Augmented reality (AR) in art museums:

Reconfiguring and mediating the museum dynamics

Ming Xin

(s1636464)

Master thesis

First supervisor: Dr. Ir. Ellen C.J. van Oost

Second supervisor: Dr. Annalisa Pelizza

29 June 2018

MSc Philosophy of Science, Technology and Society (PSTS)

University of Twente

Faculty of Behavioral, Management, and Social Sciences

Enschede, the Netherlands

Content

Acknowledgments

With a passion for museum enterprises and cultural activities, I finished this research, during which I received help, inspiration and encouragement from many.

I would like to thank my first supervisor Ellen van Oost. Thank you for your guidance on theories and empirical methods as well as the inspiration you gave to me to develop my research framework. All the discussions we had and all your elaborate comments have helped me a lot. Thanks to my second supervisor, Annalisa Pelizza. My interests in ANT started to grow because of your clear explanation in class. Thank you also for your encouraging words and valuable suggestions for improving my work.

I also want to extend my thanks to my interviewees from Groninger Museum, Van Abbe Museum, Museum Boijmans van Beuningen, Tetem, and Museum TwentseWelle. Thank you for your willingness to participate in my research and for sharing so many significant and professional insights with me. I have enjoyed every interview very much. I have benefited a lot from your perspectives and felt encouraged to carry on working on this topic.

Besides, I owe my thanks to family and friends for their consistent support. Circumstances are sometimes difficult, but I have gained power from you all. Although my family is far away in China, I get strength from them. Especially, I thank my husband Menno. Thank you for supporting me all the way through the years in the Netherlands, helping me to adjust to the new environment and culture. Also thank you for inspiring and encouraging me, from our discussions and little chats to handling my diffidence and proofreading. We have been through so many things and finishing this research probably signifies a new start in our life heading for a bright future.

Lastly, thank all the kind spirits that have helped me in one way or another.

Enschede, 20 June 2018

Ming Xin

Summary

Augmented reality (AR) is increasingly used in art museums to provide added value for museum visits by attaching virtual contents onto physical museum environments. However, despite high expectations of museums, the possibilities of AR for museum use still require further exploration and reflection. This research takes a science and technology studies (STS) perspective and an exploratory qualitative approach to analyze how AR can be embedded in the museum dynamics and construct new visitor experiences, both from a positive side of technological promises and from a critical side of limitations, conditions, and potential losses.

Aiming to bridge relevant theoretical concepts and institutional practices, the research combines insights from various angles. Actor-network theory (ANT) is applied as the theoretical framework to account for the fuzzy, pluralistic museum dynamics. The empirical methods primarily include an analysis of earlier cases of AR use in museums, studies on academic publications about the design and use of AR in museum contexts, and interviews with museum professionals.

Through the analysis of possibilities and tendencies of using AR to facilitate exhibitions, a continuum of AR between informative and experiential emerges. From one side to the other, AR is implemented decreasingly to assist exhibits by augmenting certain elements in the museum dynamics, and increasingly to gain agency by itself and transmit agency to visitors, aiming at challenging the original configuration of the museum system, creating new elements and bringing in new actors, thus more fundamentally reconstructing the museum dynamics. The technique of AR is not strictly bounded to certain manners of realization; it is adaptable, flexible, and responsive based on its core idea of mixing virtual input with real-world elements. How to apply AR to exhibitions can be seen as a matter of balancing between being purely informative and drastically experience-creating, depending on museum and exhibition characteristics.

However, because AR fundamentally reconstructs the museum dynamics and user experience, tradeoffs may occur countering the original intentions behind using AR. The research elaborates on three tradeoffs: isolated phenomenon, balanced problem, and fragmentation. They are potential hazards of the museum use of AR, and require museums to weigh pros and cons, reflecting on their ambitions, values, and capacities when planning to add a high-tech flavor to exhibitions. By thoroughly considering possible tradeoffs and problems, museums can make well-considered decisions about using AR and sufficiently prepare for its design and redesign, applying specific elements to steer desirable uses. Besides these fundamental tradeoffs, there are also practical issues, such as meaningfulness, user accessibility, and technological sufficiency, which may affect the success of AR applications in engaging museum visitors. By taking such practical issues into design considerations, museums and designers can try to limit undesirable consequences such as non-use.

Generally, facing AR's complicated agency and the variety of relevant actors, museums should retain an open attitude and reflect on design assumptions. Regarding the specific actor of visitors, applying AR can benefit from visitor research and surveys, which not only address users but also non-users. To achieve goals museums have with AR, besides configuring the actor-network in the design considerations involving different stakeholders, continuously reacting to real use based on feedback loops and redesign is crucial.

Chapter 1. Introduction

In a conventional sense, art and technology are regarded as two distinct human enterprises which may contradict. Reflecting on modernity and technology, great thinkers sometimes consider art as separate from and sometimes even opposed to modern technology. Benjamin (1935), for instance, stated that artworks gain authenticity from their unique existence, which will be lost in mechanical reproduction enabled by technology. Therefore, the special values of fine art will be eroded by modern technology and the resulting mass production. Philosophically, Heidegger (1954) explicated that the essence of modern technology is a way of making sense of the world, restricting human thinking into framing reality only in terms of function and exploitation. To escape from this dangerous restriction, poetical practices such as art can help people understand reality differently, thus freeing them from the technological framework. In a more recent reflection on art being monumentalized, Maleuvre (1999) argued that a work of art is unprecedented, creating its own concept instead of being derived from preset ideas. This inaugural nature makes art "essentially distinct from other forms of human production ruled by skill, craft, that is, technology" (p. 64).

Despite the arguments dissociating art from technology, it is unimaginable nowadays to see art as completely isolated from technology: Not only because creating art cannot exist without the involvement of technology, but also because the practices of presenting and appreciating art have become intertwined with technology. In art museums, generally considered to be dedicated to preserve and present art, technologies are an integral part, ubiquitous though often on the backstage. They are not only applied for the conservation and restoration of artworks, but also for an optimal presentation and exhibition, involving, for instance, lighting, security, architecture, and interior design. Technologies are becoming increasingly visible for museum visitors. Firstly, they are used as a vehicle for artistic expressions, a way of constituting modern art and performing arts. Secondly, as this research focuses on, technologies are also salient in museums aiming at contributing to the visitor experience in exhibitions. With traditional audio guides becoming a standard offer in many museums and video presentations accompanying many special exhibitions, visitors may already take such technologies for granted. More recently, however, the rise of high-end

information and communication technologies (ICTs) brings about new possibilities for museums to enrich the experience of museum visitors.

The emerging technology of augmented reality (AR) is a current example of ICT entering museums. AR features a technique which generates virtual augmentation based on real environments and creates combinations and interactions between virtual and real elements. Noticeably, distinguishing between virtual and real elements does not signify an ontological reality/virtuality dichotomy but a generally perceived distinction, which is contingent on cybercultural contexts and has been constructed through cultural history (Pelizza, forthcoming). The concept of AR can be grasped by referring to the Reality-Virtuality Continuum proposed by Milgram and Kishino (1994): Real environments and virtual environments are the ends of a continuum, with in-between various forms of mixed reality. When the mixture is closer to real environments, it can be called augmented reality. Different arrangements between hardware and software can realize AR. The hardware concerns capturing and processing real environments, generating and displaying virtual elements, and so on; the software focuses on combining augmenting virtual overlays with real-world elements. Therefore, not only specially designed head-mounted sets but also portable daily digital devices like smartphones and tablets can conveniently enable AR and transfer real environments into mixed reality.

Attaching virtual contents onto physical museum contexts, AR is gradually entering art museums. Artists sometimes build art projects based on AR[1]. Meanwhile, museums are exploring possibilities of using AR to provide added value for museum visits. Embodying the ambitions of museums and developers to improve or optimize the visitor experience in museums, various applications have been developed. After traditional digital technologies like audio guides, AR seems to be on its way of becoming a new technological manner for museums to engage and educate visitors.

However, despite the high expectations of museums on using AR to facilitate visits and exhibitions, the possibilities of this emerging technology for museums still require further

[1] For example, artist John Craig Freeman worked with the Los Angeles County Museum of Art in launching a location-aware AR public art project called “Things We Have Lost”. It started with interviews about tangible and intangible things people lost in Los Angeles and displayed 3D virtual objects of the lost things at accurate geolocations. Thus this project transformed how we sense the notion of place by connecting individual experiences and memories with public places using digital technology. (http://www.lacma.org/eeg-ar-things-we-have-lost)

exploration. Although AR applications for museums have been designed and tried out since the 2010s, there still seems to be no well-established exemplar, as we can see in the practices of museums. Moreover, the picture of applying AR in museums is not always optimistic. The potential of AR has sometimes been questioned, with doubts about its real value and impacts[2], and professionals have reflected on whether using AR for museums or galleries is merely hype[3].

All the ongoing anticipations, suspicions and discussions around using AR in museums make it an intriguing topic. Guidelines for designing and implementing AR applications in museums are still insufficiently explored and reflected upon. Firstly, museums expect AR to mediate[4] the practice of museum visiting and create desirable visitor experiences, but what the technological mediation may involve is not yet systemically addressed. Secondly, current studies and pilots regarding AR in museums primarily focus on promises of AR, embracing a very positive image of the possibilities of high-end technology, while critical reflections on potentials and limitations are rather inadequate. Furthermore, despite plentiful design and engineering projects and museum practices which take AR as promising for museum use, little research takes a social perspective addressing how AR can, or can better, fit in museum contexts and even society. Intending to fill in these gaps, this research tries to take a science and technology studies (STS) approach to explore how AR fits in the museum dynamics and constructs new visitor experiences, both from a positive side of technological promises and from a critical side, reflecting on limitations, conditions, and potential losses.

Noticeably, the practice of using AR in museums is still at a beginning stage marked by engineering research, experimental and pilot uses. Limited by the current state of the art, I do not intend to complete a social picture of AR in museums. Rather, this research aims to be

[2] For example, USA Today columnist Bob O'Donnell posted the critic on AR that the disappointment is real. Retrieved from: https://www.usatoday.com/story/tech/columnist/2017/04/25/augmented-reality-disappointment-facebook-snapchat-microsoft/100836274/

[3] A tweet posted by @MuseumNext in 2010 triggered a debate. The question in the post was "Is augmented reality really useful for a museum/gallery or is it over hyped?" Retrieved from http://museum-id.com/augmented-reality-museums-beyond-hype-shelley-mannion/

[4] "To mediate" in this research takes the meaning of this word in a sense of everyday language, indicating something/someone intervening between different elements in order to achieve reconciliation or other desirable consequences. This concept does not denote particular academic frameworks about technological mediation, such as Verbeek's (2005) postphenomenological technological mediation.

an orienting empirical study giving a first impression of the mediating role of AR in museum environments.

The next chapter introduces an STS-oriented approach as theoretical framework. The research methods are then described in chapter 3. As an analogy for better understanding how AR may be defined in museum contexts, chapter 4 describes a case study analyzing how the use of another ICT application (QR code) is shaped in museum environments. Chapters 5 and 6 address the mediation of AR in museum dynamics and visitor experiences from two sides, one focusing on promises and possibilities, the other on conditions for a desirable use. Chapter 7 concludes the research and provides theoretical reflections and practical recommendations. By exploring the problem of applying AR in museums both theoretically and empirically, this research can inspire critical reflection on and creative use of AR applications in the practice of museums.

Chapter 2. Theoretical discussion on technological mediation in art museums

To understand the mediating role of AR in art museums and facilitate effective and engaging AR applications, it is important to conceptualize the involved elements of art museums and their relations on which AR exerts mediation in museum visiting. This chapter explores such a conceptualization based on theories which can account for AR not as tools but as agents with active shaping abilities.

Introduction

Throughout studies and practices around museum visiting, two sets of vocabulary seem to underlie different conceptualizations of this activity. According to the first, ‘viewers’ directly relate to ‘artworks’ through ‘art appreciation’, so the relationship at stake for the museum experience is a series of straightforward ‘viewer-artwork’ relations, which are primarily personal and individual, probably cognitive and aesthetic. In this sense, the viewer is the subject of the activity and artworks are the objects; the museum is assumed to be a neutral space, simply providing a spatial possibility for people to experience art. This perspective implies reductionism: Great architecture and interior design of a museum may add to the experiences of people, but only as an extra, detached from the viewing experience achieved from artworks.

The other vocabulary emphasizes the social institution of museums. People in art museums are ‘visitors’ who relate to ‘exhibitions’ in the ‘museum space’, conducting the activity of ‘museum visiting’. Accordingly, we arrive at a holistic view in the sense that the single relationship between visitor and artworks does not solely account for the visitor experience, but the museum also actively constructs the visitor experience. Various museum-related elements play a role, together creating a dynamics based on which people accomplish certain experiences. Following this perspective, we can even more radically argue that an explicit ‘visitor-artwork relation’ does not exist, as visitors and exhibits do not directly relate to each other but are two elements in the broad museum dynamics, connected with the involvement of other elements. The direct relation with artworks as perceived by visitors may

rather be a partial representation of the whole dynamics, which is constructed by interlinking elements on a social level.

These two vocabularies are not necessarily conflicting and can be applied onto one case simultaneously and sometimes interchangeably. Notwithstanding, they represent two different angles of looking at art museums that may affect public attitudes towards museums, research in museum studies, and the building and curation of museums. For example, as demonstrated in a museum architectural study by Newhouse (2006), some architects try to build art museums as neutral environments where people can view art without distraction; in contrast, others attempt to construct special contexts for exhibited artworks instead of using just white walls and thus design bold and outlandish museum buildings. Behind the architectural design there are different assumptions about the proper function of museums and meanings museums should have. Architects of the first type match more with the 'viewer-artwork' vocabulary, seeing neutrality as the ultimate goal for museum space. Architects of the second type fit better with the 'visitor-exhibit' vocabulary, working towards organic and unique museum environments which can become monumental by themselves. No agreements have yet been reached answering which approach is more favorable among artists, architects, and curators (Milojković & Nikolić, 2012). The two vocabularies are merely two theoretical perspectives to grasp the mechanisms behind visitor experience in art museums, though they may have different consequences in practice. Evaluating them is not about truth value but about which is more appropriate when applied to a certain scenario.

Preparing a theoretical framework for studying the mediating role of AR, the following section will assess the two perspectives and vocabularies and argue that if we reduce museum visitors to art viewers and the activity of art museum visiting to art appreciation, we lose fruitful perspectives which could be beneficial for applying technologies in museums and, in general, constructing art museums to fulfill their communicational and educational goals. A network-oriented perspective—actor-network theory (ANT)—helps to understand the dynamics of museum space and museum visiting. Based on ANT, this chapter will theorize the occurrence of mediation as well as the mediating characteristics of ICT in art museums.

Viewer versus visitor

Adopting the viewer-oriented or visitor-oriented vocabulary makes a difference in understanding how experiences are constructed in art museums. Following the viewer-artwork vocabulary, museum visiting can be narrowed down to a straightforward and linear relationship of art appreciation between the artwork and the viewer. Taking this reduction as a presumption, studies about experiences in art museums only or primarily need to account for the appreciating individual as subject and artworks as objects, coupled in a cognitive and aesthetic relationship. For example, the experience of appreciating artworks that consists of perceiving artworks and thinking may be identified as saccade-fixation patterns of viewers when scanning artworks (e.g., Gregory et al., 1995). And furthering this behaviorist simplification, empirical research sometimes takes only the content of paintings and the eye movements of viewers into consideration when studying cognitive factors of aesthetics within museum contexts (Heidenreich & Turano, 2011).

On the other hand, the importance of non-artwork elements in the museum setting has been addressed following the vocabulary featuring 'visitors', taking the social behavior of museum visiting as the basic activity in art museums and the museum as a behavior setting (Falk et al., 1985). 'Social' in this sense does not necessarily mean social interactions between individuals, but rather implies an overarching embedding of social elements surrounding museum visiting. For example, the museum would be seen as a social institute instead of merely a physical location, thus the environmental elements of the museum space in which the behaviors of museum visiting occur become more crucial: "Space is formed largely through social action, and space controls the activities that take place within it, and how the objects are understood" (Goulding, 2000, p. 264). Thus appreciating and understanding artworks is no longer confined as a solely personal activity, but must be seen as a social activity constructed in interactions with surrounding entities.

In everyday talking, people refer to both vocabularies addressing their experiences in art museums. But along with several tendencies in the museum world, the 'viewer-artwork' vocabulary is increasingly challenged. First, although traditionally collections and curatorship had been at the center of museum enterprises, the arrival of 'new museology' in the late 20th

century has drawn attention to diverse social groups and the importance of roles and functions of museums in communities and for the general public (Stam, 1993; Vergo, 1989). This trend is not only reflected in philosophies of museums, but also influences and is represented in artists' perspectives (Gehry, 2000) and museum practices (McCall & Gray, 2014), treating the museum no longer as a temple for art collections, but as an important urban space which presents art to the community. Second, with the development of technology studies as well as museum studies, interdisciplinary theories and practices combing the two disciplines are emerging, generating new knowledge like museum informatics (Marty & Jones, 2008), the establishment of the new 'virtual museum' (Schweibenz, 1998), and specific uses of digital devices for non-art-appreciation purposes in museum visiting, such as guiding (Hornecker & Bartie, 2006) and enhancing participation (Vom Lehn & Heath, 2005). Therefore, museum visiting is increasingly seen as a pluralistic activity beyond merely art appreciation.

Furthermore, technologies, especially media and digital technologies, reframe art appreciation itself. One reason is that in modern art forms such as interactive art, enabled by digital technologies, visitors are not relatively passive viewers, but play a pivotal role in forming and presenting the artwork (Kwastek, 2013). Thus the visitor experience does not lie in the appreciation but in interaction, which is mutual and co-constructive between the human visitor and the non-human artwork. Another reason involves the topic of this research, namely digital technologies applied in museums aiming to assist exhibitions and enhance visitor experiences. Presently, such technologies, like audio guides, often provide contextual information about exhibitions for museum visitors. Such information is not neutral or transparent, but can play a role in creating significance in the viewers' perception of artworks and building relationships between viewers and artworks (Hubard, 2007). Thus exhibition-facilitating technologies more or less participate in forming art appreciation. AR as a currently emerging digital technology may offer more than contextual information when applied in art museums, and thus has the potential to more radically reconstruct art appreciation. Therefore a linear subject-object formula between viewer and artwork is insufficient to conceptualize art appreciation, let alone museum visiting.

In conclusion, it is no longer plausible to consider museum visitors as merely viewers or take artworks as the only element into account when talking about the museum environment, especially in a digital era. This vocabulary cannot grasp the complexity of museums, and if we simplify this complexity to a viewer-artwork relationship, or even reduce viewers to their behaviors and equal artworks with their concrete content, many important elements which seem to be contextual but are actually crucial to museums will be lost. A holistic view and the visitor-oriented vocabulary acknowledge the relevance of the seemingly peripheral contextual elements and their weights in museum visiting. They include but are not limited to social and environmental factors like the environment where viewers perceive artworks, prior experiences and non-behavioral psychological states of viewers, and the historic meanings and social implications of artworks. Moreover, by discarding the linear 'viewer-artwork' relation, this perspective also entails using a dynamics to describe and understand museum visiting, in which different elements interact and construct each other. For example, people entering the museum space constitute a part of the museum dynamics through visiting and meanwhile the museum setting also constructs visitors, making them into "individuals who are perfectly predisposed socially, psychologically, and culturally to enact" (Duncan, 2005, p. 89) the symbolic behavior of museum visiting. In this technological age, such a perspective allows for investigating the role of technology in museums and can further promote designing and applying technologies to facilitate exhibitions.

Actor-network theory

A new question now emerges: How can we conceptualize such a fuzzy, pluralistic dynamics with heterogeneous elements, ranging from human visitors to non-human museum settings, from technological devices to aesthetic objects, and from concrete physical existences to abstract meanings? Along with the introduction of novel ICTs like AR into art museums and the emphasis on the visitor-oriented vocabulary, we need a theory to grasp the complicated museum dynamics and its diverse, numerous elements in order to account for what AR brings to museum visiting and visitor experience. For an attempt to construct the understanding of museum dynamics, actor-network theory (ANT) appears to be a beneficial approach, as it

comprehensively accounts for heterogeneous elements, both material and human, with agency from a network perspective.

ANT, though called a theory, is “descriptive rather than foundational in explanatory terms” (Law, 2009, p. 141), featuring an attempt of depicting relations in systems rather than giving strong explicative accounts. It was grounded in a social vision of studying successes and failures of engineering innovations. Although system-sensitivity has always existed in accounts of successful innovations, it was Callon (1981) who drew the social-system-oriented perspective to the whole material world by questioning how we can describe all these socially and materially heterogeneous systems given their fragility and fuzziness. Further developed in the scope of social studies of science, ANT concepts were applied to describe how the knowledge of reality is generated, referring to a heterogeneous web of relations (Latour, 1993). This offers a view of the world, taking systems instead of entities as the basic scale of describing and understanding. Systems are networks, in which heterogeneous elements are actors (or ‘actants’) relating to each other and the basic force in networks lies in relations. Therefore, ANT can to a large extent be treated as a theoretical and methodological approach to describe the world as well as understand the social by calling for relations among actors in networks, and thus it serves as a toolkit for understanding relations in systems (Law, 2009).

Believing in relational forces, one prominent characteristic of ANT is anti-essentialism, against the assumption that there is something necessary or a priori of an entity as its identity. All entities, instead, exist relationally in constantly changing networks, both in a material and physical sense and in a conceptual and semiotic sense. The dynamics of museums is not limited within a geographical museum space but external factors also play as actors in the museum network. As a part of an urban public space in society, the museum itself can be seen as an institutional actor in a bigger network of society, connecting with other actors both physically in terms of location and conceptually in terms of institutional position. Likewise, the meaning and definition of an exhibit, say a painting in the museum, is not essentially embodied in its physical existence and content. Not in colors, strokes, or the canvas, also not predefined by makers or authorities, it gains meaning by how it is posited in a network, relating to physical environments like the museum space where it is, institutional structures

around it, such as the academy and market, and how individual visitors perceive and make sense of it. It is constituted and identified as what it is only in those relations. Therefore, the role of an actor in the network is not self-determined but relies on the relational network, and "a single actant may take many different 'actantial' shapes, and conversely the same actor may play many different 'actorial' roles" (Latour, 1994, p. 33). So to speak, the identity of an entity is not pre-given but continuously shaped and defined in networks. By relating to other entities, both the physical existence and the conceptual meaning of an entity change throughout the relations and interactions with others, and the entity simultaneously changes other entities too. The forces of changing do not exist in the entities themselves but in the relations around them. Therefore, social phenomena are only to be explained by relations among actors instead of the actors' essences (Latour, 2005). By actively looking for actors and studying relations among actors, this vision serves as a strategy to discover and recognize underlying hidden factors and assumptions (Mol, 2010).

Networks are always in motion and all elements in networks are actors who have the power to change, shape, act, and interact with and against others. This draws forth another important characteristic of ANT, countering the human-nonhuman asymmetry in social studies. ANT endows all actors with agency, unlike traditional approaches that take only humans as subjects of agency. To study science and technology from a social scope, ANT intends to challenge conventional humanism, which is featured as anthropocentric, regarding manpower as mastery to technology. As Byrne et al. (2011) argued in the explication of the diverse and plentiful human agents in the dynamics of museum collections, human actors are, of course, important in an ANT analysis of museum dynamics, generally encompassing five types[5], each having its particular actions which embody their agencies (p. 7). But it is also important to notice that the changing force of these human actors does not exist because of their identity as human, but because of how they are positioned in the network. When we try to depict or construct networks in analysis or practice, "natural and social actors seem to come into the networks as malleable beings, to be shaped in accordance with the designs of the network builders" (Murdoch, 1997, p. 738). Thus the analysis should not predefine an actor in

[5] The five types are the creator community, the field agent/collector, the collector/middleperson/broker/auction house, the museum/curator, and the public.

terms of human or nonhuman but only define it according to its relations in the dynamics, so that nonhumans are also actors with agency.

Besides against the dualism of human versus nonhuman, ANT is also against, and holds on a principle of agnosticism towards, another long-lasting dichotomy presumed in STS, namely the opposition between natural and social elements. ANT presupposes a ‘generalized symmetry’ (Callon, 1986): Differences between natural elements and social elements are not a priori but only formed in relational actions. Thus the analyst should be impartial in treating science and engineering aspects as well as social aspects. By abandoning presumed distinctions between technological and social phenomena and discarding the artificial dichotomy of technology versus society, it also challenges the specific divisions of technology versus art, technology versus people, and so on in the context of art museums. For all sectors, including those which are commonly considered as distinct and maybe conflicting under a dualist understanding of society, the same vocabulary of description should apply. Therefore, we should not take distinctions between technology and art or between technological devices and social activities of museum visiting for granted when studying the museum environment and the use of technology in it.

To better understand and illustrate the mutual dynamics between the technological and the social, ANT employs a series of notions based on the conception of ‘script’, attempting to explain the designer-technology-user relationship by analogizing with the writer-text-reader relationship. We humans delegate jobs to technologies but the artifacts do not merely serve as tools; neither is the social completely determined by the technology as an unstoppable force. Between social constructivism and technological determinism, ANT compares artifacts to a written text which starts from an author but can be interpreted differently by readers (Latour, 1992). A technological artifact is created by designers but remains relatively independent from designers after the making, and is open to different uses according to individual users. On the one hand, designers make artifacts based on their anticipations and assumptions about how the technology shapes and mediates human actions and relationships. So, in the design process, designers deliberately ‘write’ their assumptions about intended mediations into the script. In other words, designers ‘inscribe’ (Latour, 1992). The inscription materializes in the

artifact, which creates transaction possibilities between individuals and their environments, namely the artifact's affordances (Gibson, 1979). On the other hand, users react to the artifact, appropriating it according to their own environments and contexts, 'interpreting' the script in their own ways. They thus 'describe' the technology (Akrich, 1992). Therefore, the script of the technology in real use is a co-production of inscription on the designers' side and description on the users' side. Technological mediation is also rooted in the tensions between designers inscribing and users describing artifacts. Thus designers and users are connected in mutual relationships through the technology, or the 'script'. Based on analyses of the script of AR in museums, the relations among museum institutes, technology developers, museum staff, and visitors in an actor-network can be depicted.

With the increasingly prominent role of technologies in museums, such an approach discarding prejudices of regarding technology as conflicting or alien to museum exhibiting and visiting seems to be especially cogent. Visitors, artworks and technical devices are not predefined with essential and static identities assembling the museum environment. On the contrary, they are constructed in the network in which the three elements relate, form and define each other, interacting with other actors within an overarching museum actor-network, free from presupposed asymmetries between human and nonhuman actors or between the technological and the social. An ANT perspective cannot ignore the uniqueness of particular dynamics of each individual museum, which may have distinct goals, social status, physical environment, curation, and visitor groups. But ANT can also on a basic level assist to grasp the general structure of museum dynamics and offer emphases on usually understated actors in the dynamics of art museums that can possibly inspire a close analysis of the specific dynamics of a particular museum. Thus in order to study AR mediation in art museums, this research will adopt ANT to understand the holistic ensemble of the museum environment and study the role of technologies in it. AR as a newly introduced actor, therefore, does not merely mediate a specific linear relationship but the whole network. The next section explores the critical characteristics of actors and relations among actors throughout the museum actor-network.

Actors as mediators

With the help of ANT, the museum dynamics is conceptualized as a network with diverse and multitudinous actors ranging from human elements such as visitors, museum personnel, and technology designers to nonhuman elements like artworks, buildings, interior environment, technological devices, and even the society outside of the museum space. To better understand the comprehensive museum dynamics, this section further elaborates on what relations between actors entail and what counts as actors.

The network-oriented perspective featuring heterogeneous actors and dynamic networks can and should be applied to all kinds of elements and their relations in museums. A specific example may concern exhibits and museum interior: The museum will be decorated responding to a certain exhibition, and exhibits also need to be arranged adjusting to the indoor setting. So the balancing and negotiating between the two elements will contribute to the eventual exhibition arrangement along with other considerations. Actors shape and define each other, limiting as well as supporting each other at the same time. But despite the attempt to conceptualize the relation between two actors, such an isolated relation implied by mechanism is not possible (Latour, 2005). Museum visiting is in a holistic sense co-shaped by actors and relations that may be perceived as peripheral or taken for granted.

Firstly, seemingly contextual elements may play significant roles in forming and conceptualizing the perception of artworks. For example, in his book ‘Ways of Seeing’, which gives classical insights about art appreciation, Berg (2008) discusses the meaningfulness of physical environments in which a visual artwork is preserved. Besides the artwork and viewer, “the place, the cave, the building, in which, or for which, the work was made” (p. 32) exerts power in creating the experience of an artwork. When artworks are removed from their original contexts and put into museums, their meanings and significance to viewers change. Furthermore, textual materials surrounding artworks also have important roles: Words change images, and, in some cases, images illustrate the words (Berg, 2008, p. 28). Various textual materials can in one way or another participate in forming visiting experiences and visitors’ aesthetic judgments. For example, associating different titles with a same artwork may result in individuals describing it differently (Franklin, Becklen, & Doyle, 1993), and whether titles

appear or not when presenting artworks may influence how viewers make sense and attach meanings to the artworks (Russell & Milne, 1997). The textual material can also be artists' statements, which may influence how viewers assess the artworks, as an experiment-based study indicated (Specht, 2010). Therefore, textual information is not simply contextual and explanatory for artworks as the background, but it contributes to people's holistic perceptions.

Secondly, actors involved in museum visiting are not simple, homogeneous particles but heterogeneous dynamics in themselves. ANT sees an actor in a network as made up by and consisting of complex and detailed (sub-)networks (Latour, 2005). Take museum visitors as an example: If we query in terms of visitor experience, it seemingly appears to be an assumption that 'visitors' are one element in the dynamics, as a single node on the net. However, visitors are not unified with the same intention of visiting museums or having highly generalized interactions and experiences in exhibitions. On the contrary, museums serve diverse audiences of different ages and cultural backgrounds, and museum education is based on each individual's 'free-choice' learning (Falk et al., 1985). As Berg (2008) remarked, when someone chooses collections for a pinboard in the room, which resembles a personal museum, the choice is highly personal because the chosen ones are to "match and express the experience of the room's inhabitant" (p. 30). Different personal histories, experiences and aesthetics of visitors constitute various individual networks, defining different actors on a most basic level, which will result in different experiences and reactions to the exhibitions. Simplifying dissimilar individuals as a whole on a relatively macroscopic level depends on certain situations, based on generalization and representation (Akrich, 1995). Furthermore, the macroscopic actor of visitors can also be seen as a complicated network, in which all sub-actors, namely individual visitors, relate, enabling, promoting and limiting each other. For example, a study on information kiosks in museums observed that visitors' use of those interactive technologies largely depended on the presence and behavior of other visitors (vom Lehn & Heath, 2005). Therefore, understanding the museum actor-network requires an awareness of the complexity of actors, acknowledging the existence of and interactions among sub-actors and reflecting on simplifications when generalizing individual visitors into an integrated actor of 'visitor' or several categorized representative visitor groups.

Actors throughout the network change and modify each other and such modification or impact among actors can be seen as mediation, so each actor mediates other elements and the overall network. The experience of visitors in museums "is mediated by a number of socio-cultural, cognitive, psychological orientators, and physical and environmental conditions, all of which need to be seen as interrelated if a quality experience is to be provided" (Goulding, 2000, p. 273-4). Given the emergence of digital technologies in art museums, they surely play a non-negligible role in mediating the experience of visitors. The mediation of technology, following ANT, is not impacting on certain directly related actors. Instead, mediation is in the network as a whole because any relation between two actors cannot be properly discussed isolated from the whole network.

Talking about technologies mediating a network, some further clarifications are necessary regarding the concept of network and actor. While nowadays the word 'network' commonly implies information being transformed without deformation in the context of computer science, ANT is against this implication (Latour, 1999). Relations among actors in the network are actually transportation with transformations. When different actors relate to each other, the whole system is not static but in constant change. Each relation involves transductions and transformations so as to achieve alignment between actors. Thus when we think about the mediating role of technology such as AR affecting the relation between museum visitors and exhibits, mediation cannot be analogized to placing a transparent glass wall through which visitors and artworks connect as if there is no obstacle in between, as if the technology merely gives additional information attached on the glass as a supplement to the exhibit and the already existing information on plaques. Such understandings about the network echo a distinction between mediator and intermediary in understanding actors.

Intermediary and mediator represent two opposite accounting styles for understanding roles of actors in networks (Latour, 2005). An intermediary honestly transports agency from one actor to another without modification. Thus it seems to be transparent in linking input and output in a relation that resembles a chain: The consequence can be predicted given the antecedent, despite the intermediary. In contrast, a mediator modifies what is supposed to be transported and opens up bifurcated possibilities in the course of actions, triggering new

actors and accomplishing a much more complex system than a causal connection. The role of an element can be considered either as an intermediary or as a mediator in a network, but from the ANT perspective, “there exist endless number of mediators” (Latour, 2005, p. 40). In studying networks, the analysts also play as actors and their attitude or angle from which they look at it can modify the network systemically. Therefore, studying the mediation of one actor in a dynamic network calls for a viewpoint of discovering and understanding elements in the network more as mediators and less as intermediaries. By taking such a perspective, the meaning and significance of actors can be considered more specifically and comprehensively.

Actors in an ANT analysis should always be considered firstly as mediators with the power of challenging and reframing relations and other actors. In the museum dynamics, ICTs like AR construct museum visiting and visitor experience and thus are definitely regarded as typical mediators. But traditional facilitating technologies, such as audio guides, QR codes and even artifacts like plaques are often defaulted in practice as parts of the museum environment or even the original museum setting, namely as intermediaries offering additional information. Probably when they entered museums at first they were also regarded as mediators, fundamentally changing the museum dynamics and the structure of museum visiting. But nowadays these technologies may be mistaken as intermediaries and their functioning as mediators may be black-boxed. That is because it is easy to take a system as a whole instead of as different parts relating to each other in a network, as long as the system works appropriately. For example, people always take a machine as a single entirety until it stops working properly. Only then, the machine will be considered in terms of various components, and the functions of each component and the connections among components will start to draw people’s attention. Similarly, when AR becomes a mature and standardized application for exhibitions, its mediating role may also be black-boxed. Therefore, to study how AR mediates art museum visiting, this research is actually an attempt to resist the black box, seeing AR in museum uses not as an intermediary but as a mediator.

Taking digital technologies as mediators in museum visiting does not mean that our perception and appreciation of artworks were not mediated before the digital era. Without ICTs, our experience with artworks was already a result of mediation by all kinds of elements

in the museum dynamics. Actually, all actors have the potential to be seen as mediators as they all actively relate to each other and possibly trigger new activities and actors. The museum as an institute itself, for example, is already a mediator mediating how people look at artworks, both through its physical settings and its conceptual social meaning. As this research aims to understand the mediating agency of AR, it is worth noticing that technology does not add its mediation onto the already mediated experiences in museums, but fundamentally remodels the whole network. The previously mediated experience of visitors will be transferred into something totally new, not straightforwardly predictable given the pre-digital technological museum dynamics. Although the specific network will be very different for each application of technology, the comprehensive mediation necessarily occurs along with the new digital technology getting into the museum environment. The next section uses the ANT concept of translation to conceptualize what happens to the museum dynamics in such an occasion.

Translation and re-assembling of actors

As argued before, the impact of digital technologies on the museum actor-network does not simply involve one additional actor and the new relations around it. Applying AR in museums at least changes contextual elements of the museum environment, for instance the museum interior and textual materials, which tend to be directly subjected to the modification as AR can create a virtual space and reconstruct background environments for exhibits. But in addition to modifying the contextual environment of museum visiting, AR has more potential. By offering various informational or entertaining materials on a virtual layer, AR combines the virtual space with the originally realistic museum environment. Thus AR, as a mediator, fits into the museum network by delicately but definitely transforming the original museum dynamics into a new one. This section attempts to analyze theoretical patterns of this transformation.

When ICT innovations enter museums, technologies do not perform like a bridge between certain separate factors adding to the museum visiting, but transform the whole picture of museum dynamics with a series of negotiation and coordination among old and new actors happening in the network. Before the transformed network stabilizes, all actors and

relations have to be influenced. Actors find their place in the new network and new relations are built, replacing old ones. This process can be conceptualized as 'translation', in which actors transact with each other and get transformed while the network develops, "during which the identity of actors, the possibility of interaction and the margins of manoeuvre are negotiated and delimited" (Callon, 1986, p. 202).

Although this research does not study how an AR application is introduced and stabilized in a museum setting, some notions about translation help to understand the role of AR in the museum actor-network. Callon (1986) suggests different moments of translation. Translation starts with problematization. In this phase, one actor takes the initiative to conceptualize the network and define the identities of all other actors so as to identify or establish a crucial 'obligatory passage point', where the interests of all actors can ally. In other words, a hypothesis is made, defining the identities of actors and clarifying their interests.

When implementing AR, the museum itself, which actually constitutes complicated networks of institutional and personnel structures, can generally be seen as the actor initiating the translation process. Different considerations may be involved in the problematization of museums, such as improving existing communicational fashions, attracting new visitor groups, or experimenting with new high-end technologies, based on which museums may decide that reality is limited and virtual elements can be desirable. Trails of problematization in specific cases can be very diverse and are sometimes not entirely clear or sufficiently reflected upon. This phase can be regarded as identifying reasons for applying AR in museums.

The implementation of AR aims to fulfill the problematized considerations, which corresponds to the second moment of translation, interessement, where an entity attempting to stabilize the identities of actors is established. While actors identified earlier are integrated into or refusing the transformation, the initiating actor may use devices to "impose and stabilize the identity of the other actors it defines through its problematization" (Callon, 1986, p. 204). AR can be seen as such an interessement device: It tries to create a balance of power among all parts of the network, including personnel, exhibits, visitors and so on, and this balance should be generally favored by all groups. It should be noted that AR is two-fold, both as the technological device and as the attached virtual elements. While introducing ICT

devices into the museum dynamics remodels visitors' behavior and understanding, the virtual content enabled by devices may also influence visitors' perceptions, thus constructing the visitor experience and transforming the actor-network. Therefore, the agency of AR as an interessement device lies in the match between its material device as hardware and its virtual input as software.

This balance AR attempts to achieve in the actor-network does not necessarily stabilize and the interessement device is not guaranteed to succeed, because success depends on the next moment of translation, enrollment, in which all actors actually ally stabilizing the newly-assembled network. Actors identified in problematization may refuse to accept the new roles attributed to them. Besides, in enrollment, all kinds of elements may be involved in the negotiation, sometimes as obstacles. Not only museum visitors who directly use AR are parts of the coordination in enrollment, but various elements like museum personnel and infrastructure may influence visitors using the technology and thus promote or impede the visitors being enrolled in the network. The interessement technology thus needs to relate to all kinds of actors and solve their resistance against enrollment before it can be successfully applied. So, the stabilization of a new network is not easy and requires collaboration of all actors. In each moment of translation[6], risks exist. Museums must be aware of and address potential obstacles and impediments if they want to initiate AR in the museum setting.

Conclusion

When digital technologies are introduced into exhibitions and museum visiting, it is not reasonable to merely study viewer-artwork relations. Instead, the museum space can be conceptualized as a heterogeneous network in which all elements are actors relating with each other and visitor experience is based on a combination and coordination of the actors in the network. With the introduction of ICTs into museum visiting, the visitor experience can be fundamentally changed because the museum network will go through a process of translation, during which all actors acquire new identities and build new relations. But the new relations

[6] According to Callon (1986), translation includes a last moment, mobilization, in which all the masses mobilize to their spokespersons so that various individuals can be represented by generalized actors. Such a representative can both be concrete and abstract. For example, visitors in the museum may mobilize both into a concrete visitor group defined by a survey and into an abstract image of ideal or standard visitors. But this is always risky, because the diverse visitors may not behave like the representative in reality. Because this research focuses on design considerations, the phase of mobilization will not be used in framing the empirical study.

may not be stable and actors do not necessarily engage in the new network. Thus the museum, as the actor initiating technology pilots, should recognize the complicacy of the actor-network and actors, which may challenge this translation process. To achieve some clarity about this complicacy, this research takes a qualitative empirical approach as a next step. Chapter 3 will describe the research methodology.

Chapter 3. Methodology

This research took an exploratory qualitative approach to study AR mediation based on the actor-network of museums. According to the vision of ANT, AR mediation in museums concerns specific museum environments with particular actors and contexts. Thus it would be ideal to gain insights into the AR-mediated museum dynamics from on-site field studies of pilot AR initiatives in museums with observations of actual practices. But limited by the current museum use of AR and accessibility of such initiatives at present, this approach was not practical. Therefore, this research took a more distant angle to explore the potential technological mediation in a broader sense.

Although primarily intended for art museums, the empirical study did not restrain the resources used within the field of traditional art museums but also addressed other types of museums, including historical museums and science and technology museums. First, the traditionally assumed boundaries between different museum types are not clear-cut and increasingly blurred. AR can be adapted to all kinds of spaces dedicated to exhibiting and presenting. Second, due to high costs and AR knowledge that is still under development, the number of AR-facilitated exhibitions is limited worldwide, especially in art museums. Thus one specific AR application in exhibitions can also further inspire and encourage other AR possibilities in different instances. Although specific AR projects often correspond to particular contexts, the technology and contribution of these examples of AR usage may be more generally applicable. For example, as Damala et al. (2013) argued, although their AR project was designed for usage in cultural heritage sites, its functions are suitable for all museum and gallery settings to satisfy individual visitors' needs and preferences. Therefore, the use of AR in all kinds of cultural spaces can offer insights in the possibilities and limitations of using AR in exhibiting and presenting art.

Due to the scarcity of first-hand experiences of and information about specific AR projects in museums, the research predominantly used indirect resources and methods. First, a comparison with another ICT in museums (QR code) served to shed light on how ICTs may be defined in the museum actor-network. After that, two types of empirical data were collected to further shed light on AR mediation. The first was a content analysis of

international progress and pilots of AR applications, based on primary sources of museum web pages describing AR applications and secondary sources of museum studies and design articles reflecting on problems and limitations of AR in museums. The second method took the perspectives of museum professionals. Using interviews with museum educators of five museums in the Netherlands, ideas and concerns about how AR mediates museum dynamics were collected and analyzed. Below, these methods are described in more detail.

Analogy with a QR code case in museum context

Because the perspectives of different actor groups on AR applications in museum environments are rather limitedly explored, this research first indirectly drew inspiration from user research on the use of another ICT namely QR (quick response) code in the museum context, based on a literature review. Although QR code is different from AR with unique characteristics from a technological perspective, what makes the two comparable is the similar agency of technologies: They both enter original museum environments and create new dynamics for museums, forming new networks while being shaped by other museum-related actors. Therefore, a study on the actor-network around one QR code application, despite its clear limitations, can shed light on AR-related museum dynamics in different contexts. The comparison made here especially illustrates how the mediation and use of QR code is shaped in a network related to exhibits and visitors. Learning from that, we can gain better insights into how different elements in the museum dynamics may affect the use of digital technology for exhibitions.

Content analysis

The sources used in the content analysis focusing on the current design and use of AR applications in museums come from published text materials, including three basic categories.

First, representing the general museum perspective, museum websites introduce the AR applications used in museums and how they are integrated into exhibitions and museum tours. Via an internet search about AR exhibitions and applications in museums, an inventory was made of past and current initiatives. These sources always use language that is easily understandable and interest-provoking to the public and sometimes include short videos trying to attract visitors and promote the new technologies in the museum, thus likely to be

biased towards positive images. As primary resource, such web pages help to construct an image of AR from the perspective of museums, yet limited to positive impressions.

Second, some AR applications are described in the secondary sources of academic articles from the perspective of engineers and developers. Using a vocabulary of the engineering and design professions, such materials often pay much attention to the technical details of design, focusing on technological justifications and usability. By combining keywords such as 'augmented reality', 'museum', 'visitors', 'exhibitions', and 'museum education', articles were collected, mainly from journals and conference proceedings. Platforms where the articles were published are often in interdisciplinary fields of ICT studies and museum studies, with journals like *Computers & Education* and conferences like *International Symposium on Mixed and Augmented Reality* and *Digital Heritage International Congress (DigitalHeritage)*.

Third, though there is a lack of research investigating AR in museums entirely from a user's perspective, some texts report on observations of museum visitors and application users or on interviews with users. Such secondary sources are often one section in design and engineering articles, based on testing the AR applications in real museum contexts or collecting comments and suggestions from test users for justification and further improvement. From a standpoint of museum professionals, museum studies scholars also write reports about pilot uses of AR in museums, describing how the technology interacts with visitors, how it is embedded in the museum environment, and how users behave and interact with AR devices and exhibitions. Such materials were collected mainly from websites of museum studies conferences, such as *Museum and the Web*.

Semi-structured interviews

In order to get insights in how AR may influence different elements in museum environments, the research methodology also consisted of interviews with museum professionals. Invitations were sent by e-mail to 14 museum professionals working in various Dutch museums, five of them replied and were willing to participate in the research[7].

[7] Although one prestigious art museum (Stedelijk Museum, Amsterdam) in the Netherlands has had experiences with AR, the contact person there did not reply.

Because the interviewees had limited experiences with applying and implementing AR in museums, the interviews mostly focused on their experiences with other digital technologies in museums and reflections on possibilities and limitations of AR in museums. From their experiences with other digital technologies, comparable considerations could provide inspiration for applying AR in museums; their reflections sketched a broader picture of ideas and considerations about using AR in the museum environment for new visitor experiences.

The interviews were semi-structured with an overall guideline, but the interviewees' responses were not limited to this framework. The interview guideline consisted of two main parts. Firstly, questions were asked about interviewees' work and experiences with digital technologies in museums. Secondly, interviewees talked about their experiences with and attitudes towards using AR in museums. The interviews were recorded and transcribed (except for one, which was summarized and authorized by the interviewee) and then qualitatively coded and analyzed.

The interviewees were educators working for a Dutch museum or art space. Although they all had the function of museum educator, devoted to optimizing how museums instruct visitors and improving the visitor experience, their specific tasks were rather different. For example, some interviewees had expertise on museum communication in their work, one interviewee was specialized in digital education, and some interviewees were more engaged in designing exhibitions than others. Furthermore, the five institutes where interviewees worked differed in size and status and had different focuses on exhibitions and collections. The five institutes are listed and introduced below; abbreviations are used for references and citations (see the table 1):

- Groninger Museum, Groningen (GM) is commonly seen as an art museum. It has a relatively small permanent collection but organizes many temporary exhibitions with a broad range of interests, including design, fashion, and history. Focusing on a wide

audience, Groninger Museum aims to “amaze and astound visitors and prompt them towards an opinion”[8].

- Van Abbe Museum, Eindhoven (VA) is a museum for contemporary art. Having “an experimental approach towards art’s role in society”, it takes openness, hospitality and knowledge exchange as three important values and tries to challenge visitors to “think about art and its place in the world”[9].
- Museum Boijmans van Beuningen, Rotterdam (BB) is one of the most prestigious museums in the Netherlands, attracting large numbers of domestic visitors and foreign tourists. Seen as an art museum, it has large collections including paintings, sculptures and everyday objects. Temporary exhibitions and public activities are often organized, involving different fields including classical and contemporary art, applied art, and design[10].
- Tetem, Enschede (TT) is an art space which does not categorize itself as a museum in the traditional sense. It is dedicated to connecting art and society, exploring the contribution and significance of visual arts in the quality of society and the development of humans. It organizes many digital art exhibitions in which digital technologies such as virtual reality play important roles[11].
- Museum TwentseWelle, Enschede (TW) is a regional museum which does not position itself as a certain type of museum but as a combination of a natural history museum, an art museum, and a science and technology museum[12].

To conclude, though the sample is limited, the interviewees as well as the institutes where they work are diverse with different characteristics. Thus the interviews can offer broad and insightful information and perspectives for this research.

[8] http://www.groningermuseum.nl/en/mission-statement
[9] https://vanabbemuseum.nl/en/about-the-museum/organisation/who-we-are/
[10] https://www.boijmans.nl/en/about-the-museum
[11] https://www.tetem.nl/in-het-kort/
[12] https://www.twentsewelle.nl/content/1439/nl/over-museum-twentsewelle

Table 1. Institutes interviewed and abbreviations used.

Name of the museum or art space	Cited as
Groninger Museum, Groningen	GM
Van Abbe Museum, Eindhoven	VA
Museum Boijmans van Beuningen, Rotterdam	BB
Tetem, Enschede	TT
Museum TwentseWelle, Enschede	TW

Data analysis

Data collected from content analysis and interviews were processed qualitatively to develop taxonomies of promised AR mediations presented in chapter 5 and arguments of conditions for positive AR uses in chapter 6. First, characteristics and design intentions of AR applications were studied in the content analysis. Drawing from different approaches and levels of how AR mediates museum dynamics, four categories were generalized from the data in chapter 5. Interviews were used to further support the categorization and supplement the detailed possibilities in each category. Second, investigating in-depth the design considerations addressed in some technical design articles about developing AR applications for museums, chapter 6 outlines three aspects of AR use that may lead to undesirable consequences. The professional perspectives in the interviews also underpinned these points. Besides, based on the interviews, chapter 6 also includes a section about practical conditions that must be met before AR can successfully be used in museums.

Chapter 4. ICT in the museum actor-network: A case study on QR code

Before getting into the mediating role of AR, this chapter, as an analogy, analyzes a case study about using QR code in the museum context in order to illustrate how a newly-introduced ICT actor is shaped by while shaping the actor-network when entering the museum dynamics. QR code is a kind of two-dimensional barcode which contains information and can be read by compatible devices. Though originally invented for industrial use, it is nowadays expansively used in various contexts because of its advantage over traditional bar codes in readability and storage capacity (Denso ADC, 2011). Attached to items, QR codes can provide users with a variety of digital content, including texts, images, videos, and web links. Thus this technology can be seen as a channel connecting physical items with separate virtual and digital existences. To read QR codes, users need compatible devices and applications, which can be realized in most smartphones nowadays. In these respects, QR codes are rather comparable in function with AR.

Using QR codes in museum contexts

Besides their industrial and business use, QR codes are also entering cultural and educative spaces, trying to make up for weaknesses of traditional digital technologies and also adding new flavors to visits. A study about museum visitor experiences and digital technologies suggested that there is a gap between experts' expectations about the potential of ICTs in museums and visitors' perceptions of possibilities and advantages of those technologies (Rey & Casado-Neira, 2013). The authors also gave advice about starting ICT initiatives in museums: Unlike traditional plaques and audio guides, what is needed are "tools which enrich the visit not only offering information but possibilities of experiencing and living a cognitive and sensory-enriched experience" (p. 703). QR code may fulfill such required possibilities because it can enable mutual interaction between users and objects. A recent study indeed showed that QR codes with two-way social components positively influenced the engagement of visitors in terms of the time visitors spent on exhibits (Pérez-Sanagustín et al., 2016).

Used in museums, QR codes can connect the physical museum space and exhibits with their electronic counterparts. Similar to AR, by implementing QR codes designers can offer

users various additional multimedia materials in the digital part. The design and implementation of QR codes is mostly initiated by museums, which select exhibits for implementation as well as compose the digital information (Chivarov et al., 2013). However, in real use the museum is not a unified actor: General personnel, technology developers and designers, educators and curators may have different knowledge and opinions, giving different instructions to visitors. The complete realization of the technology will be a negotiated result between museum initiatives and the use by visitors, which both constitute parts of the complicated museum dynamics with possible mismatches, conflicts, and divergences. The following sections will elaborate on two issues reported in the literature: one mismatch in the design/use dynamics, and another involving the complexity and diversity of real users compared to configured users.

Mismatches in the actor-network

An example of mismatches between museum initiatives and real use is shown in the study of Schultz (2013) on perceptions of QR codes, particularly focusing on expectations and reactions, of museum visitors and staff. By observing and interviewing personnel and visitors from the Museum of Inuit Art in Canada, this study revealed a discrepancy between the museum staff's expectations of QR codes and visitors' real use. Most visitors assumed that QR codes function one-directionally to provide information, while many staff members emphasized how the use of the technology could promote conversations between visitors and artists by connecting physical objects with social network sites. This divergence implies underlying asymmetric assumptions between the inscription on the side of design and description on the side of use.

Various elements contributed to the mismatch. Besides taken-for-granted assumptions in design that visitors will use the conversational functions, according to the author, it is also the mindset of visitors regarding the technology and the museum space that led to visitors' understanding of QR code as merely a means of information provision. Most visitors already had experiences with barcodes in quite different settings such as in stores, where barcodes are used to give information such as price about items they are associated with. This reference to the common use also created confusion about the intention of implementing QR code, as

some visitors suspected that the codes may be for personnel to use instead of assisting visitors. So the possibilities of a two-way conversational function of QR codes were not evident to visitors. Regarding the museum space, a reason behind visitors' mindset is that throughout history, museums are traditionally considered as institutes enlightening and educating the public (Valtysson et al., 2011), and such communication in museums has more often been perceived as unidirectional. So within the museum environment, visitors do not spontaneously expect conversations and interactions even when using the technologies.

In conclusion, various elements can perform as mediators, impacting the engagement of other actors in the transformed actor-network. What constructs the assumption of visitors is not only the specific museum environment and the onsite technology used, but also the abstract meanings and implications of the concepts of museum and barcode. In this sense, the museum and the technology themselves are two actors that participate in constructing and enrolling the actor of visitors, which materially and semiotically co-shape of the real use of QR code thus define the technology in museums.

Complexity and diversity of actors

The mismatching expectations and perceptions regarding the technology are results of a constant mutual shaping in the systemic network, which comprises many heterogeneous actors, with each actor nested in its own detailed networks and constructed by diverse sub-actors. Following this path of ANT, another set of asymmetric assumptions found in the study of Schultz (2013) can also be analyzed as it reveals how the complexity and diversity in one actor can enlarge mismatches between inscription and description, and even create non-use.

In the case study, museum staff and even visitors bore the idea that there was a visitor group of 'young people' who would be the main target group of digital technologies. From the perspective of museum personnel, this group is assumed to be technology-aware, knowing and using QR codes, and largely overlapping with smartphone users. In fact, reaching and engaging young visitors was even part of the motivation for applying this technology. But the actual use and interviews showed that identifying a 'young visitor' user group as museum staff assumed is complicated. Such a user group did not clearly exist, because for visitors

being young is not drawn by an objective age but largely depends on self-recognition, which resulted in mismatches between assumptions and reality. For example, some visitors who were identified as young adults by observers still talked about ‘young visitors’ as a group apart from themselves (p. 213). Moreover, the demographics of visitors did not correlate with their technological abilities and interests following a postulated age pattern. In other words, the reception and evaluation of ICTs in museums were not as age-related as assumed. Hence, it is crucial to note the diversity of dynamics within one actor because taking the generalizations of individual sub-actors for granted can wrongly cause unrealistic assumptions and mismatches.

Furthermore, the implementation of QR codes excluded some visitors from becoming users and thus created non-use, because the use required scanning codes with a mobile device with QR scanning function and internet connection (Chivarov et al., 2013), while such devices are normally not provided by museums. So visitors need to have a smartphone with the required functions. Visitors who do not meet this precondition are excluded from the user group. The role of smartphones also affected the expectation of visitors, as some interviewees assumed that one who owns a smartphone would automatically become a QR code user (Schultz, 2013). Thus QR codes and visitors are not exclusively relating with each other, but other actors like smartphones also play in the network, mediating the behavior of visitors and how the codes are used.

Comparing QR code with AR

Comparing QR code and AR does not only require similarities between the two but also awareness of differences. Apart from varying museum contexts of each ICT application, the technologies themselves are also different scripts, bearing designers’ different assumptions and expectations about specific uses and impacts. In other words, they are inscribed with different functions that can enable different relations with different actors and may lead to different perceptions and behaviors of users.

Most obviously, AR more directly and instinctively links digital materials with the real environment based on GPS or image-capture-recognition technologies. Without the redundancy of scanning “an extra square matrix barcode that has no meaning about the

artwork" (Chang et al., 2013, p. 187), viewers and artworks can be positioned in a more straightforward connection. The absence of the middleman-like code therefore diminishes the distraction and can better enable attention and immersiveness in the experience of museum visiting. Moreover, concerning how people may conceptually perceive the technology, for people who have experiences with this technology, AR does not necessarily have the connotation of merely providing information, given its other uses such as games. Due to the enabling function of giving visitors more initiative, AR may be more inviting in creating two-way conversations, interactions, and participations. However, although these points can easily be interpreted as positive promises of AR, they do not necessarily guarantee better or more successful uses. Such technological affordances can also mediate the museum actor-network in a direction countering the museums' initiative and result in failure and unsuccessful use against the intentions of developers, which will be further analyzed in Chapter 6.

Conclusion and discussion

In summary, this chapter used a case study on QR code in a museum context to illustrate how actor-network analysis can be applied to ICTs in museums. Mismatching expectations and assumptions between developing and using QR codes may limit the user engagement of the application. In general, the usage of QR codes during the visits was very low according to the observations in the case study of Schultz (2013). But museums could also promote desirable technology use based on the awareness of such mismatches. For example, when recognizing the asymmetry in the assumptions about QR code providing information, deliberately adding and emphasizing conversational elements in the design could help engage visitors more effectively. By studying the network, which comprises actors including the QR code technology, smartphones which enable QR codes, museum personnel, museum visitors, and the museum itself, developers of ICTs for museum use can identify and pay attention to such asymmetric assumptions in the design and development of ICT initiatives.

The two following chapters will shift the focus back to AR and explore how it may transform the museum environment and exhibitions. Chapter 5 focuses on the promises and positive aspects of the technology, namely what museums and developers expect to achieve in

offering visitor experiences by using AR. By acknowledging how this technology is and may be used in museums, possibilities of AR applications based on their functions as well as future trends of using AR are illustrated. Chapter 6 reflects on the elements that may be challenged by the use of AR in museum space, addressing conditions which have to be considered in order to achieve a desirable and positive use. Hence, the two chapters will analyze AR mediation from two perspectives: a positive perspective focusing one of promises, achievements, and potentials, and a negative perspective focusing on conditions, limitations, possible loss, and tradeoff. Both sides contribute to reflections on the technological mediation in a broad actor-network as well as practical recommendations to AR developers for museum use, which will be addressed in the last chapter.

Chapter 5. AR mediation based on tendencies and possibilities

Introduction

Gradually entering the museum space to facilitate exhibitions, AR materializes anticipation and ambition of museums and technology developers in terms of improving or optimizing the museum visitor experience. As a result, developers of museum AR projects commonly talk about using the technology to 'enhance visitors or user experience' (e.g., Pikov et al. 2015, Vera et al. 2016), counting on the technological mediation to achieve something positive in the museum dynamics and visitor experience. AR is thus regarded as beneficial and desirable given that it can serve to fulfill goals of exhibitions. But the values of using AR can be various and the achievements AR tries to make are not always clearly defined. Hence, it is important to clarify what the AR 'enhancement' and 'achievement' may include and entail.

Taking the term from ANT, technological promises are conceptualized based on a script-based understanding. AR as a technique can be applied in different ways in museums. Behind each application, developers, who may include museum personnel such as educators and engineers, bear certain ideas and expectations about the technology and its use. To grasp the connection between the material application and the abstract ideas behind it, the technological applications can be understood in terms of scripts, into which developers inscribe their ideas about what they expect AR to bring about in the museum as well as what visitors receive from AR. In other words, how AR applications are designed and introduced reveals what and how the technology is supposed to mediate.

This chapter tries to generalize the expected or desired mediation role of AR referring to inscriptions of AR applications revealed in design and engineering articles as well as potentials and affordances developers and museum professionals see in the technique. Because AR can enter the museum dynamics and be embedded in the museum context in various ways, highlighting and strengthening different actors and relations in the museum actor-network, AR mediation involves different perspectives and dimensions. The same AR application quite often refers to different focuses of augmentation; for example, an application aiming to arouse visitors' interest may also offer information. In the narrative and analysis, the most representative and emphasized one will be addressed as the main augmentation

perspective. Drawing from cases of AR applications for museum use in the content analysis and further supported by the opinions of museum professionals from the interviews, this chapter inductively proposes four general categories of promised mediation perspectives of AR.

Providing information

One primary use of AR in museums is to offer additional information about exhibitions to visitors, comparably to most digital techniques currently used in museums such as audio guides. By using virtual elements, AR can create possibilities to make exhibitions more accessible for visitors to perceive and understand, with targeted information about details, contexts, craftsmanship, and so forth. The information enabled by AR devices can be diverse in terms of content, perspective and how it manifests.

AR can visualize what visitors get from their audio tours, like in an undeveloped AR project where curators talk about artworks in interviews on a virtual platform of the museum (BB). Another example is the application ArtLens in Cleveland Museum of Art (USA), which displays additional curatorial and interpretive information about artworks on the smartphone[13]. Sometimes the use of AR aims to offer visitors access to otherwise inaccessible details and hidden elements of exhibits by enhancing the conditions of viewing. For example, one interviewee mentioned the possibility of using AR to allow visitors to enlarge paintings and closely look at details or see the backside of paintings on a digital layer (BB). Another interviewee talked about using AR to enable information for exhibits in a five-meter high showcase (TW). And Pikov et al. (2015) proposed a 3D-display-based AR application for the State Hermitage Museum (Russia) to make details of exhibits more accessible for visitors to look at, and thus try to solve difficulties in viewing such large and unclear objects.

AR is also combined with multi-media to offer contextual information about exhibits. For example, Capuano et al. (2016) proposed to create digital stories for exhibitions and supplement new meanings to exhibits using AR with input of relevant real-world elements. The information can also be provided from an aesthetical perspective. Chang et al. (2014) focused on art appreciation and developed an AR guide for viewing paintings based on image

[13] http://www.clevelandart.org/artlens-gallery/artlens-app

recognition. By offering visitors extensive information like the subject of the painting, design elements and principles, knowledge about details, information about related artworks and so on, the application guided visitors in painting appreciation on four levels, namely description, analysis, interpretation, and judgment. According to their user study, most participants reached a stronger motivation and more knowledge of the artworks, higher autonomy, and a good visual experience by using the application. Another AR application was introduced into art museums to give visitors both background knowledge of artworks and guidance through the exhibition space (Miyashita et al., 2008). Receiving explanatory 3D information of exhibits, animations of the routes and an outline of the exhibition from the application, users found it helpful for visiting the exhibition and "felt motivated to examine the artwork more closely" (p. 105).

Designing and applying AR to provide visitors with information, museums inscribe their intentions and expectations of strengthening relations among visitors, exhibition, and individual exhibits into the applications. By enriching exhibits with abundant and diverse information, AR technology 'augments' them, transforming them from plain objects into synthesized sub-networks combining relatively independent elements, including material objects, contexts, background stories, close-up details, and so on. In some applications, AR also emphasizes other actors in the exhibition, like making curators more visible for visitors. Therefore, when used to provide information, AR does not mean to radically reconstruct the museum dynamics, but holistically reforms the exhibition by highlighting certain actors and transferring the actor of exhibits using information on the virtual platform, and thus tends to reinforce the bond between visitors and the exhibition and specific exhibits.

Enhancing engagement and interest

More than just being informative, AR can give information in a fun way, as an interviewee expressed (VA). The 'fun' character marks AR's entertaining value. Entertainment enabled by overlaying virtual elements on the real environment is an important approach of engaging visitors in exhibitions. To increase the interest of visitors and engage people, AR is also used for storytelling and personalizing exhibitions in the museum.

As a prime way to engage visitors, entertainment is sometimes the main objective of using AR in museums. For example, the Natural History Museum in London used an interactive and informative AR animation film for drawing the public's attention (Barry et al., 2012). But in many other cases, the entertainment offered by the technique is closely combined with the exhibition, aiming to give visitors a holistic experience of the exhibition. In an application for cultural heritages, entertainment is available by bringing multimedia resources into a location-aware-AR-based dynamic walking tour which combines navigating and information provision functions (Van Aart et al., 2010). Such applications can mediate the emotion and attention of visitors while reducing their cognitive load when experiencing exhibitions.

Specifically, engaging visitors by creating amusement, AR gamification is an example of AR bringing entertainment into museum visiting. Hammady et al. (2016) wrote about applying gamification techniques to influence players' behaviors in museum settings. Inspired by the gamification mechanism, they developed AR games in heritage museums to inform and educate about the exhibition, while bringing about engagement and immersiveness. The American Museum of Natural History in New York also launched an AR mobile game, MicroRangers, in which players were guided by an animated figure through the visit, fulfilling missions about protecting biodiversity, which were all based on real-time location of visitors as well as museum exhibits and environments[14]. In another project, AR was applied to display 3D models in cultural heritage sites and to create interactive games for playing during the visit. Carrying out missions, visitors were asked to find certain areas or points of interest (POIs) in the museum. By doing so, players could gather knowledge and become familiar with the heritage. This project combined interactive playfulness during the visit with before-visiting route planning and after-visit shopping, so that a dynamic museum visit was configured around the during-visit gamified interaction with POIs (Vera et al., 2016).

Enhancing visitors' interest also combines with information provision in the form of tour guiding or storytelling. Some current examples can be found in cultural heritage sites and historical museums. The uses of AR in cultural heritage sites are often less strictly bounded

[14] https://www.amnh.org/learn-teach/families/microrangers

within museum walls. An application, "England's historic cities," combines AR and tour guiding through twelve heritage sites across the UK by using 3D reconstructions of famous historical figures as tour guides and superimposing information over artifacts virtually[15]. By practices such as embedding the visitor in a storyline, AR can furthermore create immersive experiences. In 2015, an AR mobile game "A Gift for Athena" was introduced in the British Museum's Parthenon Gallery. By embedding the exhibition in stories and interactions, the game intended to educate schoolchildren about historical and mythological knowledge through the exhibition while playing[16].

Another approach of enhancing engagement in museum visiting is personalization. AR, compared to some other traditional digital devices used for museum visit, is relatively easy to allow individualized information and experience. Acknowledging the importance of interests and needs of individual visitors, Damala et al. (2013) stressed the value of personalization of using AR in visiting cultural places. They developed "Adaptive Augmented Reality" (AAR), which offered visual and acoustic augmentations and created personalized museum visits. To tailor visits to individuals, the application could monitor the physiological states of visitors and their reactions to exhibits. By modifying augmentations to adapt to visitors' reactions and physiological states, such AR applications tried to promote positive emotions and affective impacts during the visiting experience as well as encourage and motivate self-learning.

AR-enabled personalization is also used to fulfill educational goals. A study into learning affordances of AR based on multiple projects using AR to communicate about health-related concepts showed that AR is especially useful in presenting spatiotemporal relations and facilitating personalized learning as well as promoting learning by creating narratives and interactivity (Matuk, 2016). The author argued that this technology is therefore also suitable in museum environments. By combining historical and sociocultural dimensions behind science and scientific knowledge, AR has the potential to enhance learning through fulfilling visitors' interests and engaging people with immersive and interactive narratives.

[15] http://www.heritagecities.com/stories/explore

[16] http://mw2015.museumsandtheweb.com/bow/a-gift-for-athena/ presented in the annual conference of Museums and the Web, 2015, Chicago, IL, USA;
http://www.britishmuseum.org/learning/schools_and_teachers/sessions/a_gift_for_athena.aspx

Furthermore, the use of AR to personalize visiting experiences can also be combined with digital storytelling in museums. An example is the project CHESS (Keil et al., 2013), which was a pilot project launched in the Acropolis Museum in Athens (Greece) featuring interactive storytelling. In this project, AR enabled visitors to look at and interact with exhibits in various ways, such as placing the exhibit in its original background, restoring the exhibit virtually, highlighting details, and reconstructing mythological appearances. All these ways of interaction along with diverse multimedia assets were concatenated and interwoven in narratives of story plots, which were not standard or linear but dynamically adapted to individual visitors based on the visitors' predefined profiles as well as their behaviors and inputs during the visit.

To sum up, AR can function in different ways to increase visitors' interest and engage them in museum visiting. Regardless whether the engagement comes from entertainment, storytelling, or personalization, AR in principle reconstructs how visitors relate to the exhibition. Beyond modifying exhibitions by overlaying information, museums head for new ways of involving visitors in exhibitions, building up new types of relationships instead of strengthening previous ones. Meanwhile, AR also configures visitors by modifying their emotions and motivations, sometimes deciding on differentiated content different visitors receive. Mediation on the whole exhibition thus goes one step further. Noticeably, using AR to engage visitors sometimes triggers new actors such as personal data of individual visitors. New actors may raise questions that call for museums' reaction, which will be addressed in the practical reflections and recommendations in Chapter 7.

Promoting interaction

Compared to traditional technologies in museums like audio guides or plaques, which commonly allow only one-directional information provision towards users, AR is more flexible and enables more possibilities of giving initiative to visitors instead of letting visitors passively receive. Therefore, some AR applications aim to promote interactions in the museum space and exhibitions, which can be between visitors and exhibits, among peer visitors, or between the museum and visitors. Although interaction may be regarded as an approach to engage visitors, using AR to promote interactions deserves a separate section

because interaction can also be seen as a value by itself in museum visits and is often emphasized as an augmentation point in AR designs, as this section will present.

The AR-promoted interaction in museums can function in different aspects of exhibitions. For exhibition guidance, Kaohsiung Museum of History (Taiwan) incorporated AR into an interactive guidance system based on a camera and image-capture technique. Using the application to capture images on a tourist brochure, visitors could receive attached multimedia displays in 3D modeling and even manipulate the virtual objects when selecting an image (Chen et al., 2013). Using AR to collect feedback from visitors after visit is another possibility. In an interview, the educator talked about the tentative idea of using AR to find out "what people think about the exhibitions they just saw" in a fun and experiential way (TT), which would be an example of interaction between the museum and visitors.

The interaction between visitors and exhibits is sometimes combined with information provision, but AR can often give more weight to visitors in appreciating and acquiring information. For example, a historical museum in Italy applied AR for exhibits that represented local traditions. In this project, videos and photos were connected to POIs in the museum and visitors could discover this layer of hidden media resources and stories by scanning the attached QR codes, and thus interact with exhibits while receiving information (Cianciarulo, 2015). Another AR project, "The Bedroom", endeavored to demonstrate the professional practice of spectral capture of paintings to the public. Based on Van Gogh's painting Bedroom in Arles, visitors could reveal hidden spectrums of the painting which were displayed on a screen using a digitally modified spray can, choosing between various image captures such as X-ray, infrared, and ultraviolet (Kolstee & Van Eck, 2011; Van Eck & Kolstee, 2012). Therefore, by allowing visitors to interact with the painting, AR gives agency to visitors, bringing not only unique knowledge but also new perspectives and playfulness into art exhibitions. Furthermore, another application, ARtours in the Stedelijk Museum in Amsterdam (The Netherlands), organized several indoor and outdoor AR exhibitions. In one exhibition, visitors could lend artworks from the museum collection in digital forms and hang them in the public virtual space as they want. Thus users of this application gain interaction

with virtual artworks and meanwhile also interact with other peer visitors by sharing and presenting their lent artworks to the public on the virtual layer (Schavemaker et al., 2011).

Given its learning affordances, AR is also applied to promote interaction for the purpose of fulfilling educational goals in museum settings, especially in science and technology museums. Following a series of projects using AR for educational purposes (e.g. Gsieh & Lin, 2006; Iwata, Yamabe, & Nakajima, 2011), Hsiao et al. (2013) designed multimedia-integrated AR in museums to simulate weather changes as a part of a non-formal learning environment. This application allowed students to experience meteorology knowledge interactively and was found to be effective in achieving teaching and learning goals. Another project used AR combined with knowledge-building scaffolds to learn science in a museum environment. In the experiment, digital augmentation of electricity flow was projected on bodies of visitors to animate circuit flow. It generated enriching and interactive experiences, and appeared to have a positive impact on the learning of scientific concepts (Yoon et al., 2012).

Furthermore, AR is also applied in order to bridge experiences of different visitors and create interaction among peer visitors. An interviewee expressed this idea of employing AR to create open dialogs in museums and build a platform for visitors to use together, share their ideas, and react to each other (BB). An instance of encouraging interaction is VisAge, which used a POI-based AR system to display multimedia information about urban environments, aiming to engage users with cultural spaces like heritage sites during visits. It created location-based interaction between POIs and visitors as users could receive additional information like cultural histories from POIs. Besides, VisAge facilitated interaction among visitors by allowing the public to participate in creating new POIs and adding contents for existing ones. Thereby, visitors could respond to POIs created by other visitors and share their experiences with the public (Julier et al., 2016). By giving agency to visitors, AR also shows its agency as a platform to relate individual visitors and create social dimensions in museum visiting.

To conclude, by creating interaction among peer visitors and between visitors and the museum, AR also builds or strengthens other relationships in the actor-network, enabling

connections which were previously weak in the museum dynamics. Designed to promote interaction between visitors and exhibits, the technology increasingly blurs boundaries between the pre-established roles in the museum actor-network. Visitors are definitely not the passive receiver anymore, but obtain more agency, proactively requesting information and experience from exhibits, and thus actively participate in constructing their own visiting experiences. Professional roles which were previously clearly demarcated also become open to the general public when involved in interactions, such as the role of curator in the application ARtours and the role of art conservator in "The Bedroom". Moreover, both the existence and meanings of the exhibition are no longer pre-given before the visit. Visitors, by interacting with exhibits, complete the exhibition and co-construct the exhibition together with materials in the museum.

Creating new objects of seeing and experiencing

Last but not the least, AR is used to transform reality and offer new viewpoints for visitors, functioning as a lens to modify and reform what visitors see and experience in museum visiting. The new viewpoints can be an unconventional perspective built upon the physical existence of exhibits; it can also be a digital layer of radical reconstruction based on the physical space of the museum environment, relatively separate from the real exhibition. Thus, along with changing the original perception on reality, technologies like AR "constitute a new reality, a new 'objectivity'" (cf. Verbeek, 2005, p. 135) for visitors to see and experience. By creating a new objectivity, designers and museums try to offer novel experiences to visitors, sometimes assisting understanding, sometimes increasing immersiveness and engagement, and sometimes triggering further thoughts, reflections and introspections.

One of the first uses of AR in cultural space created a new outlook: As early as the beginning of the 21st century, AR was already experimentally implemented in the cultural heritage site of Pompeii, using helmet-like installations to show visitors the probable appearance of the ancient site (Papagiannakis et al., 2005). Due to the bulky device for visualization, AR applications were rather cumbersome at that time. But using AR to display animation based on real objects like relics in cultural heritage sites has become more accessible with portable devices such as smartphones and tablets which allow for easier and

more user-friendly uses of AR nowadays. The Jinsha Site Museum in Sichuan (China) recently started using AR to display the history and culture of an ancient civilization by constructing 3D models of artifacts discovered in the site and reproducing historical scenes, ancient architecture, rituals, and environments superimposed on the real relics[17].

The reconstructed viewpoints through AR are also found in recent exhibitions about natural history. The interviewee from TwentseWelle talked about an AR project implemented in that museum, which recovered a mammoths with flesh and fur in animation on the smartphone screen overlaid on the exhibited skeleton (TW). Without textual descriptions, AR let objects speak for themselves. Similarly, the 'Skin & Bone' exhibition in the Smithsonian National Museum of Natural History in Washington D.C. employed AR to allow visitors to flesh out the original stock-still skeletons from the museum collection on a smartphone application by overlaying skins and flesh and attaching movements onto the bones[18]. And in the Hong Kong Science Museum, the dinosaur exhibition 'T-Rex Revealed' integrated AR with traditional exhibits like fossils and illustrations, creating vivid images of dinosaurs and rendering "an immersive and adventurous experience" to visitors[19]. The Cincinnati Museum Center also used AR in its exhibition 'Ultimate Dinosaurs' to construct lifelike images and animations based on dinosaur skeletons, showing visitors the appearance, movement and behaviors of dinosaurs[20].

Applied to presenting artworks, the AR-mediated viewpoints can embody different aspects of art appreciation. The aforementioned digital spray-can in the project 'Bedroom' (Van Eck & Kolstee, 2012) made visitors see the original paintings from a technical perspective, looking at things that were hidden behind the oil paint on the surface, such as skill-related details. A project mentioned in an interview about '3D Picasso' aimed to transform original pieces of abstract art into realistic pictures of still life and body figures, thus informing people about the intentions of artists (VA). AR can also give new flavors to traditional artworks and create new digital and interactive experiences. The project ARART, for example, tried to bring static images alive by animation. It combined the exhibited

[17] https://youtu.be/Bu_9BYeG2CM; http://www.jinshasitemuseum.com/en/enabout.html
[18] http://naturalhistory.si.edu/exhibits/bone-hall/
[19] http://hk.science.museum/ms/trex2016/eintroduction.html
[20] https://www.cincymuseum.org/exhibits/ultimate-dinosaurs/app

pictures and paintings with multimedia like video and music displayed on the smartphone. So when visitors looked at the static images through the screen, they saw images in motion, like the figure in the painting moving, water flowing, and flowers blooming and withering[21].

A new viewpoint can bring about special experiences which may be original, novel, elaborated and, ideally, attractive. Creating such experiences is sometimes seen as a value for museums, as a museum educator expressed in the interview that what that museum wants to achieve with technologies like AR is offering new experiences to people in the museum visit, touching their emotions and engaging them (GM). Experience oriented, the National Museum of Singapore launched the exhibition "Story of the Forest", which used AR to enable a holistic and immersive experience. This exhibition brought 69 drawings of flora and fauna of 20th century Malaysia from the William Farquhar Collection of Natural History Drawings to life by digital animations displayed on the smartphone app combined with the phone camera. Besides viewing the animations, visitors could also collect the animated virtual animals and plants on their phone by 'hunting' and 'capturing' to further learn about natural knowledge of the species and get insights about the illustrations[22]. This exhibition depended on AR connecting artworks with scientific learning using animation and gamification, aiming to give visitors immersive aesthetic, entertaining, and educational experiences.

Less attached to displayed materials in the real environment, AR can serve as a digital platform to make artworks digitally available in the museum, for example, by creating virtual exhibitions based on the physical environments and locations using the virtual space the technology offers. The content of AR-enabled virtual exhibitions can be hidden artworks that are not in physical exhibitions, such as ones in storage or not related to the museum. In 2010, two curators launched an AR exhibition in the Museum of Modern Art (MoMA) in New York, in which a virtual layer of artworks was superimposed on reality, namely ordinary exhibitions in the physical museum space[23]. Being in the museum space and capturing images on camera, visitors could see digital art pieces of the virtual exhibition overlapping on the real exhibition only by using their smartphones. A similar attempt was the aforementioned application

[21] http://arart.info/
[22] http://nationalmuseum.sg/exhibitions/exhibition-list/story-of-the-forest#
[23] https://www.youtube.com/watch?v=b9T2LVM7ynM; https://www.layar.com/layers/moma; http://www.sndrv.nl/moma/

ARtours. In one project, the virtual exhibition was placed outdoors at the Museum Square and visitors could arrange their own virtual exhibition based on the physical environment by lending artworks from the digital collection of the museum (Schavemaker et al., 2011).

Along with creating novel perspectives and experiences for visitors, AR also redefines the whole museum actor-network fundamentally. In the cases of AR offering experience-oriented viewpoints based on exhibitions, the technology plays a central role in configuring and constructing the whole network of the exhibition instead of partially modifying and augmenting certain actors. Designers and museums do not merely try to display objects by applying AR as such, but aim at giving visitors a holistic experience, in which real exhibits are no longer the main element and AR functions as a necessary and indispensable actor that engages visitors into this new dynamics.

More radically, in cases of virtual exhibition, AR challenges the existing exhibition by bringing in new actors of digital artworks into the network. These new actors are only made available by AR, and they are totally different from, and even irrelevant to existing actors of exhibitions. Thus the use of the technology is not for augmenting but creating. Sharing the same physical space, AR creates an entirely new actor-network featuring two simultaneous exhibitions based on doubly utilizing the same physical space, thus allowing people to engage in the museum space from totally different approaches. Furthermore, it keeps the physical value of museum intact, and even reinforces the relationship of the physical museum environment with the exhibits. Unlike virtual reality (VR), which can also enable virtual exhibitions, AR requires visitors to be physically in the museum space and augments the connection between the virtual and the real. One interviewee described her experience with an AR project on the museum square in Amsterdam: “I like the idea that you actually had to be on the square to activate it” (BB). AR thus becomes an extra motivation to make people visit museums and emphasizes the value of reality and physical museum space. Therefore, museum educators may find AR more consistent with museums than VR, as AR still requires bodily experiencing the museum and does not rule out the bodily dimension of a museum visit (VA).

Conclusion

Considering the variety in current tendencies of using AR in museums, it becomes clear that there is no single mode of applying this technology in museum contexts. The potential of AR is large, which renders myriad possibilities of use. Although a museum educator in the interview expressed that there is still no good AR application to serve as an exemplar (VA), AR use in museums can and probably should not be confined to certain prototypes. Besides, fulfilling different kinds of goals, one AR application can function in different approaches and on multiple aspects of the exhibition. Therefore, it helps to conceptualize AR as a fluid technology, which is not strictly bounded to certain material realization or manners of implementation, but is "adaptable, flexible and responsive" (De Laet & Mol, 2000, p. 225) based on its core idea of mixing virtual input with real-world elements. Thus, AR allows for infinite possibilities, which have to be adapted to different museum environments and exhibitions.

Based on current AR uses in museums, this chapter has generalized possibilities of AR mediating museum dynamics in different categories. They indicate different dimensions of how AR shapes museum visiting and reveal a gradual shift in the role of AR, as an actor, in fulfilling and constructing museums' technological initiatives. From providing information to increasing engagement, from promoting interaction to creating new objects of experiencing, a continuum of using AR from being informative to being experiential becomes clear. From one side of this continuum to the other, AR is implemented decreasingly to assist exhibits as a helper (cf. Greimas, 1987), augmenting certain elements in the museum actor-network, and increasingly gains agency by itself and transmits agency to visitors, as a constructer reforming the museum dynamics, aiming to challenge the original configuration of actors, creating new elements and bringing in new actors, and thus more fundamentally reconstructs the actor-network. For example, some museum professionals emphasize using AR to offer additional information (BB), while some others argue that instead of giving facts, creating experiences is the ultimate goal of museums when using AR (GM). Museums, when initiating AR projects, may need to reconcile the converse orientations of being informative and experiential. How to apply AR to exhibitions can be seen as a matter of finding a balance

between purely informative and drastically experience-creating. Depending on the orientation of the museum and characteristics of the exhibition, a museum may determine how AR should be adopted to optimize the goal of the museum and exhibition.

Chapter 6. Conditions for a positive AR mediation

Introduction

As argued in the previous chapter, the museum world has been exploring AR to achieve their goals of promoting museum exhibitions, which has resulted in the described projects and tendencies of using AR in the museum space. Expectations of museums and developers of a positive AR mediation are materialized in the designs of specific applications, reflecting experiences museums expect to offer and visitors expect to get, how people are expected to use the technology, and so on. In other words, the current use of AR reveals scripts of AR applications, which can shed light on the inscription by developers. But such inscriptions are usually constructed focusing on promises of AR, and thus may idealize or overestimate its potential. The expectations may not necessarily correspond to what visitors want and achieve through the technology when visiting and how visitors use the technology in reality.

Moreover, what technology brings to the museum dynamics involves fundamental challenges to the old system and reconstructions of a new one, instead of offering additional elements. Thus the AR-mediated system is not necessarily a positive complement to the museum visit in an integral sense. Changes in the museum dynamics have to be valued from different perspectives and standpoints. From the perspective of museums, applying AR is not an arbitrary decision but is aiming for certain effects which are considered desirable. However, only considering developers' images is limited because the success of technology also depends on description, namely how visitors in museums react to it. The technology does not necessarily achieve the desired result in real use. Unexpected consequences may occur owing to unforeseeable possibilities as well as inadequate reflections and preparations. Just like the story of QR code (Schultz, 2013), the underpinning considerations in current hypes and discussions about bringing AR into museums may not be sufficient to avoid mismatches between envisioned use based on technological promises and actual use. This chapter therefore gives a more comprehensive picture of the technological mediation from different perspectives and discusses which conditions developers should be aware of in order to achieve a fruitful AR use in museums.

To draw attention to the conditions for desirable uses, this chapter discusses tradeoffs and practical problems in AR use and designs for museums. Neglecting these conditions may bring about real uses contradicting the original intentions of applying AR or lead to non-use. Thus in order to successfully inscribe aims and desires of developers into AR applications, these conditions are important to be considered during design and implementation. The chapter will start with a conceptual analysis about what tradeoff means based on the theoretical framework of the research. Primarily concluded from design articles and underpinned by interviews, then three tradeoffs are discussed. Based on the interviews, a section about practical conditions is included at the end of the chapter.

A conceptual analysis of 'tradeoff'

Inspired by ANT, actors in the network are to be seen as mediators, which can lead to unpredictably modified output, activate new actors and open up different courses of action as they "transform, translate, distort, and modify the meaning or the elements they are supposed to carry" (Latour, 2005, p. 39). Being securitized as a mediator, the technology is thus not a neutral existence and its mediation is not a linear process with a straightforward relation between input and output. It modifies, maybe involving actors that were not accounted for or noticed, revealing previously concealed agency and responsibilities of actors, and influencing relations among other actors in the network. Therefore, despite the aim of applying AR to bring positive elements such as comprehensive information or an engaging experience into exhibitions, unexpected consequences may come along impacting or even dominating the experiences of museum visitors.

All consequences that unexpectedly happen next to the original intention of applying AR in museums can be dubbed as 'tradeoffs'. Tradeoffs may directly contradict the prior goal and favored consequences of applying the technology, and thus be considered as negative. They may also involve a delicate change of value in museum visiting, which was unnoticed in the design considerations. Besides, tradeoffs may involve the highlighting and alienating of visitor groups, reforming the previous visitor structure. It is crucial to pay attention to tradeoffs and thoroughly consider the consequences instead of merely focusing on positive promises of technologies.

Tradeoffs can be grasped from different theoretical perspectives. According to Ihde (1990), the forerunner of using postphenomenology to theorize technologies mediating human perception, technological mediation necessarily involves a transformation of perception, which designates technology's non-neutrality. By experiencing the world via technologies, what we perceive is not the raw reality but a transformed reality, and technologies "simultaneously magnify or amplify and reduce or place aside what is experienced through them" (p. 76). In particular, AR amplifies certain elements in reality, and therefore differentiates between the augmented foreground and non-augmented background. The amplify/reduction distinction is also embodied in inventing and implementing technologies. As Ihde says, the fascination in technologies "attaches to magnification, amplification, enhancement. But contrarily, there can be a kind of forgetfulness that equally attaches to the reduction. What is revealed is what excites; what is concealed may be forgotten" (p. 78). The ideas behind museums implementing AR always correspond to technological amplification, intending to offer additional information or enhance visitor experience, to facilitate and assist exhibitions. But reduction, which indicates the tradeoffs, is not often part of the discussion. Consequently, it should be questioned what will be lost in AR mediation in museums and how technologies can address that. For the success of technology and stability of the transformed museum environment, a comprehensive view on the role of AR as mediator is important.

By placing technological mediation in the network perspective of ANT, tradeoffs can be seen as results of the dynamics in the actor-network. This can be approached from two angles. First, while the introduction of AR reinforces certain relations in the museum actor-network, it might weaken some others. Previously established relations among different actors will be transformed and reconstructed in the mediated network, and the rearranged relations can lead to tradeoffs. This corresponds to amplification and reduction illustrated in postphenomenology: When the mediator of AR emphasizes new actors and relations in the actor-network, the non-augmented ones become less salient and may even be overlooked and circumstantial. Second, gain and loss vary from the perspectives of different actors and individuals. As a mediator, AR can invite new actors to become parts of the network, but it can also marginalize some actors, because what is regarded as positive for some actors can be

undesired by others and there is no objectivity. Actors are reassembled through the mediation and not all actors will surely engage in the new network.

An example of a tradeoff featuring different perspectives of actors involves the actor of visitors. As an interviewee expressed, applying a specific technology in the museum has difficulties, because with it you may attract some visitors but also push some others away (VA). Currently, people who regularly go to museums in the Netherlands are a relatively small part of the population. This target group is vaguely defined by their education, cultural taste (GM) and social status (Berger, 2008). Museums want to attract more visitors. Digital technologies including AR are sometimes seen as a way to attract young people to museums, as mentioned in several interviews (VA, TW). However, at the same time other potential visitor groups may be scared away by technology. Given a new policy of attracting visitors, museums try to engage the part of the public that neither ever visit museums nor are into cultural activities. They may be slightly afraid of museums, seeing it as a place only for the highly-educated or upper class. The museum wants to "create for them an environment which feels nice and safe" (GM). But "if we give them a very high-brow device, if they come, they don't want that. They are not used to that" (GM). If such visitors see many other people walking with digital devices through the exhibition space, they may feel uncomfortable and resist future visits. The tradeoff in this case is that while museums try to attract more young visitors and technology enthusiasts, they may lose visitors who dislike or are not at ease with using new techniques. Therefore, even though visitors are sometimes simplified as one actor in the actor-network, individuals are distinct and may react differently to new actors like AR in museums. The variety within one element thus can cause tradeoffs and should be considered when introducing new technologies into museums.

Different perspectives also occur within the actor of the museum. Although the interviewees all see great potentials in AR for museums, they are predefined by their profession of museum education, which is devoted to offering visitors better information and experiences. Resistances and impediments may come from other (sub-)actors in museums: "There are directors who don't want it or curators who don't want it or artists who don't want it" (GM). One interviewee specifically talked about a curator who seriously "felt like it [the

digital technology] interferes with the experience of really looking at the arts" (BB), and thus was very much against digital technologies in museum exhibitions. Different actors may have different perceptions on technological promises. What is seen as positive from the perspective of museum educators can be seen as very negative and seriously hindering art appreciation from other actors' perspectives. Thus tradeoffs need to be addressed as perspective-laden.

In conclusion, when applying AR to achieve certain effects, there may be potential losses and tradeoffs. Sometimes such negative potentials are noticed by designers when developing AR for museums, but the awareness is not yet systemically theorized to serve as guidelines for applying the technology. Being conscious of such reductions is important for museums to try to resist and swiftly react to undesirable uses or consequences brought about by AR. Such considerations are rooted in perspectives of engineers and museum professionals because the success of a technique for museum use depends on collaborations between both perspectives. The next three sections highlight some insufficiently addressed limitations and problems of using AR in museums by scrutinizing both engineering considerations behind AR applications and insights of museum professionals about using AR, discussing whether and how AR can align with museum values and which considerations should be encompassed in designing AR to fulfill museum goals.

Isolated phenomenon

The analysis of current uses of AR in museums suggests that AR can promote personally oriented information and experience in museum visiting, and thus give visitors an immersive experience. However, increasing a sense of immersion does not necessarily entail an increase in a sense of engagement and participation in AR applications (Dow et al., 2007). Tradeoffs may occur when the attention to individuals induces individualization being a value for museum technologies. The strong immediacy of AR interfaces can make the experience of viewing art more personal and individualized, but the social function of museums may be lost. This problem is identified by Chang et al. (2014) as an "isolated phenomenon", indicating that AR offers visitors situating information and draws all their attention to exhibitions, which results in visitors immersing in their own AR devices and losing interactions with peer visitors. Although visitor-peer interaction may not be a value for all museums and exhibitions, it

should not be neglected in the considerations regarding applying AR in the museums, which are public spaces involving social interaction.

Despite the possible limitations of peer-visitor interactions, digital technologies in museums are not incompatible with social interaction and the isolated phenomenon is not a necessary consequence. Instead, some digital technologies are designed trying to avoid or reduce such undesirable consequences by designers inscribing participatory elements in applications. For example, an application used technology as a platform to support social storytelling and interaction in order to promote a proactive role of museum visitors (Díaz et al., 2015). Elements attempting to reduce isolated experiences among visitors are sometimes also added in traditional exhibition-supporting technologies such as audio tours: for example synchronization, namely the "synchronized sharing of descriptive audio content between pairs of visitors" (Grinter et al., 2002, p. 148). Although such applications themselves cannot create communications between visitors, they try to promote visitor-peer interactions and alleviate the isolated phenomenon caused by digital devices.

AR does not inevitably trigger isolation but can even become a possibility to promote social interaction. A famous example of using AR to promote social activities is the smartphone AR game Pokémon Go, which encourages players to go outside to interact with the urban environment and other players. This game may even have the potential to help the population with severe social withdrawal (Tateno et al. 2016). Concerning museum settings, scholars have also envisioned using AR to implement collaborative quests such as virtual archaeological activities to make visitors work together while learning about museum content, and thus enhance interpersonal interaction and collaboration (Hall et al., 2001). In designs of museum AR applications, there are also elements promoting interaction among visitors, such as VisAge, which allows visitors to share their knowledge and opinions about POIs with the public (Julier et al., 2016).

The isolated phenomenon does not necessarily happen following actual AR uses. Visitors, in reality, may react to technologies in various ways, contingent to individuals, environments, and specific museum dynamics. For example, when the Stedelijk Museum in Amsterdam implemented AR for a virtual art exhibition, museum professionals expected

visitors to walk around individually, but the technology actually stimulated peer-visitor interactions as visitors looked together through one screen and even attracted passers-by to join the visiting (Schavemaker et al., 2011). The authors suggested that the reason why visitors did not all use their own devices may be attributed to the device, which required a smartphone with the Layer application, which not everyone had. Similarly, told by an interviewee (TT), such an unexpected non-isolated phenomenon also happened with a QR-code-based AR application in an exhibition in an art and culture festival. In this exhibition, visitors were supposed to use their phones to download an application, with which special digital art pieces on a virtual layer appeared. Although the idea behind this exhibition refers to individualized smartphone use, in reality many visitors did not download the application but went to look together on the screen of some visitors who actually downloaded it and brought the digital artworks on screens. The interviewee suggested that the reason for this phenomenon was probably that most visitors found it too difficult or too much effort to download the required application. Although from the perspective of museum professionals, difficulties about AR devices like using smartphones and downloading applications might be the reasons why isolated phenomena did not occur, specific characteristics of the visitors may have played an important role, which requires further visitor studies. From a network perspective, environments, digital devices, personal conditions of visitors, museum personnel on site, and peer visitors can all be mediating actors that contribute to causing or preventing the isolated phenomenon, thus studies on specific situated networks are important.

Although the isolated phenomenon in the sense of reduced interaction among visitors does not always occur following the implementation of AR, it is important to realize this possibility. Whether the isolated phenomenon happens is not very predictable and controllable. More importantly, even if the interaction among visitors does not explicitly decrease when using AR, the interaction is still mediated. The interactions found in the two aforementioned cases were still mediated by AR. Such mediated interactions, though free from a typical isolation problem, do not guarantee a better experience because for example many visitors may crowd around someone who actually realizes AR on his/her device and peek through the crowd to see what happens on the screen, like an interviewee indicated (TT). The interaction

among visitors achieved by AR applications will be qualitatively different from the peer-visitor interaction in a museum space without this technology, due to the technological mediation and a re-constructed museum network with new relations among mediated actors.

To conclude, the isolated phenomenon indicates AR mediation on peer-visitor interaction as AR reforms the behaviors of each individual visitor and the relationships between them. Despite the fear that AR may decrease interactions among visitors (Chang et al., 2014) and the lower frequency of peer-visitor interaction observed when AR accompanies museum visiting, AR as a mediator modifies the museum actor-network and peer-visitor interaction not quantitatively but qualitatively. Technological measures cannot give back the original social interaction but construct a new one. It is this change that museum professionals should be aware of when implementing AR for exhibitions.

Balance problem

Another hazard of using AR is that there may be cases where "AR cueing overwhelms the user's attention causing distraction from important relevant cues of the physical environment" (Tang et al., 2003, p. 79). This problem indicates a balance between virtual and real-world elements. In the context of museum use, the balance problem is two-fold.

Primarily, the balance is about the attention visitors distribute between reality and virtuality. AR is supposed to enhance one's perception of reality by superimposing digital input on reality, unlike VR which uses the virtual simulation to replace the real-world environment (Steuer, 1992). If virtual elements become the absolute main characters in AR uses, they may overshadow the original physical elements and create misinterpretations about the perception and significance of real-world and virtual elements. Such worries about technology drawing attention of visitors from the exhibition were articulated in AR initiatives in museums. In some technological experiments in the Van Gogh Museum, it was observed that the real painting received less attention than the iPad-based interactive installation of virtual paintings with information (Van Eck & Kolstee, 2012). Thus the authors questioned whether implementing AR to track the painting and create overlays of special captures would further draw visitors' attention away from the actual paintings, which could result in people just looking at exhibitions through screens and neglecting the original artworks.

Furthermore, the problem also involves the balance between exhibited real objects and outlandish entertaining experiences enabled by virtual elements from AR. With other kinds of technologies which are implemented to give information or raise interest in the exhibition, this balance could also be disturbed. For example, one of the interviewees mentioned interactive installations used in museums, one resembling a game in which visitors could answer exhibition-related questions by shooting balls with a toy gun (TW). According to the interviewee, young visitors often just went there in order to play and did not care about the information in the questions or the exhibition. Therefore, the overly fulfilled entertainment through technology could undermine the educational and presentational goals of museums, retorting or overshadowing the meanings of original exhibitions and intentions of artists. Such a danger may be even more applicable to the use of AR. AR can attach entertaining elements so closely to exhibits and be seen as a part of the exhibition itself, but in many cases, artists are not involved in making the AR representation of their artworks. Thus the mediation of AR gives a straightforward experience to visitors, which is usually argued as an advantage but may also deviate from artists' intentions and more fundamentally change how visitors experience exhibits, redefining meanings and messages of artworks. In conclusion, the AR technology applied in museums should be designed as a meaningful contribution to the exhibition, instead of a gadget that merely offers fancy effects. If the AR mediation goes too far in terms of entertainment, the original meanings of artworks may be completely replaced by the recreational value of AR experiences, the original exhibits may be overlooked, and as one museum educator in the interviews indicated, the identity of museums in contrast to other institutes that primarily provide entertainment in the urban environment may be threatened (VA).

The problem of balance is not alleviated by AR applications that focus on giving additional information instead of entertaining experiences. Although a certain extent of background knowledge may be helpful for visitors to understand artworks better, art may lose its intuitive power of reaching people's heart if art appreciation or museum visiting becomes a primarily cognitive matter. In other words, if cognitive elements such as information and knowledge about artworks become overwhelmingly dominant in museum visiting, artworks

get different meanings compared to their original existences, and the charm of art may be undermined. To mitigate this charge, information in AR can be designed folded in different layers so that visitors can choose by themselves how much they want to learn. But as argued before, even minimal information modifies the overall perceptions people have of artworks. And offering information already presumes a way of looking at artworks that analyzes and anatomizes art following cognitive standards. Furthermore, providing information requires professional insights about the demarcation of virtual versus real elements as well as that of educational versus experiential elements, because just like creating entertaining elements with AR, the limit of how much information should be given is never obvious.

Therefore, it is questionable to what extent the use of AR aligns with goals of museums. In an interview, a museum educator expressed his concerns about visitors walking around with their head to the screen of digital devices without looking at the museum building or artworks: Visiting like that, visitors will “have an experience, but not the experience that we [the museum] want to give” (GM). If the balance between real objects and virtual elements fails, it is likely that visitors achieve their experiences though AR against the original intention of the museum launching the technology. Thus the museum, when planning for AR use in exhibitions, should not take it for granted that AR is merely an isolable extra to the pre-technological experiences. What museums present through AR is just an interpretation of museums, which may be at odds with meanings according to other interpretations, or artists’ intentions behind the artworks if the artworks were not deliberately made for AR presentations. Furthermore, the balance between actual and virtual elements does not depend on a ratio of their quantities. The quality of those elements determines how much attention they can catch from visitors and thus whether the real-world elements can be supported and augmented instead of being overshadowed by virtual inputs.

The balance problem demonstrates the various actors as mediators when the museum actor-network changes. AR is a mediator, not only transforming the actor towards which it directly acts, but also triggering new relations and reforming other actors. Along with modifying the actor of exhibits using virtual elements, AR reconstructs what visitors perceive, which further mediates visitors in terms of attention and interest. Visitors, also being

mediators, behave and react to exhibitions differently and thus bring about new unforeseeable possibilities into the museum dynamics, shaping how the technology is used and how exhibitions are constructed. Hence, when designing virtual content for AR use, museums should account for agencies of different actors as mediators as well as the continuous mutual shaping among actors.

Noise and fragmentation

AR has the potential and possibility to convey various kinds of information but is also limited by the technological constraints of communication tools in general. One major technological limit is noise, which can refer to "any internal or external source that may interrupt the communication or confuse the receiver" (Hammady et al., 2016, p. 182) and thus disturb a smooth user and visitor experience.

When conveying information from museum actors such as a curator or educator to visitors' senses via AR, internet- or server-based noise may happen. Coming from external factors, noise can be related to other actors in the museum environment—for instance, overcrowded visiting space and insufficient lighting. Internally, the functionality and usability of the technology itself may result in disturbances, thus noise, in visits. The tracking techniques used in AR application, regardless whether they are sensor-based or vision-based, are sensitive to noise caused by, for instance, ambient magnetic fields (Hammady et al., 2016), markers, or 3D tracking processes (Lang et al., 2002), and thus can load with low speed or fail, therefore causing much ineffective time in the visiting experience. The AR interaction and user interfaces as well as the display techniques can also become resources where noise appears, creating difficulties and inconvenience for visitors when using the technology and resulting in dissatisfaction in visitor experiences. For instance, depending on the different ways of displaying AR content to end users, devices may have to offer images with parallax or reduced quality in visualization in see-through head-mounted displays (State et al., 2005; Zhou et al., 2008) or require visitors to look through small screens and constantly perform certain movements like lifting arms and pointing the camera at targets when using handheld devices (Hammady et al., 2016; Zhou et al., 2008). Such problems can distract visitors from closely experiencing the museum space and exhibition, and thus challenge a smooth,

trouble-free experience of museum visiting and art appreciation. Therefore, noise is a wide-reaching concept which can be embodied in various forms of practical problems depending on devices. These problems by themselves may be minor nuisances, but when happening repeatedly, they disturb and distract visitors from an immersive visiting experience.

The noise-laden distraction can come from the imperfection of technologies, and may be reduced in future technological developments, but it may also be an implication of digital technologies existing in between visitors and the external environment. One critical impact of technologies is activity fragmentation, the concept of which was brought up by Couclelis (2003), who studied how the reorganization of activities in time and space follows the use of ICTs: "Fragmentation is a process whereby a certain activity is divided into several smaller pieces, which are performed at different times and/or locations" (p. 11). Inspired by this concept, researchers have argued that, although ICTs alleviate the traditional constraints in space and time and thus increase flexibility, they also have effects on dispersing activities thus creating fragmentation, both in work-related activities (Alexander et al., 2010) and in travel behaviors (Nobis & Lenz, 2007). More research is required, but it seems reasonable to assume that AR, as a typical ICT being used in the museum environment, can bring fragmentation into the activity of museum visiting and art appreciation.

Fragmentation itself is just a consequence of using ICT, not necessarily negative. But in contexts of museum visiting, it is disputable whether fragmentation can be desirable for visitors and museum goals. In contrast to the notion of fragmentation, the psychological concept of flow designates an optimal experience of wholehearted absorption and complete engagement in the present moment [24] (Nakamura & Csikszentmihalyi, 2009). First conceptually developed and inspired by the phenomenon that artists can be immersed in their work, persisting single-mindedly so much that they sometimes even neglect common biological needs (Gretzels & Csikszentmihalyi, 1976), flow can be found in various human activities as a subjective experience which influences the quality of one's experience. Therefore, an experience of flow could be a value for museum visiting, as the model of ideal

[24] According to Nakamura and Csikszentmihalyi (2009), flow is a subjective state which is defined by the following characteristics: intense and focused concentration on the present moment; merging of action and awareness; loss of reflective self-consciousness (i.e., loss of awareness of oneself as a social actor); a sense that one can control one's actions; distortion of temporal experience; experience of the activity as intrinsically rewarding (p. 195-196).

aesthetic experience developed by Csikszentmihalyi and Robinson (1990) argues. Actually, some art museums[25] have already "incorporated flow principles into their design of exhibits and buildings" (Nakamura & Csikszentmihalyi, 2002, p. 99). However, the flow experience is not always stable and easy to achieve: "[…] a person who is involved in a flow activity may not enter flow if distractions or excessive challenges disrupt the experience" (Nakamura & Csikszentmihalyi, 2009, 196-197). The use of AR in museums thus has a hazard of challenging flow in museum visiting, which calls for particular attention in designing AR applications and devices.

In all, when AR reforms different actors in the network, relations among actors are also mediated and reconstructed. When traditional ways of visitors engaging in exhibitions are challenged, noise may become prominent and smooth relations among actors become fragmented. Noise in the use of AR, regardless whether it originates from the external environment, internal hardware imperfection or ICT-based fragmentation, poses a threat to the state of flow in the museum visiting activity, causing distraction and disperse activities and thus disrupting the smooth, coherent, and consistent experience.

Additional considerations for successful use

Regarding the aforementioned tradeoffs, museums have to weigh gain and loss and decide about using AR based on how the museum orients its values. But when the decision to use the technology is made and AR is designed and implemented as an interessement device, there are important practical conditions that can fundamentally determine whether involved actors can be successfully enrolled, and thus whether the application can engage users and fulfill museum goals behind using AR. By including the practical conditions in the design considerations, museums and designers can try to limit undesirable consequences such as non-use. This section will mainly discuss two types of practical conditions that emerged from the interviews, namely user accessibility and technical sufficiency: the first about user-friendly design and implementation of AR and the second about facilities in the museum supporting AR use.

[25] One example is the Getty Museum in Los Angeles, described by Nakamura & Csikszentmihalyi (2002).

User accessibility indicates how easily visitors can use or access the technology. An interviewee talked about using beacons to guide visitors in exhibitions: “That makes it really accessible for visitors because you don’t need to do anything. You just put the things [earphones] in your ear and you start walking around. You get information” (BB). But in the case of AR, the use often requires more from visitors, who are seen not as natural individuals but as technology users: a hybridity of human and device. But how the assumed hybridity is constituted influences user accessibility. When museums provide AR devices, there will be complaints about devices being cumbersome or heavy to carry (e.g., Miyashita et al., 2008; Papagiannakis et al., 2005). Especially if the device takes a fancy or exaggerated form like a head-mounted display, visitors may feel anxious to put it on in public (BB). But if visitors have to use their own devices like smartphones or tablets to access AR in the museum, accessibility problems also occur. First, part of the public will be excluded from becoming users when failing or refusing to act like the assumed hybridity, as it is not for granted that all visitors have AR-compatible devices during their museum visits. Second, individuals and devices do not seamlessly interact as the hybridity. Using their devices, visitors often need to download special applications or use QR readers to enable AR. This creates hassle, as an interviewee remarked: “I want to use this, but okay then I’ve got my app and then I’ve to sign in…” (TT). Besides, facing requirements of time and internet, visitors often “do not really go download a specific application only for one visit” (BB). Therefore, the requirements of using AR can create inconvenience for visitors and undermine how visitors appreciate the technology. To popularize AR and prevent such obstacles, it is crucial to take accessibility as a criterion when designing and implementing AR applications and instructing visitors about using it.

Another practical point, related to the aforementioned noise problem but in a practical way, involves the technical sufficiency of the museum environment, which is required to make AR function properly. Whether noise can ever be completely eradicated may be a theoretical or even ontological question for technicians, but it is crucial to keep the noise to a minimal when applying AR in museum practice. Lowering noise involves different museum actors like personnel and infrastructure, because the actual functioning of AR is shaped by

interactions and negotiations among various actors in the museum actor-network. An often emphasized element in the interviews was internet facility. In an example about digital technology, visitors had to download applications, but the wireless network of the museum got overloaded and could not support the use. This resulted in people "standing in front of the painting with their phones with that app, and then only you have the window circle, turning around and nothing happened […] people say 'oh nothing happens, ok, next one'." (GM) For visitors, experiencing technology not functioning or out of order generates disappointment, and "if that is the case you could better not do it", as another interviewee stated (BB). Therefore, when applying AR in museums, it is a necessary consideration to study whether the technical conditions of the museum suffice, namely, what is possible for the museum in terms of technology, related to the number of visitors, the technological infrastructure, personnel who can instruct visitors, and so on.

Beyond these two points, other practical conditions are important for desirable visitor experience and successful use of AR applications. First, hardware, regardless whether it is offered by the museum or brought by the visitors themselves, may give rise to non-use. As described in a pilot AR study, visitors sometimes were not willing to use the application by themselves because it cost much phone energy and their smartphone batteries would not sustain a long-time use (Schavemaker et al., 2011). In this case, museums have to take measures to conquer this obstacle, for example, by offering devices or charging points. Second, the museum interior can be a condition for a good visitor experience with AR. An interviewee mentioned that visitors may not pay enough attention to their surroundings when engaged with the technological device and thus walk into museum objects accidently (TW). To prevent this, the use of technology must be taken into account when designing museum interior and curations. Third, a good combination of virtual and real elements is important for creating positive experience and engaging users. As pointed out by Damala and Stojanovic (2012), mobile devices still render an apparent boundary between the real and the virtual and thus may not favor a total immersion. This undermines the promises of AR of giving a convincing feeling of mixed reality, which is seen as an important value by several interviewees (BB, TT, GM). Therefore, in designing, museums and developers need to

optimize how virtual elements are aligned with the real environment in order to make the whole AR experience persuasive, consistent, and not abrupt.

In conclusion, the practical conditions are not negligible for AR use because meeting them is crucial for enrolling various actors in the transformed actor-network. The hybridity of visiting individuals and technological devices cannot be taken for granted but requires museums to create accessibility for visitors in different aspects, including designing, implementing, and instructing. Besides, the technological capacity of museums should match the demand of AR applications. This requires museums to have a realistic image of AR in the whole museum dynamics, neither allowing insufficient facilities to undermine technology use nor blindly expanding the technological infrastructure.

Conclusion

Because AR leads to fundamental changes in museum actor-networks, its impact is broad and may have adverse effects. Tradeoffs related to crucial properties of the technology may occur bringing about unanticipated consequences, and practical conditions need to be sufficiently met to prevent nonfulfillment. Analyzing these tradeoffs does not imply rejecting the museum use of AR but emphasizing that museums should reflect on their ambitions, values and capacities when planning to add a high-tech flavor to exhibitions. By thoroughly considering possible tradeoffs and problems, museum can make well-considered decisions about using AR and prepare sufficiently for design and redesign as reactions, inscribing specific elements to promote desirable uses.

Chapter 7. Conclusion, discussion and recommendation

Conclusion of the research

The museum use of AR is promising but lacks reflective guidance to assist designing and developing successful applications for museums. Limited by the underdevelopment of AR and accessibility to AR pilots and prototypes in museums, this research took an exploratory approach from an ANT perspective to study how AR mediates the museum dynamics, especially the visitor experience, as a preliminary step towards such guidance. By studying how AR fits in and transforms the museum actor-network based on the current design and use of AR applications in museum environments as well as insights from museum professionals, this study addresses AR mediation from two sides: the promises and possibilities AR gives, and conditions that have to be considered during design and implementation to achieve a fruitful use.

From providing visitors with extra information to creating engaging visiting experiences, the potential of AR can be realized in different ways in museums. This study has addressed four dimensions of current and potential uses: providing information, enhancing engagement and interest, promoting interaction in different respects, and creating new objects of seeing and experiencing. These dimensions are not exclusive but often co-exist in AR applications. They can be seen as different positions on a continuum between augmenting a certain actor and radically reconstructing the entire actor-network. Museums, when envisaging and designing AR applications, have to find a balance on this continuum considering the nature of the exhibition and museum goals.

However, the intentions behind applying AR for exhibitions may not necessarily be accomplished, because unexpected consequences can happen, maybe based on mismatching assumptions from designers and visitors, presumptions about potentials of the technology which are taken for granted, or insufficiency regarding the AR design and museum facilities. Thus a real use of AR fulfilling the underlying intentions requires certain conditions, which involve limitations and difficulties of applying AR in museums. In the research, the conditions are theorized in terms of tradeoffs and practical conditions. Three points of tradeoffs were addressed: the isolated phenomenon, the balance problem, and the problem of noise and

fragmentation. They are potential hazards subsequent to the museum use of AR, but they may also be consistent with certain goals and values of exhibitions. Thus developers should weigh pros and cons, deciding whether the museum is willing and able to accept and afford the consequences following these tradeoffs. Regarding the practical conditions, museums have to optimally fulfill them to avoid failures in adopting the technology and engaging visitors. Moreover, developers can also design and reactively redesign by deliberately inscribing elements to mitigate tradeoffs and optimize practical conditions.

The mediation brought about by AR comes along with an overall reconstruction of the museum actor-network. This inspires us to further question how we can comprehend museum elements when AR enters museum exhibitions as a part of the museum dynamics and what we can do in practice to optimize its use. The next two concluding sections will thus reflect on these points, giving theoretical discussions and practical recommendations.

Theoretical reflection and discussion

As argued in the theoretical framework of ANT, when AR enters the museum environment, the museum actor-network does not only receive one extra actor, but is reshaped as existing actors and relations are modified. In the context of digital technology becoming a non-negligible part of a museum exhibition, understandings of museum practices and museum visiting may be gradually reformed. Reflecting upon AR mediation in the actor-network, this section discusses the reformation of concepts related to museums and museum visiting.

First and foremost, following the anti-essentialist standpoint of ANT, the actors involved in the actor-network need non-essentialist interpretations. Instead of essentialist understandings, the actors are defined within the actor-network by their relations with other actors. As argued with respect to the balance problem, AR-mediated exhibits and original exhibits are not the same. What visitors perceive are exhibits processed through all the content and experiences from AR, thus the actor of the exhibit which relates to visitors is enabled and constrained by the actor of AR technology. Similarly, AR technology does not take any physical existence as its essence but is determined in the use. AR can be regarded as a fluid technology, based on which different kinds of possibilities of appliance can be realized. Understanding an AR application is only possible referring to its context, defined by its

specific use and how it fits in a particular exhibition. Therefore, a clear configuration in the problematization can help to design AR as an effective interessement device, facilitating and optimizing the translation process. The actor taking the initiative is important, which requires a certain role of museum professionals as actor-network analysts who realize and can discuss technological tradeoffs with different stakeholders based on a broad view of the museum dynamics.

The same network-perspective also defines visitors. Constructed by the actor-network, a visitor is not self-evidently an individual person but an actor engaging in the network while relating to others. When using AR, a person does not directly relate to exhibitions but via the AR device. Thus in a sense, the technology becomes an extension of humans, and humans become a hybridity. This assumes that individuals are willing and able to embrace and use AR devices to extend themselves, perceiving and interacting with exhibits in this technological way. Therefore, the use of AR in museums triggers further discussions about human beings as natural-technological hybridities and about what technology developers can or should expect from users.

Moreover, the transformation of the museum actor-network may also redefine museums. At present, museums, especially art museums as social institutes, are perceived by the public with a more or less distinct identity in the social division of mission and practice. But high-end technologies like AR give museum visits new elements, such as outlandish or entertaining experiences, which traditionally were not typical in such spaces, meanwhile raising the question what museums are. Such practices are already challenging the conventional understandings of museums and blurring the boundaries between museums and other social institutes, like theaters and amusement parks, as mentioned in one of the interviews (VA). This may be a phenomenon demonstrating that social institutes respond to emerging possibilities and demands enabled by new technologies, which signifies a societal transformation driven by technologies.

Last but not least, the museum use of AR poses questions about art. If AR transforms our perception of artworks in the museum environment, reforming the information we receive directly from our sense organs about art, the mediation goes further. As Ihde (1990) argues,

the technological transformation of micro-level perception affects how we discern things on a macroperceptual level. Thus, when the perceived artworks get mediated and transformed by AR, the conceptualizations of those artworks and art itself are also subjected to mediation. In the case of AR offering new objects of seeing and experiencing based on original exhibits, while serving as an informative or entertaining tool, AR creates new forms of digital and interactive art, like in the case of the aforementioned ARART project. Challenging the distinction between art and tool, Boehner et al. (2005) scrutinized the dualist understanding of ICT either as art or as tools in museums and proposed an installation which was both a tool for the utilitarian purpose of navigating and art in the sense that it poetically provoked new experiences and reactions. Thus the concept of art is no more confined to exhibited objects but also involves visitors participating in using technologies in museums. Furthermore, the extensive use of technology also triggers dialectical reflection on the significance of art: Through art, can we still reflect on social issues and human conditions, including the rapid development of technology, if art is so much dominated by technology? Maybe we need a leeway to take some distance from these immersing devices with virtual content to think about reality and the existence of modern technology itself.

Practical reflections and recommendations

As applying AR technology in museums requires practical activities including design, implementation and use, this concluding section contains advisory considerations for the museum practice along with the reflection. If developers decide to apply AR for museum visits, despite the potential tradeoffs mentioned above, these practical considerations are crucial for making the AR application work effectively as a part of the museum environment and in museum visits, and thus help to achieve a desired result of using AR.

To successfully apply AR in museums, the following aspects should be considered in practice. First, meaningfulness is arguably a decisive element in the museum use of AR when combining exhibitions with a technological presentation. Being meaningful means that the technology should not be a gadget in the museum when combining exhibitions with the technological presentation, but connect with exhibits in a constructive and organic way, reinforcing the cultural, aesthetic, or historical meanings of and reflections about the exhibit,

meanwhile creating a more attractive, informative, or entertaining presentation enabled by AR. Therefore, the starting point of applying AR in museums should focus on exhibitions, exhibits, and the museum itself, thus exploring technical possibilities and experimenting with the technology are only secondary.

Second, accessibility of the AR application refers to how easy and clear it is for visitors to use it. It is important for the application to approach and engage users. The significance of accessibility requires attention in various phases of the design process of an application. Enhancing accessibility should be included in design considerations and in the phase of implementation, in order to make the use as low-threshold and self-evident as possible to visitors. During the real interaction with visitors, necessary instructions may be inevitable, which requires instructive materials and trained museum staff. Instruction should be clear and simple, not posing the application as high-end technology estranged from normal visitors, but as something down-to-earth which people can easily benefit from and enjoy playing with.

Third, technological sufficiency of the museum should not be taken for granted. Technical problems like a malfunctioning network and overload can amplify feelings of fragmentation in ICT use, which challenges the patience and engagement of users. Thus, for implementing AR applications, museums should first learn about their own technological capacity, and design the application in proportion, to avoid technical failures in use and to optimize the user experience.

Finally, regarding specific AR applications, particular communicational, ethical and legal issues may exist. For example, personalized AR applications may collect and use data about users' physiological conditions to optimize individual experiences. Problems may appear involving the ownership of and the right to use personal data, which calls for clear communication with and consent from visitors.

Generally, facing the complicated agency of AR as well as the variety of other relevant elements, museums should retain an open attitude and reflect on design assumptions, accepting and responding to real AR usage that may not comply with the expectations. Regarding the specific actor of visitors, applying AR can benefit from visitor research and

surveys, which not only address visitors who are users but also study non-users. To steer a desirable use, besides configuring the network in the design considerations involving different stakeholders, continuously reacting to the real use based on feedback loops and redesign is crucial.

References

Akrich, M. (1992). The de-scription of technical objects. In W. E. Bijker & J. Law (Eds.), *Shaping technology/building society: Studies in sociotechnical change* (pp. 206-224). Cambride, MA: MIT Press.

Akrich, M. (1995). User representations: Practices, methods and sociology. In A. Rip, T. J. Misa, & J. Schot (Eds.), *Managing technology in society* (pp. 167-184). London, UK: Pinter Publishers.

Alexander, B., Ettema, D., & Dijst, M. (2010). Fragmentation of work activity as a multi-dimensional construct and its association with ICT, employment and sociodemographic characteristics. *Journal of Transport Geography, 18*(1), 55-64.

Barry, A., Thomas, G., Debenham, P., & Trout, J. (2012). Augmented reality in a public space: The natural history museum, London. *Computers & Education, 45*(7), 42-47.

Benjamin, W. (1935). *The work of art in the age of mechanical reproduction*. London, UK: Penguin.

Berger, J. (2008). *Ways of seeing*. London, UK: Penguin.

Boehner, K., Sengers, P., Medynskiy, Y., & Gay, G. (2005). Opening the frame of the art museum: Technology between art and tool. *Digital Arts and Culture (DAC)*, 123-132.

Byrne, S., Clarke, A., Harrison, R., & Torrence, R. (2011). Networks, agents and objects: Frameworks for unpacking museum collections. In S. Byrne, A. Clarke, R. Harrison, & R. Torrence (Eds.), *Unpacking the collection: Networks of material and social agency in the museum* (pp. 3-26). New York, NY: Springer.

Callon, M. (1981). Struggles and negotiations to define what is problematic and what is not: The sociology of translation. In K. D. Knorr, R. Krohn, & R. Whitley (Eds.), *The social process of scientific investigation* (pp. 197-219). Dordrecht, The Netherlands: Springer.

Callon, M. (1986). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. In J. Law (Ed.), *Power, action and belief: A new sociology of knowledge?* (pp. 196-223). London, UK: Routledge.

Capuano, N., Gaeta, A., Guarino, G., Miranda, S., & Tomasiello, S. (2016). Enhancing augmented reality with cognitive and knowledge perspectives: A case study in museum exhibitions. *Behaviour & Information Technology, 35*(11), 968-979.

Chang, K.-E., Chang, C.-T., Hou, H.-T., Sung, Y.-T., Chao, H.-L., & Lee, C.-M. (2014). Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum. *Computers & Education, 71*(Supplement C), 185-197.

Chen, C.-Y., Chang, B. R., & Huang, P.-S. (2013). Multimedia augmented reality information system for museum guidance. *Personal and Ubiquitous Computing, 18*(2), 315-322.

Chivarov, N., Ivanova, V., Radev, D., & Buzov, I. (2013). Interactive presentation of the exhibits in the museums using mobile digital technologies. *IFAC Proceedings Volumes, 46*(8), 122-126.

Christina, G. (2000). The museum environment and the visitor experience. *European Journal of Marketing, 34*(3/4), 261-278.

Cianciarulo, D. (2015). From local traditions to “augmented reality”. The muvig museum of

Viggiano (Italy). *Procedia - Social and Behavioral Sciences, 188*, 138-143.
Couclelis, H. (2003). Housing and the new geography of accessibility in the information age. *Open House International, 28*(4), 7-13.
Csikszentmihalyi, M., & Robinson, R. E. (1990). *The art of seeing: An interpretation of the aesthetic encounter*. Los Angeles, CA: Getty Publications.
Damala, A., Schuchert, T., Rodriguez, I., Moragues, J., Gilleade, K., & Stojanovic, N. (2013). Exploring the affective museum visiting experience: Adaptive augmented reality (A2R) and cultural heritage. *International Journal of Heritage in the Digital Era, 2*(1), 117-142.
Damala, A., & Stojanovic, N. (2012). *Tailoring the Adaptive Augmented Reality (A 2 R) museum visit: Identifying Cultural Heritage professionals' motivations and needs*. Paper presented at the Mixed and Augmented Reality (ISMAR-AMH), 2012 IEEE International Symposium.
De Laet, M., & Mol, A. (2000). The Zimbabwe bush pump: Mechanics of a fluid technology. *Social Studies of Science, 30*(2), 225-263.
Denso, A. (2011). QR code essentials. *Denso Wave, 900*. Retrieved from: http://www.nacs.org/LinkClick.aspx%3Ffileticket%3DD1FpVAvvJuo%253D%26tabid%3D1426%26mid%3D4802
D áz, P., Bellucci, A., & Aedo, I. (2015, Sept. 28 2015-Oct. 2 2015). *Enabling social interaction in the museum through the social display environment.* Paper presented at the 2015 Digital Heritage International Congress (DigitalHeritage)
Dow, S., Mehta, M., MacIntyre, B., & Mateas, M. (2007). *AR fa ɕade: An augmented reality interactive drama*. Paper presented at the 2007 ACM symposium on Virtual Reality Software and Technology, Newport Beach, California.
Duncan, C. (2005). The art museum as ritual. In G. Corsane (Ed.), *Heritage, museums and galleries: An introductory reader* (pp. 85-97). New York, NY: Taylor & Francis.
Falk, J. H., Koran, J. J., Dierking, L. D., & Dreblow, L. (1985). Predicting visitor behavior. *Curator: The Museum Journal, 28*(4), 249-258.
Franklin, M. B., Becklen, R. C., & Doyle, C. L. (1993). The influence of titles on how paintings are seen. *Leonardo, 26*(2), 103-108.
Gehry, F. (2000). *Recent work, a lecture delivered at the Art and Architecture Symposium, hosted by the Chinati Foundation, April 25 and 26 1998.* Paper presented at the Art and Architecture Symposium, the Chinati Foundation, Texas.
Getzels, J. W., & Csikszentmihalyi, M. (1976). *The creative vision*. New York, NY: Wiley.
Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton Mifflin Harcourt (HMH).
Gregory, R. L., Harris, J., Heard, P., & Rose, D. (1995). *The artful eye*. Oxford, UK: Oxford Univeristy Press.
Greimas, A. J. (1987). *On meaning: Selected writings in semiotic theory*. London, UK: Frances Pinter.
Grinter, R. E., Aoki, P. M., Szymanski, M. H., Thornton, J. D., Woodruff, A., & Hurst, A. (2002). *Revisiting the visit: Understanding how technology can shape the museum visit.* Paper presented at the 2002 ACM conference on Computer Supported Cooperative Work.

Hall, T., Ciolfi, L., Bannon, L., Fraser, M., Benford, S., Bowers, J., . . . Flintham, M. (2001). *The visitor as virtual archaeologist: Explorations in mixed reality technology to enhance educational and social interaction in the museum*. Paper presented at the 2001 Conference on Virtual reality, Archeology, and Cultural Heritage, Glyfada, Greece.

Hammady, R., Ma, M., & Temple, N. (2016). *Augmented reality and gamification in heritage museums.* Paper presented at the Joint International Conference on Serious Games.

Heidegger, M. (1954). The question concerning technology. In C. Hanks (Ed.), *Technology and values: Essential readings* (pp. 99-113). Malden, UK: John Wiley.

Heidenreich, S. M., & Turano, K. A. (2011). Where does one look when viewing artwork in a museum? *Empirical Studies of the Arts, 29*(1), 51-72.

Hornecker, E., & Bartie, P. (2006). *Technology in tourism: Handheld guide systems and museum technologies*. Christchurch, New Zealand: University of Canterbury. Retrieved from: http://www.ehornecker.de/Papers/TR-2006-1.pdf

Hsiao, H.-S., Chang, C.-S., Lin, C.-Y., & Wang, Y.-Z. (2013). Weather observers: A manipulative augmented reality system for weather simulations at home, in the classroom, and at a museum. *Interactive Learning Environments, 24*(1), 205-223.

Hsieh, M.-C., & Lin, H.-C. K. (2006). *Interaction design based on augmented reality technologies for English vocabulary learning.* Paper presented at the 18th International Conference on Computers in Education.

Hubard, O. M. (2007). Productive information: Contextual knowledge in art museum education. *Art Education, 60*(4), 17-23.

Ihde, D. (1990). *Technology and the lifeworld: From garden to earth*. Bloomington, IN: Indiana University Press.

Iwata, T., Yamabe, T., & Nakajima, T. (2011). *Augmented reality go: Extending traditional game play with interactive self-learning support.* Paper presented at the 17th International IEEE Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA).

Julier, S., Blume, P., Moutinho, A., Koutsolampros, P., Javornik, A., Rovira, A., & Kostopoulou, E. (2016). *VisAge: Augmented reality for heritage.* Paper presented at the 5th ACM International Symposium on Pervasive Displays.

Keil, J., Pujol, L., Roussou, M., Engelke, T., Schmitt, M., Bockholt, U., & Eleftheratou, S. (2013, Oct. 28 2013-Nov. 1 2013). *A digital look at physical museum exhibits: Designing personalized stories with handheld Augmented Reality in museums.* Paper presented at the 2013 Digital Heritage International Congress (DigitalHeritage).

Kolstee, Y., & van Eck, W. (2011). *The augmented Van Gogh's: Augmented reality experiences for museum visitors.* Paper presented at the 2011 IEEE International Symposium on Mixed and Augmented Reality-Arts, Media, and Humanities (ISMAR-AMH).

Kwastek, K. (2013). *Aesthetics of interaction in digital art* (N. Warde, Trans.). Cambridge, MA: MIT Press.

Lang, P., Kusej, A., Pinz, A., & Brasseur, G. (2002, 2002). *Inertial tracking for mobile augmented reality.* Paper presented at the 19th IEEE Instrumentation and Measurement Technology Conference (IMTC/2002).

Latour, B. (1992). Where are the missing masses? The sociology of a few mundane artifacts. In W. E. Bijker & J. Law (Eds.), *Shaping technology/building society: Studies in sociotechnical change* (pp. 225-258). Cambride, MA: MIT Press.

Latour, B. (1993). *We have never been modern*. Brighton, UK: Harvester Wheatsheaf.

Latour, B. (1994). On technical mediation — philosophy, sociology, genealogy. *Common Knowledge, 3*(2), 29-64.

Latour, B. (1999). On recalling ANT. *The Sociological Review, 47*(1), 15-25.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford, UK: Oxford University Press.

Law, J. (2009). Actor network theory and material semiotics. In B. S. Turner (Ed.), *The new Blackwell companion to social theory* (pp. 141-158). West Sussex, UK: Wiley-Blackwell.

Maleuvre, D. (1999). *Museum memories: History, technology, art*. Palo Alto, CA: Stanford University Press.

Marty, P. F., & Jones, K. B. (2008). *Museum informatics: People, information, and technology in museums*. New York, NY: Taylor & Francis.

Matuk, C. (2016). The learning affordances of augmented reality for museum exhibits on human health. *Museums & Social Issues, 11*(1), 73-87.

McCall, V., & Gray, C. (2014). Museums and the 'new museology': Theory, practice and organisational change. *Museum Management and Curatorship, 29*(1), 19-35.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems, 77*(12), 1321-1329.

Milojković, A., & Nikolić, M. (2012). *Rethinking museum architecture – Art museum at the beginning of the 21 century.* Paper presented at the International Conference on Architectural Research "ICAR 2012 - (RE)writing history", Bucharest, Romania.

Miyashita, T., Meier, P., Tachikawa, T., Orlic, S., Eble, T., Scholz, V., . . . Lieberknecht, S. (2008). *An augmented reality museum guide.* Paper presented at the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality.

Mol, A. (2010). Actor-network theory: Sensitive terms and enduring tensions. *Kölner Zeitschrift für Soziologie und Sozialpsychologie. Sonderheft, 50*, 253-269.

Murdoch, J. (1997). Inhuman/nonhuman/human: actor-network theory and the prospects for a nondualistic and symmetrical perspective on nature and society. *Environment and planning D: Society and Space, 15*(6), 731-756.

Nakamura, J., & Csikszentmihalyi, M. (2002). The concept of flow. In C. R. Snyder & S. J. Lopes (Eds.), *Handbook of positive psychology* (pp. 89-105). New York, NY: Oxford University Press.

Nakamura, J., & Csikszentmihalyi, M. (2009). Flow theory and research. In C. R. Snyder & S. J. Lopes (Eds.), *Oxford handbook of positive psychology* (2 ed., pp. 195-206). New York, NY: Oxford university press.

Newhouse, V. (1998). *Towards a new museum*. New York, NY: Monacelli.

Nobis, C., & Lenz, B. (2004). Changes in transport behavior by fragmentation of activities. *Transportation Research Record: Journal of the Transportation Research Board, 1894*, 249-257.

Papagiannakis, G., Schertenleib, S., O'Kennedy, B., Arevalo-Poizat, M., Magnenat-Thalmann,

N., Stoddart, A., & Thalmann, D. (2005). Mixing virtual and real scenes in the site of ancient Pompeii. *Computer Animation and Virtual Worlds, 16*(1), 11-24.

Pelizza, A. (forthcoming). Cybercultures at a crossroads. Amsterdam, the Netherlands: Institute of Networked Cultures.

Pérez-Sanagustín, M., Parra, D., Verdugo, R., García-Galleguillos, G., & Nussbaum, M. (2016). Using QR codes to increase user engagement in museum-like spaces. *Computers in Human Behavior, 60*(Supplement C), 73-85.

Pikov, N., Rumyantsev, M., Vishniakova, M., Kizhner, I., & Hookk, D. (2015). *Touching an ancient stone: 3D modeling and augmented reality techniques for a collection of petroglyphs from State Hermitage Museum.* Paper presented at the 2015 Digital Heritage International Congress (DigitalHeritage).

Rey, F. B., & Casado-Neira, D. (2013). Participation and technology: Perception and public expectations about the use of ICTs in museums. *Procedia Technology, 9*(Supplement C), 697-704.

Russell, P. A., & Milne, S. (1997). Meaningfulness and hedonic value of paintings: Effects of titles. *Empirical Studies of the Arts, 15*(1), 61-73.

Schavemaker, M., Wils, H., Stork, P., & Pondaag, E. (2011). *Augmented reality and the museum experience.* Paper presented at the Museums and the Web 2011 Conference, Toronto, Canada.

Schultz, M. K. (2013). A case study on the appropriateness of using quick response (QR) codes in libraries and museums. *Library & Information Science Research, 35*(3), 207-215.

Schweibenz, W. (1998). The" virtual museum": New perspectives for museums to present objects and information using the internet as a knowledge base and communication system. In H. H. Zimmerman & V. Schramm (Eds.), *Knowledge-Management und Kommunikationssysteme: Workflow-Management, Multimedia, Knowledge-Transfer: Proceedings des 6. Internationalen Symposiums für Informationswissenschaft (ISI '98), Prag, 3. - 7. November 1998* (Vol. 34, pp. 185-200). Konstanz, Germany: Universitätsverlag.

Specht, S. M. (2010). Artists' statements can influence perceptions of artwork. *Empirical Studies of the Arts, 28*(2), 193-206.

Stam, D. C. (1993). The informed muse: The implications of 'the new museology' for museum practice. *Museum Management and Curatorship, 12*(3), 267-283.

State, A., Keller, K. P., & Fuchs, H. (2005). *Simulation-based design and rapid prototyping of a parallax-free, orthoscopic video see-through head-mounted display.* Paper presented at the Fourth IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR'05).

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication, 42*(4), 73-93.

Tang, A., Owen, C., Biocca, F., & Mou, W. (2003). *Comparative effectiveness of augmented reality in object assembly.* Paper presented at the SIGCHI Conference on Human Factors in Computing Systems, Fort Lauderdale, Florida.

Tateno, M., Skokauskas, N., Kato, T. A., Teo, A. R., & Guerrero, A. P. S. (2016). New game software (Pokémon Go) may help youth with severe social withdrawal, hikikomori.

Psychiatry Research, 246(Supplement C), 848-849.
Valtysson, B., Holdgaard, N., & Ling, R. (2011). The iPhone and its uses in museums. In J. E. Katz, W. LaBar, & E. Lynch (Eds.), *Creativity and technology: Social media, mobiles and museums* (pp. 104-127). Edinburgh, UK: MuseumsEtc.
Van Aart, C., Wielinga, B., & van Hage, W. R. (2010). Mobile cultural heritage guide: Location-aware semantic search. In P. Cimiano & H. S. Pinto (Eds.), *Knowledge engineering and management by the masses: 17th International Conference, EKAW 2010, Lisbon, Portugal, October 11-15, 2010. Proceedings* (pp. 257-271). Berlin, Germany: Springer.
Van Eck, W., & Kolstee, Y. (2012). *The augmented painting: Playful interaction with multi-spectral images*. Paper presented at the Mixed and Augmented Reality (ISMAR-AMH), 2012 IEEE International Symposium.
Vera, F., Sánchez, J. A., & Cervantes, O. (2016). Enhancing user experience in points of interest with augmented reality. *International Journal of Computer Theory and Engineering, 8*(6), 450-457.
Verbeek, P.-P. (2005). *What things do: Philosophical reflections on technology, agency, and design*. University Park, PA: Pennsylvania State University Press.
Vergo, P. (1989). *The new museology*. London, UK: Reaktion Books.
Vom Lehn, D., & Heath, C. (2005). Accounting for new technology in museum exhibitions. *International Journal of Arts Management, 7*(3), 11-21.
Yoon, S. A., Elinich, K., Wang, J., Steinmeier, C., & Tucker, S. (2012). Using augmented reality and knowledge-building scaffolds to improve learning in a science museum. *International Journal of Computer-Supported Collaborative Learning, 7*(4), 519-541.
Zhou, F., Duh, H. B.-L., & Billinghurst, M. (2008). *Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR*. Paper presented at the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality.