission, and museum objectives is fundamental. AR must be introduced in these spaces through a strategic approach that depends more on the exhibition's meaning, quality, and content than the technology itself.

On the other hand, so that visitors can adequately understand the message of an exhibition, and understand its context and its history, technologies such as AR can act as communication and motivation aids. However, the balance between content and technology is crucial for its effectiveness; "without the background of an original and intentional narrative, technological mediation, in isolation, can incorporate the subject of the museography experience, in an arbitrary narrative" [45] (p. 80). By strategically using new technologies such as AR, museums can motivate their visitors with innovative learning techniques that generate participation and unique experiences, and develop their critical thinking.

#### 4. Discussion

Museum spaces today are challenged to present their artifacts attractively and understandably. Classic presentations with subtitles, signs, and static graphics have become less exciting and no longer meet the demands of the new generation of visitors. AR thus emerges as a means that is capable of allowing a new interpretation and approach to the exhibited objects, creating new layers of information and complementing the visitor's experience, making it more interactive and enriching [46].

AR in the museum environment can improve the perception of space and artifacts. AR allows the creation of new expository resources that make it possible to superimpose different layers of text, sounds, or animations linked to a given artifact. AR is the new communication media within the museum, through which the interaction between visitors

and the objects and/or ideas of an exhibition is phased and respects the rhythm of the visitor, facilitating the relationship between visitor and museum [2].

Throughout this work, we observed that AR offers several variations of experiences to its visitors. The obtained results answered our research questions: (1) How are museums currently using AR technology in their spaces? What are their roles and uses? (2) Which Museum departments deal with emerging technologies like AR? How are the teams and strategies? (3) What advantages, challenges, and limitations do museum professionals face with AR technology? And (4) What do museum professionals expect about the future of AR in the museum environment? Our results also give us a general perception of the implementation of AR in the Portuguese museological context.

Concerning the first research question, the use of AR technology in Portuguese museums, we can highlight the following:

1. The adoption of technology took place, mainly in the last four years, and especially in a permanent format through the adoption of mobile applications accessed via electronic devices, such as tablets available in the museum or the smartphones of the visitors;
2. AR was developed with the main objective of creating a more profound knowledge of the exhibited pieces through storytelling or the reconstruction of artifacts, which would provide a better understanding of the museological collection and engagement with the public;
3. Technology was mostly linked to the educational aspects of the institution. Its predominant functions were the awakening of curiosity, the enhancement of learning, and the retention of new information around the themes displayed;
4. Most respondents highlighted the added value of adopting new technologies such as AR within the museum environment as a way to meet the new demands of current visitors and expose and communicate their cultural heritage.

Concerning the second research question related to departments, museum teams, and their digital strategies, we found from the interviews that only half of the museums had a sector responsible for managing new media, and only one of the museums had a specialist in new technologies. The other half of the museums studied here worked with external companies or allocated this responsibility to the museum's communication department. Usually, this communication department also supervises AR experiences, adding even more work to its already diverse functions. All of this demands multidisciplinary tasks from museum professionals to implement technologies such as AR in these spaces. We discovered that museum professionals proposed all the analyzed AR experiences in this study, although there were no AR specialists in this area among the professionals inquired. Of the museums studied, the vast majority did not have a procedure for evaluating AR experiences or else presented a very rudimentary and deficient evaluation. Despite all these difficulties, professionals indicated a growing interest in their institutions in finding new ways to meet emerging demands and adapt to sociocultural changes. Museums continue to look for innovative solutions, such as AR or other technologies, to showcase content and attract new audiences.

Regarding the third research question, advantages and challenges, our analysis revealed six categories of advantages perceived by museum professionals: attracting visitors; learning; interactivity; optimizing the interpretation of the exhibited objects; communication with the public; accessibility. The professionals emphasize the "attracting visitors" item. This category is explained by the fact that current museums often compete for public attention with other spaces and attractions, while visitors are becoming more demanding of differentiated visiting experiences. Most investigated museums have adopted AR technology to meet new audience expectations. Almost all museums understand this technology as a means of adapting to the new reality and keeping up to date, working as a method of attraction focused mainly on younger audiences. AR technologies provide museum visitors with unique experiences that differ from other engagement methods. Particularly younger audiences find these experiences captivating and engaging [38].

Likewise, this study showed seven categories of challenges and limitations perceived by museum professionals: distraction/interference; banalization of the museum; excess of technological mediation; cost; equipment; the need for new content; accessibility. The category of interference and distraction was one of the biggest concerns. This issue is also raised in the studied literature [38,46,47] and is based on the fact that technology can sometimes overshadow museum artifacts. Since AR is directly connected to the narrative of the experience, it must be designed to complement the visit. Technology can end up causing noise or the abusive use of cell phones within the museum environment, impairing the understanding of the exhibition and the visitor's experience inside the museum and creating an impediment to the complete understanding of the visitor's experience. This category raises the following question: how to add AR without creating noise inside the museum?

Lastly, regarding the fourth research question related to the future, the perspective of museum professionals is that there is a need for greater technology robustness, and lower implementation and equipment costs. They also indicate the need for more training for museum professionals. Informing that, according to the museum professionals' experiences, AR should be designed according to the museum's mission, considering the meaning of the contents in the context of the museological narrative. All professionals agreed that museums must adapt and incorporate new technologies, obviously needing to invest more in these areas.

In order to keep up with the current technological paradigm and the demands of new generations of visitors, museums remain at the forefront of experimentation, obligatorily reinventing traditional exhibition concepts. Its audiences of different ages and origins require research into ways and techniques of implementation, usability, and accessibility, as well as methods of evaluating the AR experience in the museological space. As indicated throughout this paper, this investigation has been carried out [15–19]. We believe, however, that the vision of everyone involved in the creation/implementation of these experiences, including designers, developers, visitors, and museum professionals, must be considered. This work aims to fill the gap regarding research on the perception of museum professionals. As we have seen, the perception of museum professionals is highly relevant insofar as these are the only actors who work daily with the AR experience, who help to implement it, who introduce it into the narrative and exhibition context of the museum, and who finally observe the reactions of their visitors and their ways of interacting with that same experience. Through this investigation, we understand the experiences and perceptions of museum professionals of using AR technology, and critically discuss the future of these technologies inside the museum. We therefore believe that the new substantive theory generated from this study creates new knowledge about the implementation of AR in museums. The theory, which we built from the codes that emerged from the analysis of the interviews and in constant critical comparison with the facts and theoretical references raised in the current literature, suggests:

1. A holistic management of the AR implementation, carried out and thought of by the parties that will use it in order to obtain better and more compelling experiences;
2. The importance of the complementary nature of AR experiences in museum environments, taking into account that when the technology is not used, there is no impairment of the general understanding of the exhibition;
3. To provide an effective AR experience, the museum needs to understand the elements involved in the operation of the experience, finding the tools and devices that best suit the mission and purposes to be achieved. Technology emerges as a way to enhance the museum's activities and should be treated as a museology instrument, and for that purpose, its use must be duly justified and designed in advance, taking into account usability, accessibility, and evaluation procedures;
4. AR applications and experiences must always be well-contextualized, because if this care is not taken in their development, the system can become just a gimmick to excite and delight the visitor. It is crucial to ensure the visitor's route within the museum so

that AR fits the proposed museological narrative and does not become a distraction. The training of museum professionals regarding new technologies must be ensured, and the costs of updating content and adequate equipment must be considered to promote the best possible AR experience.

From this study, we understand that it is crucial to use an interdisciplinary approach when developing AR experiences in museums. This approach implies the need for collaboration and knowledge exchange between the various disciplines that are needed to create AR experiences and the museum itself, allowing for the consideration of cost, usability, accessibility, memorability, and other issues involved in the design and development process. AR must be employed in accordance with the institution's approach and strategy, leading to experiences that depend more on the quality and content of the exhibitions than on the technology itself, with the connection between museum artifacts and visitors being crucial for the relevance and survival of these institutions. Likewise, AR should not be understood as a mandatory tool for museums but as one of several possibilities for implementing new technologies within the museological environment.

We hope that the results of this study can be used in museological practice, allowing the development and implementation of new AR experiences that are more intuitive, efficient, interesting, and informative. We also hope that the results obtained serve as a basis for further studies.

## 5. Conclusions

This study provides insight into Portuguese museum professionals' perceptions when they are involved in implementing AR systems in Portuguese museums. According to our results, the perception of museum professionals on the role and use of AR indicates that the adoption of this technology was made in the last four years in a permanent format through apps, and accessed via visitors' smartphones or tablets from the institution. Professionals also point out that AR, mostly linked to the educational sector of the institution, aims to deepen visitors' knowledge and arouse curiosity about artifacts and themes related to museum collections. These professionals see adopting this technology as a way to meet visitors' needs. Since introducing an AR system is challenging, it requires a multidisciplinary team with scientific and technical knowledge, which most institutions do not have. Despite this lack of specialized personnel, most of the AR experiences in this study were proposed by museum professionals. We also found no adequate procedures for evaluating AR experiences in Portuguese museums. Despite the difficulties and the lack of qualified personnel, museums are constantly looking for innovative technological solutions that can continue to attract new audiences.

Our study also indicates that the major advantage of AR experiences for these museum professionals is the attraction of visitors, and the major challenge and limitation is the interference and distraction that could take the visitor's attention from the museum artifacts. For the future, these professionals believe that this technology needs more stability, with minor implementation costs. They suggest that future AR experiences be projected according to the mission of the museums and the meaning of the contents inside the museological narrative.

The theory resulting from this study suggests a holistic management of AR implementation: attention to the complementarity of AR without compromising the traditional exposition; the justification and design of AR experiences in order to adapt the tools to the mission and purposes of museums; the contextualization of the AR experience within the museological narrative; and, finally, the adequacy of the training of museum professionals; and the consideration of the costs of the equipment and updates of the experience. We believe that designers and museum professionals can use these suggestions to implement and design innovative and meaningful museum experiences.

## 6. Research Limitations and Future Research

One of the limitations of this study is that it was only carried out in Portuguese museums. The insights and data collected are limited to the Portuguese museum sector. Therefore, future research carried out more globally, with the perceptions and information of museum professionals from different countries, can offer us more data on the subject, offering a more profound vision and more parameters. In this way, it will even be possible to carry out comparative studies regarding the creation, implementation, and interaction strategies of AR in museum environments around the world.

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