
Miscellaneous

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New technology in Museums: AR and VR video games are coming

Abstract

Museums have gone through a modernization process which has seen the adoption of new technologies in what they offer visitors. Within the framework of the new critical museology, these organizations have been transformed into places of encounter and experience, the key tools in this change being socialization and play. Gamification are now intrinsic to collections and are a way of inviting visitors to share new museum experiences through the latest technology such as AR (Augmented Reality) and VR (Virtual Reality). In this way, the museum becomes a playground and a space for creativity (Borja-Villel *et al.*, 2014). In this research, we focus on what we consider to be an important link between the three central aspects of museum change: sociability, gamification and virtualization; and the growing interest in museums for videogames. Our aim is to reach a better understanding of the AR and VR video games developed for museums and how these technologies can not only motivate visitors' interest but also improve their learning skills. Our analysis focuses of literature published between 2015 to 2018 and follows the analytic structure established by Connolly *et al.* (2012) with additional features related to learning experience, platforms, and the use of technologies (VR and AR). The general aim is to map the interest of the research community in the field of museum-developed video games, more specifically those that use augmented and virtual reality.

Keywords

Video games, museums, tourism, visitors, learning experiences.

1. Introduction

It is pertinent to remember that since the middle of the 20th century, museology has undergone a process of continuous change and the resulting alteration to the very idea of “the museum” has been enormous. Indeed, museums have gone through a wholesale modernization and what has been termed the “museum-mausoleum” (Adorno, 1967, p. 175), that is, old-fashioned museum centers, have become open and plural spaces of exchange and shared knowledge. In the new critical museology, these organizations are transformed into places of encounter and experience. Simon (2006) proposes that the museum should be a place of social and virtual encounter, where the story is constructed by dialogue, pluralistically. This reinforces Eileen Hooper-Greenhill's statement: “The histories of the museum successes and failures demonstrate that the use of knowledge is contingent upon other power practices” (1992, p. 193). Since the beginning of the

20th century, that some changes must occur in museums has seemed certain although, at the same time, they remain difficult to predict. As Simon J. Knell (2004, p. 12) points out:

The future contexts of collecting will almost certainly change as much as they have in the last twenty-five years. Some changes, such as in available technologies, are more predictable, but where political and social forces operate change is always an unknown. However, we can expect the era of accountability to continue, so change will continue to present risks to long-term institutions. The recent past tells us that museums can expect no assurances of having a future unless they too change in order to demonstrate their relevance.

Socialization and play have been key tools in the process of museum change. Gamification is now intrinsic to many collections and is a way of inviting visitors to share new museum experiences through the latest technology such as AR (Augmented Reality) and VR (Virtual Reality). Indeed, some artists build their sculptures, so that visitors have to play their way through them, as is the case with Carsten Höller's huge slides that sometimes take the viewer right through his constructions. Here, and in other contexts, play invites us to enter the museum or space of creation (Borja-Villel *et al.*, 2014).

In addition, the importance of using virtual spaces (social networks, websites, and others) is recognized as a way to enable the free construction of a given collection's story (Capriotti & Losada-Díaz, 2018; Losada-Díaz & Capriotti, 2015; Claes & Deltell, 2014). The goal of museums is no longer just to build a large collection, but above all to formulate a story in collaboration with visitors and communities (Kotler, 2008) so overcoming the traditional boundaries of these institutions (Sookhanaphibarn & Chatuporn, 2013).

In this paper, we focus on what we consider to be a link between the central aspects of this movement for change in museums: sociability, ludification, and virtualization; and how museums have grown increasingly interested in videogames.

Over the last twenty years, interest in the world of video games has grown not only in museums but also amongst researchers. A search of the Association for Computing Machinery Digital Library (ACMDL) database shows the high number of publications that have appeared in the most important academic journals since the 1990s. Indeed, it could be said that since 1990 growth in this sector has been exponential.

The most remarkable fact is that video game research is still such a new field. Society is consuming more and more videogames, we just need to look at the numbers: according to Stroz *et al.* (2015), by 2015 the video games market was worth 56 billion dollars to the global economy and a year later, in 2016, the value of the global market had increased 8.5%, representing a growth of around 99.6 billion dollars. Thus, from a research point of view, this relatively unexplored area is a hot topic.

Although the popularity of video games saw important growth towards the end of the 20th century and at the beginning of the current one, it was the arrival of the smartphone and other new mobile devices which allow the user to play anywhere that drove the industry into exponential growth rates. In 2016, 144 million users were using their phones to play games, which means that eight out of ten people with a mobile phone were using it for gaming (Styhre *et al.*, 2018).

Play is generally considered part of life learning (Rieber, 1996) and thus has greatest significance for younger age groups. This is the reason the educational establishment has shown such interest in integrating play into the learning process. That interest is becoming more solid with the arrival of new technologies such as the internet, personal computers, and mobile phones. Furthermore, new models of play for learning have been made possible due to access to those technologies (Amory *et al.*, 1999). The idea of Serious Games (SGs) arises directly from the interest in integrating play into learning, bringing together the world of video games and education. Educators, institutions, and researchers are attracted by the SG concept (Djaouti *et al.*, 2011).

Our research will involve detailed consideration of articles published in high-impact journals in the period 2015–2018 that have a particular focus on AR and VR in museum-developed video games. Through this work we hope to reach a better understanding of the use of video games in museums and how they can not only motivate visitor interest, but also improve learning skills. Amongst the many avenues of interest to explore is discovering whether video games increase the time visitors spend in the museum and if, for instance, visitor satisfaction increases with the use of video games.

Our general aim is to map research interest in the area of video games developed for museums, specifically those that use augmented reality. Two further aims spring from this general objective, these being: to understand the role of AR in video games used in museums and to place these AR games in relation to Serious Games in terms of the research interest in this topic within the time period 2016–2018.

2. Literature Review

2.1. Video games

The two key innovations in video game development are Augmented Reality (AR) and Virtual Reality (VR). These technologies were released in the nineties and have had their difficulties since then. AR and VR are often mistakenly thought to be the same thing, but it is important to understand each of them separately. While VR tries to reproduce the tangible world in a virtual model and place the user inside this digital environment (Dubois & Nigay, 2000), AR expands reality with digital artefacts. Usually, AR adds relevant visual, textual, or sonic information to the physical world through a device.

According to Dubois & Nigay (2000) there are 4 classes of AR. This classification is derived from the two main characteristics of AR: *task focus* and *nature of augmentation*. These characteristics can be thought of as defining two orthogonal classification axes each of which has two values. Combinations of the two values of task focus with the two values of nature of augmentation define four classes as illustrated in Table 1:

Table 1: Four types of AR systems.

Task Focus	Nature of augmentation	
	Execution	Evaluation
Virtual Object	(1) Media Blocks	(2) Realistic Graphics
Real Object	(3) Digital Desk	(4) Augmented Museum

Source: Dubois and Nigay (2000).

“Media blocks and more generally tangible user interfaces (1) augment the execution phase by defining new modalities involving real objects” (Dubois & Nigay, 2000). As an example, these modalities enable the user to manipulate virtual objects as multimedia documents. “Augmented evaluation for interacting with virtual objects (2) refers to realistic graphics on-screen and output modalities that mimic real world feedback” (Dubois & Nigay, 2000). Augmented execution in the real world (3) corresponds to systems that enable the user to perform new actions on real objects that would not be possible without a computer. Augmented evaluation in the real world (4) involves superimposing visual information onto real objects.

Our research is quite restrictive in terms of the field of action in which it is developed: only includes video games at museums. Since 1970, critical museology has provoked a revolution in museum centers and collections that has changed the nature and role of museums fundamentally. As pointed out by Ross (2015), what used to be exclusive institutions that emphasized differences in social class have become inclusive and welcoming to the public at large.

The vision of critical museology is to move away from exhibitions as collections of objects to a focus on the discourse constructed between exhibits, the museum space, and the visiting public. Museums have lost their elitist character and turned into centers of art and creation. The process of modernisation instigated by this paradigm shift has resulted in not only better collections, but also better ways of exhibiting them and, above all, a better exchange with visitors (Ross, 2015) and a new relationship with technology and the virtual.

At the end of the nineties, two important social changes occurred: the appearance of mobile phones as personal devices used for leisure (Amory *et al.*, 1999), and an increase in the interest of families in taking their children to museums (Hooper-Greenhill, 1994). These factors pushed museums to incorporate the use of video games, virtual reality and augmented reality into their curatorial repertoire (Claes & Deltell, 2019).

The effects of games on users are a broad field of research and numerous studies have been conducted seeking to demonstrate not only their good but also their bad effects (Ke, 2009). Despite the interest in this subject, the available literature is somewhat fragmentary and lacking in coherence due to insufficient systematization in the study of video games.

Video games in museums are no exception to this general observation. Our research takes inspiration from Paliokas and Sylaiou's (2016) article "The Use of Serious Games in Museum Visits and Exhibitions: A Systematic Mapping Study", which contains a systematic and exhaustive review of the field. The work provides an overview of how this type of game has been used by museums to promote knowledge transfer. This article also highlights the lack of structure in the study of video games in museums and the absence of a standard model for this research.

2.2. Categorization of Games

Games that incorporate AR technology are not yet widespread and, as discussed, there is no standardized way to categorize them. For this reason, we will take as a reference the taxonomy proposed by Connolly *et al.* (2012) and adapt it to our study. In this way, our analysis aims to be more rigorous and as a result we hope to reach a better understanding of these AR games.

One feature that can be used to categorize video games is the intention with which a particular game has been created. This generates three categories: pure entertainment (commercial game); a Game for Learning (GFL); or a Serious Game (SG). Although GFL and SGs are used as synonyms in many cases, SGs go beyond GFL, because they aim to change players' behavior through training and are often designed to address the specific needs of various specialized disciplines business, industry, marketing, medicine, and politics (Sawyer & Smith, 2008).

Another important characteristic of video games, inherited from traditional games and the theory of play (Rieber, 1996), is known as the general purpose of the game (Paliokas & Sylaiou, 2016). General purpose of the game has 2 categories: to teach or to entertain.

On the other hand, video games are also part of the entertainment industry. Presented to general public as one more leisure option, growing out of the cinema and television, they are a new medium for entertainment with a novel format: one allowing more active input from the consumer. Video games present an opportunity for digitalizing well-known games as well as for creating new, as yet unknown ones (Skalski *et al.*, 2011).

Another feature that can be used for game classification focuses on gameplay, or game genre. This classification is mainly employed for commercial games; however, it is also applicable to GFL and SGs. Following Connolly *et al.* (2012) and earlier work by Herz (1997), it is possible to define seven game genres: action games (reaction games such as shooters), adventure games (based on puzzle solving to advance through a digital world), fighting games, puzzle games, role-playing games, sports games, and strategy games. The additional category

of simulation is also recognized by Connolly *et al.* (2012) and while it is not strictly a game genre, we will use it.

A further option involves categorizing games according to the device on which they are played, or the environment in which they take place. As Connolly *et al.* (2012) discuss, games can now be played on mobile devices (phones and tablets), PCs, on consoles, online, in VR or using some combination of these. For museums, each of these formats has a set of technical and/or spatial challenges to overcome such as the constant updating of mobile devices; where to locate PCs within the museum space; the limitations of virtual reality glasses; and so on.

3. Method

Our analysis of papers published in high-impact journals from 2015 to 2018 will follow the analytic structure established on Connolly *et al.* (2012) with additional features related to learning experience and platforms.

3.1. Data Analysis

The following elements of data collection and analysis will be used to achieve a set of detailed objectives including an understanding of the durability of museum-developed video games and how time influences their presence in museums in addition to differentiating these video games, following the classification established by Connolly *et al.* (2012), as: Serious Games (SGs), Games For Learning (GFL) or entertainment. Furthermore, we will establish what kind of study, or evaluation has been carried out on each of the video games, catalogue the video games studied according to the genre to which they belong (Herz, 1997) and determine which distribution platform the games are aimed at. We will also clarify how many of these games are currently active and whether they are accessible to the general public. Where possible, we will also look at whether playing the video game extends the average visit duration and whether it promotes additional learning compared to non-gamified museum visits.

3.2. Data Collection

The databases consulted for this work included: ACMDL (Association for Computing Machinery Digital Library), ASSIA (Applied Social Sciences Index and Abstracts), BioMed Central, Cambridge Journals Online, Child Data Index to Theses, Oxford University Press (journals), Science Direct, EBSCO (consisting of Psychology and Behavioral Science, PsycINFO, SocINDEX Library, Information Science and Technology Abstracts, CINAHL, ERIC (Education Resources Information Center), Ingenta Connect, Infotrac (Expanded Academic ASAP), Emerald, IEEE (Institute of Electrical and Electronics Engineers), Computer Society Digital Library (CDSL).

3.3. Search Terms

In order to make the search manageable, we limited our search terms to the following four: "Museum," "Museums," "Videogames" and "Videogame." Where advanced searching was available logic operators were included and the search terms entered as: "*Museums & Video Games*"; "*Museums*"; "*Videogames*." Whenever possible, year of publication was established in advanced (i.e., from 2015). Also, when possible, it was specified that search terms should appear in the abstract of articles.

We chose not to include the search terms VR, AR, Virtual Reality, Augmented Reality, VR & Museums, AR & Museums, etc. While these terms are interesting, it was felt that they should be left for consideration in future work.

3.4. Inclusion and exclusion criteria

Even with such a narrow search, not all search results were relevant to our work. Thus, it was necessary to establish certain inclusion and exclusion criteria to determine which of the articles were suitable for analysis.

Papers were excluded if they involved discussions or analysis of:

- Games aimed at the inclusion of disabled people. This was because such games are not designed for the general public, although they can also play them, and they are too limited by their context.
- Games which do not interact with the museum as their main mechanism, or those which are so self-contained that they do not need the museum for gameplay (i.e., Pokémon Go would be considered self-contained in this way as it can be played inside a museum but does not involve interaction with its collections or exhibits).
- A purely theoretical approach.
- Other applications for interaction with the museum but which did not involve any game element such as audio guides, interactive tours, etc.
- Non-digital games. Museums have many strategies to attract the attention of visitors, especially the smallest ones, however games that involve pencil and paper, while of vital importance for museums, are not relevant to the state of the art we are considering here.
- Those that do not require a physical presence in the museum (virtual tours from home). These kinds of games are increasingly widespread, and despite being technologically close to the games we are analyzing, the lack of physical contact with the museum justifies their exclusion.

Papers were included if they involved discussions or analysis of:

- Other applications that, although not being specific games, incorporated some form of gamification (audio guides with a scoring system, interactive activities that encourage visitors to find certain exhibits, amongst other activities).
- Audio guides with AR or VR systems.
- The use of AR in museums generally although not in a gaming context.

4. Results

4.1. Review findings

Fifteen museum games were analyzed using a data analysis proforma that we developed, based on previous research by Conolly *et al.* (2012) and Paliokas and Sylaiou (2016). Of the 21 articles analyzed, 15 were fully or partially developed game; 2 were gamified audio guides; 1 was focused on AR as a good strategy for museums with limited budgets; 1 was an analysis of the pros and cons of digital audio guides *vs* traditional ones; and 2 suggested innovative approaches to attracting more visitors to museums, either through new activities (including new AR and VR exhibits) or modernizing existing activities through technology.

Only 2 out of 15 games described in the papers we analyzed are currently active: InhabitatVR (Ji & Wakefield, 2018) and The Ojoo and the Action Bound (Ioannou & Kyza, 2017). The 21 articles included in our study are summarized in Table 2 which also shows which articles dealt with games developed for specific museums.

Table 2: Summaries of the 21 articles analyzed.

Article	Author(s)	Game	Aim of the article	Summary
Small Group Learning with Games in Museums: Effects of Interactivity as Mediated by Cultural Differences	Apostolellis y Bowman (2015)	C-Olive	To know the impact of interactivity on learning in collaborative game play, during museum visits.	The aim of the article is not persuaded because the experiments were conducted into a laboratory and not at the museum. Nevertheless, those results show learning when using the game.
The Ocean Game: Assessing Children's Engagement and Learning in a Museum Setting Using a Treasure-Hunt Game	Cesário y col. (2017)	The Ocean Game	Learning comparison between traditional tours against gamified tours. Giving special importance to participation and enjoyment.	Visitors show more satisfaction when the exhibition has a video game. Knowledge about the content of the exhibition decreases when they play The Ocean Game. There are significant differences between boys and girls learning, boys learn more than girls.
Shredding with Mom and Dad: Intergenerational physics gaming in a children's museum	Dietmeier y col. (2017)	Skating Game	Presents the idea of a game to show the basic physics law through construction.	The game has not been developed but it shows the idea of a construction process that will focus on physic laws and how they run.
Hybrid Augmented Reality for Participatory Learning: The Hidden Efficacy of Multi-User Game-Based Simulation	Oh y col. (2018)	Arfract	Create and analyze a 2 steps AR experience: firstly a video game and then a simulation.	With a pre-post structure it seems important the order of the 2 steps into the experience, being better to play after the simulation. Sample is too small for generalization (20 players).
Viking VR: Designing a Virtual Reality Experience for a Museum	P. Schofield y col. (2018)	Viking VR	Discussion of the future of VR experiences related to cultural heritage. Focused on design, development and authorship.	Based on the Vikings VR experience in Yorkshire, it resembles some of the problems founded like: Audio problems (museums are louder than what we think), overheat of the VR devices.
Survival at the Museum: A Cooperation Experiment with Emotionally Expressive Virtual Characters	Torre y col. (2018)	Lunar Survival Task	Determine if an IA with smiley face is more trustable than one with a neutral face.	More than 500 visitors determined that yes, IA with smiley face and neutral tone is more trustable than others.

Inhabitat: An Imaginary Ecosystem in a Children's Science Museum	Ji y Wakefield (2018)	Inhabitant VR	Artistic and visual experience with the pretention of teaching children about ecosystems and their relations.	The game had several design problems and it was hard to try on visitors. Sample was small and the user experience was not satisfying.
QuakeQuiz – A Case Study on Deploying a Playful Display Application in a Museum Context	Prange y col. (2017)	QuakeQuiz	1. Accomplish interaction between strangers. 2. Get to a global public. 3. Full integration on the current exhibition.	2 experiments were conducted looking for the perfect installation. People have had to answer surveys about different subjects as: Demography, gameplay, usability, tablet position in the room and general user experience.
Multitouch NetLogo for Museum Interactive Game	Martin (2018)	NetLogo	Presentation of the idea for a game related with modelling.	There was no experimentation, but it assembles the video game to a board game.
Treasure codes: augmenting learning from physical museum exhibits through treasure hunting	Ng y col. (2018)	Kualalumpur Treasure Hunt	Measure the impact of the game into families visitors.	That research shows a very splitted sample, only 84 subjects and 5 groups. Also, the app is evaluated in 3 different parts. Results are positive for learning only in 1 out of 3 of the parts. The inner feeling of the families is to learn with the visit. The time spent into the museum is longer with the game.
Mobile family learning in the science museum	Ayudhya y Vavoula (2017)	The Museum Pool	Development and evaluation of a mobile app for families visiting a science museum in Thailand. The app was designed to help adults in family groups to support children's learning during the visit while learning about new science concepts and ideas themselves.	Findings suggest that the app: 1. Significantly increased family dwell time. 2. Provided an additional platform for family interactions. 3. Amplified learning outcomes.
The role of gamification in activating primary school students' intrinsic and extrinsic motivation at a museum	Ioannou y Kyza (2017)	The Ojoo and the Action Bound	Intrinsic and extrinsic motivation of the primary students when using a mobile phone with and without gamified platforms. Using those 2 platforms in class and at the museum.	It is detected a better learning experience with the gamified experience. Extrinsic motivation was also better with the gamified experience.

MagicHOLO - A Collaborative 3D experience in the museum	Kasomoulis y col. (2016)	MagicHOLO	Accomplish interaction between strangers through holograms.	There is no experimentation on that paper, it only presents the idea and details about the development of that technology.
From remote sensing to a serious game: Digital reconstruction of an abandoned medieval village in Southern Italy	Gabellone y col. (2017)	LiDar Yrsum	Creation of a Serious Game using a 3D medieval town reconstruction.	Exposes how was the process of reusing a 3D reconstruction for the implementation of a Serious Game.
Seek out katipunan: A Mobile Augmented Reality for Museum Visualization	C. R. Colcol y col. (2017)	Seek Out Katipunan	Attract more people into the museum using new technologies.	15 visitors were interviewed about their impressions. It establishes an initial point for future research.
An Initial Framework for a Museum Application for Senior Citizens	Rodrigues and col. (2016)	-	Adaptation of an audio guide on the phone for elder people.	It shows the necessity of experiments to determine the success of the app. Relates the interesting process of development.
ARtLens: Enhancing Museum Visitors' Engagement with African Art	Pollalis and col. (2018)	-	Enhance learning and engagement with museum's collections.	Evaluation of the app ArtLens for interactive goggles into a very preliminary state, only 3 subjects had used the artifact.
A survey on developing personalized content services in museums	Kosmopoulos and Styliaras (2018)	-	State of art about personalization of museum visits.	A general vision about museum visit personalization, how they evolved from audio guides to BYOD's. Exposure of the main problems: localization, costs, actualization and desires: the unicity of client, personalized data...
Value of augmented reality at cultural heritage sites: A stakeholder approach	Dieck y Jung (2017)	-	How can AR help to small museums with small budget.	All the good reasons why a small museum should invest into AR.

The Augmented House Museum: Co-Exploring Tangible Interaction to Increase Engagement with Heritage in House Museums	Claisse (2017) -	<ol style="list-style-type: none"> 1. What are the challenges and opportunities for designing interactive exhibits in the specific context of House Museums? 2. How may the museum volunteers be included in the process of designing interactive exhibits for House Museums? 3. How can tangible interaction engage visitors with heritage at HMs? 	<p>An exhibition was placed at the museum, it was interactive.</p> <p>The experience was satisfactory and the conclusion is that more actions like that are needed in house museums.</p>
Phone vs. Tangible in Museums: A Comparative Study	Petrelli y O'Brien (2018) -	Understand how visitors react to new technologies at museums and establish the better digital approach for museums.	Visitors prefer tangible objects to apps. Key to appreciation and engagement is the match between the personal visiting style and the interaction that better affords that style.

Source: Own elaboration.

4.2. Game intention and purpose

The 15 games from the articles we analyzed have been categorized according to Connolly *et al.* (2012) with the focus on the intentionality behind their creation. In this way, 8 games are SGs, 8 are GFL and 5 are entertainment games. It is interesting to compare this categorization with classification according to the general purpose of the game. This classification system generally has only 2 categories, but as a result of our review, we suggest the addition of 2 more categories: artistic creation and research. These purposes are apparent from observations within the articles studied and are established by the authors of the games themselves. Our classification, including these two new categories, is shown on Table 3 alongside that of Conolly *et al.* (2012) and Herz's (1997) genre classification scheme.

Table 3: Classification of games.

General Information		Herz (1997)		Conolly et al. (2012)
Author(s)	Name of the game	Genre	Game purpose	Game intention
Apostolellis and Bowman (2015)	C-Olive	Cooperative	Learn	GFL
Cesário et al. (2017)	The Ocean Game	Treasure Hunt	Learn	GFL
Dietmeier et al. (2017)	Skating Game	Construction	Learn	GFL
Oh et al. (2018)	Arfract	Puzzle	Learn	SG
Schofield et al. (2018)	Viking VR	Simulation	Entertain	Entertainment
Torre et al. (2018)	Lunar Survival Task	Cooperative	Research	Entertainment
Ji and Wakefield (2018)	Inhabitant VR	Simulation	Artistic Creation	Entertainment
Prange et al. (2017)	QuakeQuiz	Cooperative	Learn	GFL
Martin (2018)	NetLogo	Cooperative	Learn	GFL
Ng et al. (2018)	Kulalumpur Treasure Hunt	Treasure Hunt	Learn	GFL
Ayudhya and Vavoula (2017)	The Museum Pool	Treasure Hunt	Learn	Entertainment
Ioannou and Kyza (2017)	The Ojoo and the Action Bound	Puzzle	Learn	GFL
Kasomoulis et al. (2016)	MagicHOLO	Cooperative	Entertain	Entertainment
Gabellone et al. (2017)	LiDar Yrsum	Simulation	Learn	SG
Colcol et al. (2017)	Seek Out Katipunan	Treasure Hunt	Learn	GFL

Source: Own elaboration.

It is important to note that game purpose and the intention of a game are not the same; for instance, The Museum Pool (Ayudhya & Vavoula, 2017) was designed with the purpose that participants should learn something, but the game's intention is entertainment.

4.3. Game genre

As shown in Table 3 three different genres are represented among the games studied here including: Cooperative (5 games); Treasure Hunt (5 games); and Simulation (3 games).

Genre is an important classification for videogames because it helps determine not only esthetic questions but also the mechanics of the game. For instance, if the game genre is "cooperative" we understand that the game is focused on making players cooperate and will preclude solo play mode.

It is worth pointing out that none of the papers we looked at in this study explored the possibilities of shooting games, sports games or fighting games in the museum environment. This undoubtedly reflects how some genres are more suitable than others for specific contexts.

4.4. Game evaluation method

Two methods predominate in the evaluation of video games in museums, one is qualitative research, and the other is the use of surveys. Only two of the articles used quantitative analysis such as correlation, or other statistical methods as part of their game evaluation. One of these was Apostolellis and Bowman's (2015) assessment of the C-Olive game which was conducted in a closed, controlled environment. The other was that of Ng *et al.* (2018) which evaluated the

Kuala Lumpur Treasure Hunt. A third study that could also be considered quantitative is that by Torre *et al.* (2018) which used a Randomized Controlled Trial (RCT) to assess the Lunar Survival Task game.

Table 4: Study Design.

General Information Game Title	Study Design					
	Qualitative	Correlational	Quasi-Experimental	RCT	Survey	Descriptive Study
C-Olive		x			x	
The Ocean Game	x		x		x	
Skating Game						
Arfract			x (ab testing)			
Viking VR					x	
Lunar Survival Task				x		
Inhabitant VR	x					
QuakeQuiz	x				x	
NetLogo						x
Kualumpur Treasure Hunt	x	x	x (ab testing)		x	
The Museum Pool	x		x		x SUS	
The Ojoo and the Action Bound			x (pre-post)		x	
MagicHOLO						x
LiDar Yrsum						x

Source: Own elaboration.

It should be noted that quantitative research into museum video games is extremely difficult because it would ideally require a controlled social environment. One issue in a number of the articles that we studied was that participants in the test sample did not match the target audience for which the game was designed, or that these two populations were confused. Another problem was that of sample size. Many studies we looked at involved samples that were too small to obtain statistically valid results.

Finally, it is hard for us to make comparisons between these museum video game studies due to the widely differing priorities of the researchers who produced this body of work. Through our analysis of this work, we distinguished 3 main parameters used to assess the various video games: usability, user satisfaction, and learning. It is not useful to compare research focusing on one of these parameters with that focusing on another because there is nothing to compare between them.

4.5. Distribution platform

According to Dieck & Jung (2017), mobile phones and tablets are the favorite platforms used for videogames in museums. Out of the 21 articles we analyzed, 9 offer mobile based solutions; 5 offer computer solutions; 2 offer VR solutions; and 1 considers a holographic solution using HoloLens. The remaining 4 articles did not mention a platform.

There is a great deal of interest in bringing new technologies into museums, not only among content creators but also among museum curators. The hope is that museums investing in this type of innovation will be able to attract a younger audience. Generally, it is the museum itself that determines the platform on which they want to present a given video game to the public.

4.6. Visitor satisfaction and duration of the visit

Visitor satisfaction was measured for 7 out of the 15 games, and one article mentions measuring satisfaction in future research. In all cases, researchers concluded that players found the games to be satisfactory and 3 out of the 15 articles showed that games improved levels of visitor satisfaction with the museum in general. Even in this very specific area of visitor satisfaction, it must be pointed out that it was measured differently in all the studies we looked at and, therefore, it is difficult to make comparisons between findings.

Only 3 video games examined resulted in visitors spending more time in the museum, these were: *QuakeQuiz*, *Kuala Lumpur Treasure Hunt*, and *The Museum Pool*. However, visit duration is not always a good measure of success. It is quite common that a video game is included in a museum as an extra activity and as visitors often plan to spend a maximum time at the museum, time spent on a video game often detracts from time spent with other exhibits.

4.7. Learning

Learning is a very broad topic covering a wide range of aspects, from psychology to education, and this field of research can be approached in many different ways. There is some research concerning learning and video games in museums, but, as yet there are no standardized models for measuring how video games with AR affect the learning of museum visitors.

Taking Beale (2011) as starting point, there are several different types of learning and a video game developed for a museum may address, or not, any of these. Some authors, such as Yiannoutsou and Avouris (2012), suggest a direct association between the type of learning offered by a videogame and the game's genre. We believe that this statement is not entirely accurate since, while the intrinsic nature of a game's genre can trigger a particular kind of learning –a collaborative game might plausibly result in users learning collaboration skills– it is a mistake to assume that this will happen.

The significant learning in museum video games is that directly related to the institution for which it was designed. Here again, there are different kinds of learning to be considered: traditional, or factual learning (relying on the recall of certain facts in the short, medium, and long term); and more informal, or meaningful learning (depending on the intrinsic and extrinsic characteristics of the player).

Table 4 shows a breakdown of data examined for the 15 games studied. As can be appreciated, not all fields were completed in all studies showing how different studies focused on different aspects of the video games. This does not aid comparison between studies.

5. Discussion and Conclusions

There is clearly significant research interest in the topic of videogames in museums. Our literature search found 21 articles relevant to this field published in the last 3 years. These articles come from a broad range of disciplines (marketing, education, computing, among others). Of the 21 articles, 15 concerned a totally or partially developed video game designed for a museum but only 2 of these remain currently active. The fact that only 2 are still active highlights one of the main problems with video games in museums, that is, while there is interest from researchers, the potential market is small.

Most of the games analyzed were Serious Games or Games For Learning. It seems that museum curators and game developers work, organically, towards a common idea: museums are for learning and so, the video games they host must be, somehow, a gateway to knowledge. This can be a misapprehension, but it is the one that comes naturally.

Table 5: Other relevant aspects of the game.

Game Title	Do players learn?	Still active?	Measures satisfaction?	Increases time of visit?
C-Olive	Yes	No	No	Missing data
The Ocean Game	Missing data	No	Yes	Missing data
Skating Game	Yes	Under implementation	No	Missing data
Arfract	Yes	No	Yes	No
Viking VR	Missing data	No (temporary exhibition)	No	No
Lunar Survival Task	Missing data	No	No	Missing data
Inhabitant VR	Missing data	No	No	Missing data
QuakeQuiz	Contradictory data	No	Yes	Yes
NetLogo	Missing data	No	Future project	Future project
Kulalumpur Treasure Hunt	Missing data	No	Yes	Yes
The Museum Pool	No	No	Yes	Yes
The Ojoo and the Action Bound	Yes	Yes	Yes	No
MagicHOLO	Missing data	No	No	Missing data
LiDar Yrsum	Missing data	No	No	Missing data
Seek Out Katipunan	Missing data	No	Yes	Missing data

Source: Own elaboration.

The research community are motivated to design video games for museums because it provides them with an opportunity to experiment with the new capabilities of a new technology. This is definitely the case for AR, which is at the incipient stage of its development and has some limitations with regards to its implementation. The potential benefits of AR offer exciting research possibilities. In spite of the comments of Ayudhya and Vavoula (2017), AR can provide a better understanding of museum exhibits because it enables the enhancement of physical objects with additional external information, as discussed by both Apostolellis & Bowman (2015) and Oh *et al.* (2018).

According to the data we have collated, it is clear that visitor interest increases where museums provide gaming experiences. Whenever satisfaction is evaluated it is found that people appreciate the inclusion of games in museum exhibits. However, 7 out of the 15 articles in our study did not measure visitor satisfaction.

Results from our review suggest that museum games have a short lifespan and, in fact, the majority of them are never released to the general public, remaining purely as artifacts for research. Whenever they are released for public use, games do not remain alive for very long because of the difficulties associated with maintaining them. New mobile phones, for instance, are released all the time, and technology quickly becomes obsolete. The cost of maintaining a game is therefore too high for most museums. Another reason for the short lifespan of video games in museums is their rigid structure. For example, it is very common for museum exhibits to go on tour, and it is hard for game play to adapt to the absence of a specific exhibit that may constitute the main clue in a game.

The type of visitor is another factor to consider when designing and implementing video games for museums. Many visitors will be independent, but a large number will come on educational visits as part of a school or university course. This latter type of visitor, students, may have low motivation for visiting the museum as they are forced to be there. Groups of students are also usually guided by a curator and they have a fixed time to spend in the museum. In contrast, the independent visitor is at the museum in their free time and can spend any amount of time that they wish to on their visit, freely taking part in museum activities. Their motivation for visiting museum exhibitions is likely to be high. Thus, it is easy to see how these two types of visitor would give quite different feedback about the museum.

It is not easy to determine how many of the 55,000 museums (*Museums of the World 2017*, 2017) in the world are focused on art and how many on science. We suspect, however, that there are more dedicated to science since this subject area encompasses such a broad range

of disciplines: from engineering to physics, including all natural and social sciences. This inequality is reflected in the fact that we find more museum video games related to science than art.

The main conclusion of this research is that there is a lack of any standardized structure when it comes to evaluating museum videogames. Although there have been a significant number of studies in this area, as yet no standardized research model has been developed. The lack of a standard model can be explained by the nature of the subject. This is an area of study where it is often difficult to determine what should be measured: evaluating a game that aims to promote collaboration or one whose aim is to create art requires a very different approach.

What is clear, however, is that video games are an important part of the new image that museums are looking for. Young people are attracted to technology applied to new contexts. Researchers are equally keen to use pluralistic, technological strategies to make museum spaces that are designed for co-creation and promote participation between museums and their visitors. Indeed, it is a perfect research field because it is so full of new dynamics that need to be investigated.

As another tool of critical museology, the video game definitively puts paid to Adorno's (1967) conceptualization of the museum-mausoleum by offering the visitor a more playful and shared museum experience. Furthermore, and by way of a final conclusion, we believe that video games in museums will eventually become part of museum collections rather than being simply about them.

References

- Adorno, T. W. (1967). Valéry Proust museum. in memory of Hermann von Grab. In T. W. Adorno (Ed.), *Prisms* (S. Weber Trans.) (pp. 175-185). Cambridge, MA: MIT Press.
- Amory, A. (1999). The use of computer games as an educational tool: identification of appropriate game types and game elements. *British Journal of Educational Technology*, 30(4), 311-321. <https://www.doi.org/10.1111/1467-8535.00121>
- Apostolellis, P., & Bowman, D. A. (2015). Small Group Learning with Games in Museums: Effects of Interactivity As Mediated by Cultural Differences. In *Proceedings of the 14th International Conference on Interaction Design and Children* (pp. 160-169). IDC '15. Boston, Massachusetts: ACM. <https://www.doi.org/10.1145/2771839.2771856>
- Ayudhya, W. S. N. & Vavoula, G. (2017). Mobile Family Learning in the Science Museum. In *Proceedings of the 16th World Conference on Mobile and Contextual Learning* (pp. 221-228). mLearn 2017. Larnaca, Cyprus: ACM. <https://www.doi.org/10.1145/3136907.3136948>
- Beale, K. (Ed.), (2011). *Museums at play: Games interaction and learning*. Edinburgh: MuseumsEtc.
- Borja-Villel, M. et al, (2014). *Playgrounds, Revindicar la plaza. Museo Nacional Centro de Arte Reina Sofía*. Madrid: Siruela.
- Capriotti, P. & Losada-Díaz, J. (2018). Facebook as a dialogic communication tool at the most visited museums of the world. *El Profesional De La Información*, 27(3), 642-650. <https://www.doi.org/10.3145/epi.2018.may.17>
- Cesario, V. et al. (2017). The Ocean Game: Assessing Children's Engagement and Learning in a Museum Setting Using a Treasure-Hunt Game. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play* (pp. 99-109). CHI PLAY '17 Extended Abstracts. Amsterdam: ACM. <https://www.doi.org/10.1145/3130859.3131435>
- Claes, F. & Deltell, L. (2014). Museos sociales. perfiles museísticos en Twitter y Facebook 2012-2013. *El Profesional De La Información*, 23(6), 594-602. <https://www.doi.org/10.3145/epi.2014.nov.06>
- Claes, F. & Deltell, L. (2019). Museo social en España: redes sociales y webs de los museos estatales. *El profesional de la información*, 28(3). <https://www.doi.org/10.3145/epi.2019.may.04>

- Colcol, C. R. *et al.* (2017). *Seek out Katipunan: a mobile augmented reality for museum visualization*. <https://www.doi.org/10.1145/3162957.3162980>
- Connolly, T. M. *et al.* (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers and Education*, 59, 661-686.
<https://www.doi.org/10.1016/j.compedu.2012.03.004>
- Dieck, M., Tom, C. & Jung, T. H. (2017). Value of augmented reality at cultural heritage sites: A stakeholder approach. *Journal of Destination Marketing and Management* 6.2., Special edition on Digital Destinations, 110-117. <https://doi.org/10.1016/j.jdmm.2017.03.002>
- Dietmeier, J. *et al.* (2017). Shredding with mom and dad: intergenerational physics gaming in a children's museum. In *FDG. DIS '17 Companion: Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems (2017)* (pp. 1-4). Edinburgh: ACM. <https://www.doi.org/10.1145/3102071.3106365>
- Djaouti, D. *et al.* (2011). Origins of Serious Games. In M. Minhua, A. Oikonomou & C. Lakhmi (Eds.), *Jain Serious Games and Edutainment Applications* (pp. 25-43). London: Springer. https://www.doi.org/10.1007/978-1-4471-2161-9_3
- Dubois, E. & Nigay, L. (2000). Augmented Reality: Which Augmentation for Which Reality? In *Proceedings of DARE 2000 on Designing Augmented Reality Environments* (pp. 165-166). DARE '00. Elsinore: ACM. <https://www.doi.org/10.1145/354666.354695>.
- Gabellone, F. *et al.* (2017). From remote sensing to a serious game: Digital reconstruction of an abandoned medieval village in Southern Italy. In *Journal of Cultural Heritage* 23. *Beyond the modern landscape: Earth Observation to see the unseen* (pp. 63-70). <https://www.doi.org/10.1016/j.culher.2016.01.012>
- Herz, J. C. (1997). *Joystick Nation: How Videogames Ate Our Quarters, Won Our Hearts, and Rewired Our Minds*. Boston, MA: Atlantic/Little, Brown.
- Hooper Greenhill, E. (1992). *Museums and the Shaping of Knowledge*. London: Routledge. <https://www.doi.org/10.4324/9780203415825>
- Hooper-Greenhill, E. (1994). *Museums and Their Visitors*. London. Routledge. <https://www.doi.org/10.4324/9780203415160>
- Ioannou, I. & Kyza, E. A. (2017). The Role of Gamification in Activating Primary School Students' Intrinsic and Extrinsic Motivation at a Museum. In *Proceedings of the 16th World Conference on Mobile and Contextual Learning* (pp. 8:1-8:4). mLearn. Larnaca, Cyprus: ACM. <https://www.doi.org/10.1145/3136907.3136925>
- Ji, H. H. & Wakefield, G. (2018). Inhabitat: An Imaginary Ecosystem in a Children's Science Museum. *Leonardo*, 51(4), 343-348. https://www.doi.org/10.1162/leon_a_01641
- Kasomoulis, A. *et al.* (2016). MagicHOLO: A Collaborative 3D Experience in the Museum. In *Proceedings of the 20th Pan-Hellenic Conference on Informatics* (pp. 74:1-74:6). PCI '16. Patras: ACM. <https://www.doi.org/10.1145/3003733.3003813>
- Ke, F. (2009). *Gaming and Simulations: Concepts, Methodologies, Tools and Applications*. I. Management Association. <https://www.doi.org/10.4018/978-1-60960-195-9>
- Knell, S. (Ed.). (2004). *Museums and the Future of Collecting*. London: Routledge. <https://www.doi.org/10.4324/9781315248561>
- Kosmopoulos, D. & Styliaras, G. (2018). A survey on developing personalized content services in museums. *Pervasive and Mobile Computing*, 47, 54-77. <https://www.doi.org/https://doi.org/10.1016/j.pmcj.2018.05.002>
- Kotler, N.-G., Kotler, P. & Kotler, W. I. (2008). *Museum marketing and strategy: designing missions, building audiences, generating revenue and resources*. San Francisco: John Wiley & Sons.
- Losada-Díaz, J. C. & Capriotti, P. (2015). La comunicación de los museos de arte en Facebook: comparación entre las principales instituciones internacionales y españolas. *Palabra Clave*, 18(3), 889-904. Retrieved from <https://dialnet.unirioja.es/descarga/articulo/5241926.pdf>

- Martin, K. (2018). *Multitouch NetLogo for Museum Interactive Game*. In *Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing* (pp. 5-8). CSCW '18. Jersey City, NJ: ACM. <https://www.doi.org/10.1145/3272973.3272989>.
- Museums of the World 2017 (2017). Berlin, Boston: De Gruyter Saur. Retrieved from <https://www.degruyter.com/view/product/479786>
- Ng, K. H., Huang, H. & O'Malley, C. (2018). Treasure codes: augmenting learning from physical museum exhibits through treasure hunting. In *Personal and ubiquitous computing. 22.4* (pp. 739-750). <https://www.doi.org/10.1007/978-3-319-779-018-1126-5>
- Oh, S., So, H. & Gaydos, M. (2018). Hybrid Augmented Reality for Participatory Learning: The Hidden Efficacy of Multi-User Game-Based Simulation. In *IEEE Transactions on Learning Technologies 11.1* (pp. 115-127). <https://www.doi.org/10.1109/TLT.2017.2750673>
- Paliokas, I. & Sylaiou, S. (2016). The use of serious games in museum visits and exhibitions: A systematic mapping study. In *8th International Conference on Games and Virtual Worlds for Serious Applications, VS-Games 2016* (pp. 1-8). <https://www.doi.org/10.1109/VS-GAMES.2016.7590371>
- Petrelli, D. & O'Brien, S. (2018). Phone vs Tangible in Museums: A Comparative Study. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (pp. 112:1-112:12). CHI '18. Montreal: ACM. <https://www.doi.org/10.1145/3173574.3173686>
- Pollalis, C. *et al.* (2018). ARTLens: Enhancing Museum Visitors' Engagement with African Art. In *DIS '18 Companion: Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems* (pp. 195-200). <https://www.doi.org/10.1145/3197391.3205435>
- Prange, S. *et al.* (2017). QuakeQuiz: a case study on deploying a playful display application in a museum context. In *MUM '17: Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia* (pp. 49-56). <https://www.doi.org/10.1145/3152832.3152841>
- Rieber, L. P. (1996). Seriously Considering Play: Designing Interactive Learning Environments Based on the Blending of Microworlds, Simulations, and Games. In *Educational Technology Research and Development 44.2* (pp. 43-58). <https://www.doi.org/10.1007/BF02300540>
- Rodrigues, J. M. F. *et al.* (2016). An Initial Framework for a Museum Application for Senior Citizens. In *Proceedings of the 7th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion* (pp. 414-421). DSAI 2016. Vila Real: ACM. <https://www.doi.org/10.1145/3019943.3020002>
- Ross, Max (2015). Interpreting the new museology. *Museum and Society 2.2*, 84-103. Retrieved from <https://www108.lamp.le.ac.uk/ojs1/index.php/mas/article/view/43>
- Schofield, G. *et al.* (2018). Viking VR: Designing a Virtual Reality Experience for a Museum. In *Proceedings of the 2018 Designing Interactive Systems Conference (DIS '18)* (pp. 805-815). New York: Association for Computing Machinery. <https://www.doi.org/10.1145/3196709.3196714>
- Simon, N. (2006). *What is museum 2.0?* Retrieved from <http://museumtwo.blogspot.com.es/2006/12/what-is-museum-20.html>
- Skalski, P. *et al.* (2011). Mapping the road to fun: Natural video game controllers, presence, and game enjoyment. *New Media & Society, 13*(2), 224-242. <https://www.doi.org/10.1177/1461444810370949>
- Storz, C., Riboldazzi, F. & John, M. (2015). Mobility and innovation: A cross-country comparison in the video games industry. *Research Policy, 44*(1), 121-137. <https://www.doi.org/10.1016/j.respol.2014.07.015>
- Styhre, A., Szczepanska, A. M. & Remneland-Wikhamn, B. (2018). Consecrating video games as cultural artifacts: Intellectual legitimation as a source of industry renewal. *Scandinavian Journal of Management, 34*(1), 22-28. <https://www.doi.org/10.1016/j.scaman.2017.11.003>.

- Sawyer, B. & Smith, A. (October 2008). Keynote address. In *The second European conference on games-based learning* (pp. 16-17). Barcelona: Universitat Oberta de Catalunya.
- Sookhanaphibarn, K. & Chatuporn, U. (2013). Expanding the Experience of Museum Visitors with a Social Application on Facebook. In *ICDS 2013 The Seventh International Conference on Digital Society* (pp. 74-80).
- Torre, I. *et al.* (2018). Survival at the Museum: A Cooperation Experiment with Emotionally Expressive Virtual Characters. <https://www.doi.org/10.1145/3242969.3242984>
- Yiannoutsou, N. & Avouris, N. (2012). Mobile games in Museums: from learning through game play to learning through game design. *Museum Education and New Media*, 23, 79-86.
- Witcomb, A. (2003). *Re-imagining the museum: beyond the mausoleum*. London: Routledge. <https://www.doi.org/10.1111/j.2151-6952.2004.tb00369.x>