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Exploring the effect of diverse technologies incorporated in virtual museums on visitors' perceived sense of presence

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Abstract: This paper presents the preliminary results of a research project aimed at exploring the perceived sense of presence incorporated in diverse technologies used in Virtual Museums. It initially presents the selection criteria and the five museum websites involved in the analysis. Then, it describes the evaluation process, in which a group of subjects explored the museums' on-line resources and completed a presence. The results of a double-phased statistical analysis are discussed, which investigated the technological conditions under which a Virtual Museum enhances the visitors' experience of presence.

Keywords: Virtual museum, presence, evaluation

Introduction

Cultural organizations, such as museums are in continuous development and performance improvement, effectively monitoring trends and assessing their progress. Cultural organizations such as galleries and museums, experience a fast-moving change derived from the proliferation of ICT tools and technologies, including the WWW. Interactive 3D computer graphics content is often adopted by museums in order to entertain and educate the wide public in an innovative and interactive manner. Virtual museum exhibitions allow museums to easily exhibit vast collections of digitized objects and overcome limitations of the physical objects' fragility, lack of exhibition space and cost. The virtual museums provide also the opportunity to people that live far away from the "brick and mortar" museums and to people with disabilities to visit their exhibitions and obtain an engaging and educative museum experience. Virtual museum visitors are becoming accustomed to technology being increasingly technologically aware also expecting exhibits and information to be technologically aware [1]. They demand a high level of experience quality through interactive digitized content. Virtual

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museums should be engaging and legible, so as to be correctly interpreted, stimulate thought, and trigger enjoyment, inspiration and creativity satisfying human curiosity. One of the main quality criteria that contribute significantly to the quality of experience while engaged in a virtual museum exhibition is associated to users' level of 'presence' or 'sense of being there', in the virtual museum. Presence has been considered a generic metric assessing the overall experience of the visitor rather than the information retained or the visitor's success in task completion. Previous research explored the effect of technologies such as interactive 3D graphics and augmented reality incorporated in a virtual museum website on visitors' perceived presence [2, 3, 4].

As more museums, libraries, archives and galleries move towards digitizing displays and exhibitions incorporated in their official websites, a series of questions have emerged from scholars as to how visitors and the wider society perceive 'online museums' and their 'digital heritage' [5, 6] in relation to the physical museum's experience. Museum visitors may interact with the virtual museum environment via a constructive dialogue that provides them with access to thematic information and explanations about the museum objects' context selecting the level of information and the amount of detail they prefer. They shift their focus from the high-quality presentation of collections to the making of meaning related to the artefacts and their interpretation. There is the constant need for virtual museums to reach out and attract larger and more diverse audiences and find ways to understand visitor expectations and experiences, in order to address the needs of diverse user groups and be responsive to various communities' interests. On-line museum resources signifying 'digital heritage' provokes an innovative area of studying the visitor's interaction with on-line catalogues, digital objects and virtual exhibitions in relation to the technologies embedded in digital cultural spaces [7, 8]. The study presented in this paper describes compares and evaluates visitors' sense of presence after being exposed to five virtual museum websites that incorporate diverse technologies, such as panoramic images, scalable images, searchable database, web3D environments, Flash technologies and videos. The scope of this paper is to explore the effect of diverse technological characteristics of on-line digital museums on users' level of perceived presence or sense of being there, in the virtual museum environment.

1. Background

1.1 Presence in Virtual Environments

The main aim of a Virtual Environment (VE) is the ability to mislead one's senses so well that the illusion of being in the real-world situation simulated is created. Thus, the sense of presence is the design aim of a simulation. Presence is defined as the sense of ''being there'' in a mediated environment, e.g. the degree to which the users feel that they are somewhere other than they physically are while experiencing a computer generated simulation [9, 10]. Perceived presence could also be explained as the extent to which a VE becomes the dominant one—i.e., that the participants will tend to respond to events in the VE rather than in the real world [11]. In a study [12] the sense

of presence signifies behaving in the VE as in the real-world. Presence in the virtual environment, as sensed by the users of a simulator, cannot be directly linked to a specific type of technology; it is a product of the mind [13]. According to Heeter [14] there are three different kinds of Presence; Personal, Social and Environmental Presence. *Personal Presence* is the degree that someone feels part of the VE. *Social Presence* is the degree that someone feels that other beings exist in the VE aware of the user's *existence. Environmental Presence* refers to the degree the environment is aware of user's existence and responds to user's interaction. According to his empirical definitions [15] Schloerb distinguishes two types of presence; S*ubjective presence* is the degree that a VE user feels physically present in the VE; and *Objective presence* is the likelihood of successfully completing a task, which is considered as the most significant criterion. The idea of *Cultural Presence* was introduced by Champion [16] and corresponds to the feeling that people from a specific culture while occupying a VE transform a digital space into a culturally meaningful place. Presence will be enhanced if the content is realistic and relevant in terms of social or cultural factors [17]. Pujol and Champion [17] also suggest that a definition of presence as simply 'being there' is unacceptable, because "*these words have different meanings in different societies, and because culture is understood by ongoing usage rather than by instantaneous depiction*." The first studies on presence assessment mainly focused on measuring the effects of VE technologies [18] using questionnaires [19, 20]. According to [21] researchers must collect complementary information in order to explore and investigate the factors inducing a high level of presence in cultural VEs. Here, we examine perceived presence after exposure to specific virtual museums and related artifacts and their context. The goal of the study presented in this paper is to explore whether users' level of 'presence' or 'sense of being there' is affected by the diverse technologies incorporated in the web sites of five on-line museums.

1.2 Virtual Museums Incorporating Diverse Technologies

In order to group the existing museum websites into representative categories, a team of four scientists with extensive experience in art education, educational design and ICT in education was assembled. Museum online resources were firstly divided according to their general representation method, which corresponds to panoramic images (QTVR), scalable images with text, searchable databases, 3D environments, and videos. The experts shared a preselected pool of museum websites and worked independently to extract within these categories, the factors that influence the user's experience according to their personal experience and recent literature results. In the next step, the factors were merged into a set of five qualities or capacities: imageability, interactivity, navigability, personalization and communication (Table 1). Each of them is defined by a number of features and that can be found in different degrees in the aforementioned visualization categories. Potential on-line museums to be incorporated in the study were compared against these specifications and the on-line museum which fulfilled better each category's expectations was selected. Of the five representative cases of virtual museums, four serve as on-line extensions to existing physical museums, while one only exists on-line without a physical counterpart.

Table 1: List of the questions included in the questionnaire and their correspondence with the GLOs

Virtual museum quality	Virtual museum definition
Imageability	Perceptual quality of a Virtual Environment that makes it memorable
Interactivity	The HCI functionality that makes a Virtual Environment able to communicate with its visitors
Navigability	The degree to which navigation capabilities are perceived from structural elements of the Virtual Environment
Personalization	The degree to which a virtual visit can be adjusted to personal preferences and needs
Communication	Communicational capabilities and communicative profile of the institution

In order to explore visitors' sense of presence while interacting with on-line virtual museums, five on-line international museums have been selected. They have been classified according to the following categories.

Imageability in panoramic images

The participants experience interactively the virtual museum space via panoramic images and get a feeling of the real museum's space thanks to the possibility to rotate and pan, zoom in and out, and navigate panoramic images of the galleries. This technique is convenient for medium to big size museums in which the architectural settlement is highly memorable or it is important to convey the design of the exhibition (selection, placement, lighting of objects, and continuity and cohesion of the exhibition discourse). The selected case for this study represented as M1 is Washington's National Gallery of Arts "Virtual Exhibition Tours" (http://www.nga.gov/onlinetours/index.shtm), in which visitors can select specific works of art for larger image views, close-up details, streaming audio commentary, and information about the object (Figure 1).

Figure 1: Washington's National Gallery of Arts "Virtual Exhibition Tours" website

Interacting with texts and scalable images

Image scalability and details on demand function provide the opportunity to examine museums' artifacts or parts of them in detail by applying zoom tools over high resolution images. These zoom-on-demand features take the dialectic between visitors and artifacts at a higher level since they allow seeing things that are not visible to the naked eye because of their size or because of the museums' spatial proximity restrictions. The VEs are highly interactive and enhance museum experience. The selected case for this study represented as M2 is the Metropolitan Museum of New

York (http://www.metmuseum.org/). In this website the visitors are able to navigate the museum's collections, locate exhibits of their interest, and take information via zoomable images and detailed textual exhibit information (Figure 2).

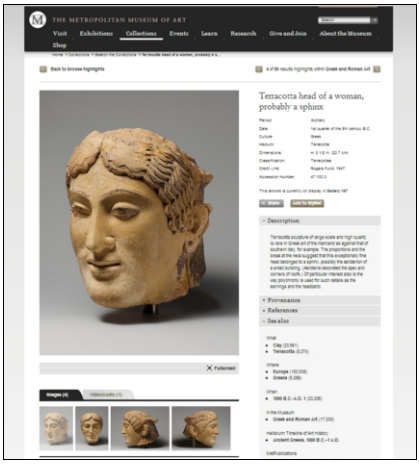


Figure 2: Metropolitan Museum of New York website

Searching utility for images and texts

This type of online museum environments offers multiple search options and enhanced image manipulation. This searchable database contains 2D representations, photos of objects along with their metadata, which are uploaded to the museum's online database in order to make a selection of the museum's collection. The website has a search engine which allows searching by content, concept, or metadata, thanks to an entry point usually consisting of a text area, in which visitors enter search criteria based on keywords. The selected case for this study represented as M3 is the Museum of Modern Art (http://www.moma.org/explore/collection/index). Through its database, visitors can navigate the various thematic areas of the museum and search its collections by artist, work or keyword. It also has an advanced search that allows adding refinement criteria such as period or object's management status (Figure 3).

Simulation and navigability in a virtual museum space

This type of online resource allows free and interactive real-time navigation in a 3D space reproducing more or less realistic reconstructions of museum galleries and containing mainly 3D representations of museum exhibits along with different kinds of associated information. This kind of online resources usually seeks to reproduce as realistically as possible [22] the experience of the visit, with the added value of the multimedia information, the hypertext/spatial navigation, and the possibility to manipulate (zooming, rotation) objects. The selected case for this study represented as M4 is the Van Gogh Virtual Museum (http://www.vangoghmuseum.nl/), which constitutes a typical example of a 3D reconstruction of a museum setting using computer-aided design tools and gaming technologies (Figure 3). The navigation is possible thanks to a user interface that is freely available for download or may be embedded in the web browser using common plug-ins.

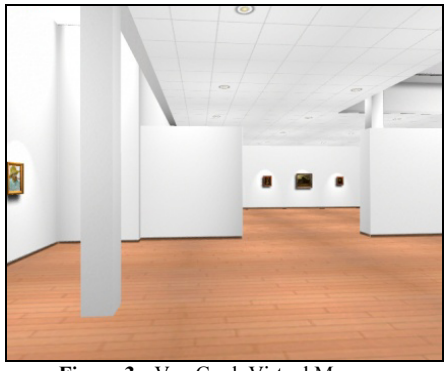


Figure 3: Van Gogh Virtual Museum

Personalized exploration of a video archive

The last category corresponds to museum websites containing embedded videos. The selected case for this study represented as M5 is the Virtual Silver Screen of the Library and Archives Canada (http://www.collectionscanada.ca/silverscreen/). The website uses Flash technologies to present different Canadian films (now historic documents) of the early 20th century organized by themes (Figure 4).

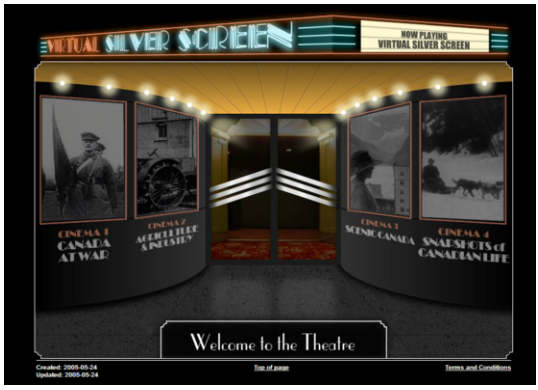


Figure 4: Virtual Silver Screen of the Canada Library and Archives website

2. Materials and Methods

2.1 Apparatus and Visual Content

The experiments ran on an HP workstation including two 2.4 GHz Xeon processors and 2048 MB of memory. Standard display technology, such as a 19' monitor was used.

2.2 Participants

A total of 64 volunteers (31 males and 33 females, aged 19-37) mainly undergraduate and postgraduate students from the Aristotle University of Thessaloniki, Greece,

participated in the experiment. Participants in all conditions were naïve as to the purpose of the experiment. After they navigated the virtual museums environment and performed the assigned tasks, they were subsequently asked to fill in the presence questionnaire. All the participants reported to have at least a basic knowledge of computers and their knowledge of the English language was excellent.

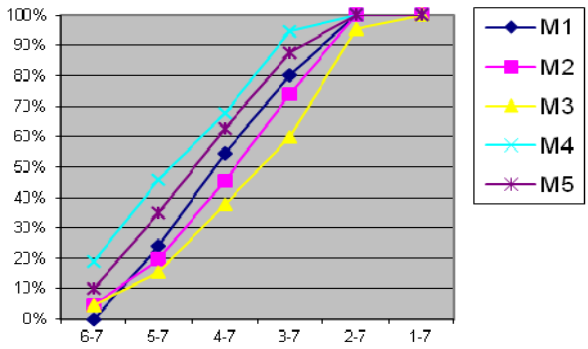
2.3 Experimental procedure and metrics

The settings were as realistic as possible with respect to those in practice. Four steps were undertaken including: (a) goal setting (users start with a plan of the tasks to be accomplished), (b) exploration (users explore the interface and discover useful actions), (c) selection (users select the most appropriate actions for accomplishing their task) and (d) assessment (users interpret the system's responses and assess its progression). Initially, the participants were informed about the scope of the study and were informally interviewed in private. The evaluation involved one participant at a time and experimental assistants provided help when needed. The evaluation and the interviews took place in the laboratory of Photogrammetry and Remote Sensing of the Aristotle University of Thessaloniki, Greece. The evaluation used cued testing, which involves explaining to the users what the program is about and asking them to perform specific tasks or to answer questions. The users were provided with written instructions concerning sets of predetermined tasks which guided them to navigate the virtual museum exhibitions' websites. The next stage was concerned with the user's ability to move through the contents of an interactive program in an intentional manner. They performed tasks such as exploring the virtual museum, selecting museum exhibits and getting informed by reading and listening to information about their context as well as zooming in the images. In order to measure perceived presence of visitor's interacting with the virtual museums presented in section 2.2, a Virtual Reality Presence Questionnaire (Slater 1999) was presented to them after they interacted with each virtual museum. The questionnaire included a series of questions inquiring about their experience rated on a numeric Likert scale from one to seven with seven representing a high level of presence and requiring around 10 minutes to complete. The original VR Presence questionnaire (Slater 1999) was modified since it was originally constructed to assess presence in immersive environments to specifically refer to a virtual museum scene in a website environment.. Its first two questions concerned the extent to which the participants used computers in their daily activities and the extent they were familiar with VR, AR and computer games, respectively. The next eight questions assessed the sense of being there and more specifically the degree to which individuals experience presence while interacting with a virtual museum exhibition (ibid.). The virtual museum visitors described their experience in virtual museums as compared with their experience in traditional museums. The participants were asked to assess whether the virtual museum visited appeared as a group of images that they had seen, or as a gallery that they had visited. They were asked to evaluate the virtual museum system intuitiveness, the naturalness of control and of the interactivity as well as the degree to which they felt present in the virtual museum exhibitions. Finally, the participants were asked to assess their involvement in the procedure evaluating the degree they lost the sense of time. The last question evaluated the degree to which the participants consider they completed the procedure and the relevant tasks.

3. Results

Initially, the average of each question per group of questions and museum was calculated. In this respect, a "virtual presence" index (denoted PM) was calculated by averaging the results of the respective questions per questionnaire and museum. Then, the Kolmogorov-Smirnov was used as a goodness of fit test and tested for normality of the distribution results. It is assumed that the average score of the presence questionnaire questions provides a way to measure the sense of presence of the end-users, derived after interacting with each of the five virtual museums. It is also assumed that the derived presence scores vary according to the technologies incorporated in each virtual museum for enhancing the virtual museum experience, e.g. causation is assumed. The presence results relevant to each of the five virtual museums were compared with a direct visual inspection of the relevant histograms. Conclusions were extracted and based on the frequency of the low (smaller than 3) and of the high ratings (greater than 5). In these graphs that present the frequency bars, the rating scale is divided in six (6) bars. Then, the total sum in each bar was divided by the total number of the participants' questionnaires and multiplied by one hundred for providing the % frequency of the counts for each bar. These graphs provide an image of participants' scores distribution. The data that emerged adding the frequencies for each bar, were visualized with the aid of cumulative histograms for the optical/ visual inspection of the differences in the data distribution. The standard deviation was also visualized. Boxplots were used to represent the central area, as well as the information concerning the range of scores. The statistical tests ANOVA single factor and t-test were used to explore whether the differences between the virtual museums' results are statistically significant or not.

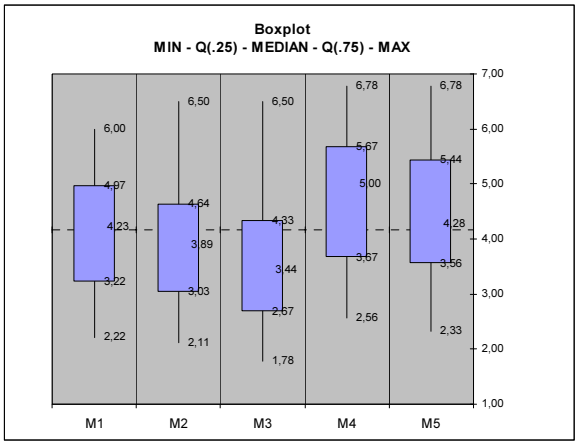
The total counts in each bin (i.e. the total number of PM indices that lie in each bin range) are then divided by the total number of counts (i.e. the total number of questionnaires) and multiplied by 100 to produce the per cent frequency of counts per bin. These graphs provide an image of the distribution of the ratings among the participants. Furthermore, by adding the frequencies of each subsequent bin a "cumulative frequency histogram" is produced (Graph 1).



Graph 1: Cumulative frequency of museums M1, M2, M3, M4, M5

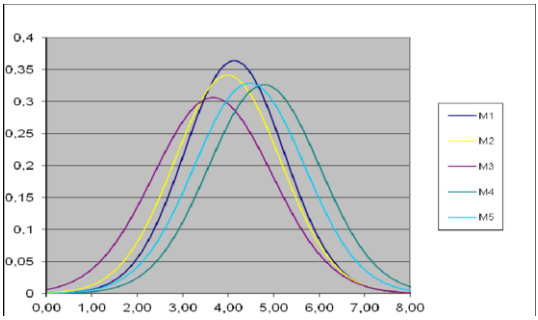
The cumulative frequency histogram (Graph 2) showed that the third museum had the lowest score in a scale range from 2 to 3 (35%). Also, the Van Gogh virtual

museum (M4) and the Cinema Virtual Museum (M5) had the highest scores in a range of 5 to 7 (41% and 36% respectively). The scores below the mean (3) were 90% for the Van Gogh virtual museum (M4) and from the Cinema Virtual Museum (M5), 80% (M1), 74% για το Metropolitan Museum of New York (M2) and 60% for the Museum of Modern Art MOMA (M3). According to the histogram of cumulative frequency and the boxplots the Van Gogh Virtual Museum (M4) has the greatest median (5) and the most high scores between 3,67 and 5,67, but at the same time it has a great range of scores. It follows the Cinema Virtual Museum (M5). Its greatest score is the same with that of the Van Ghogh Virtual Museum (M4), and more specifically 6,78 with a median 4,28. The half scores range between 3,64 and 5,44. Then it follows the virtual museum of the National Gallery of Art (M1) with median the 4,23 and the half of its scores in a range between 4,97 and 3,22. The Metropolitan Museum of New York (M2) comes immediately after with the highest score the 6,5 and the lowest the 2,11. Its median is 3,89 and its half scores range between 3,03 and 4,64. Finally, the Museum of Modern Art MOMA (M3), που has the lowest scores, with median 3, 44 and lowest score the 1,78. The half of its scores were from 2,67 to 4,33. The error bars shown in the Fig. 2 correspond to the standard deviation of each distribution. The comparative boxplots concern the sense of presence. The median scores of the five museums were noted with a dotted line.



Graph 2: Summary statistics (mean and standard deviation) for the five histograms

The elaboration methodology adheres to following four steps: (i) It is assumed that the average of the ratings in the eight questions gives a measure of "virtual presence" (PM index) for the five museums. (ii) It is assumed that this is directly related to the method used by each museum to enhance the virtual tour (i.e. "causation" is assumed). (iii) The PM results for the five museums are compared by direct visual inspection of the respective histograms. (iv) Conclusions are drawn based on the frequency of bad scores (< 3) and high scores (> 5). According to the Graph 3 that depicts a bell-shaped probability density curve there are not any results concerning the sense of presence in the websites of virtual museums. An expected result/note is that the Museum of Modern Art (MOMA) (M3) with the searchable database has accepted the most negative grades.



Graph 3: Normal distribution of museums 1, 2, 3, 4, 5

The above presented histograms revealed the following: (a) The frequency histogram of the third museum showed that it had the lowest score in the rank 2-3 (35 per cent), (b) The frequency histograms of the M4 and the M5 museum showed the highest scores in the range 5-7 (41 per cent and 36 per cent, respectively), (c) The cumulative histograms of all five museums revealed that the scores above average (3) were 90 per cent for M4 and M5 museum, 80 per cent for the M1, 74 per cent for the M2 and 60 per cent for the M3. Based on these findings (particularly the high scores M4 and M5 and the low score of M3) it may be argued that the methods employed to enhance the virtual presence in M4 and M5 are better than those used in museums M1 to M3. With the statistical test ANOVA single factor showed that there is marginally statistically significant difference between the museums in the sense of presence, because p=0,0019 (p<0,01). In order to explore whether there are statistically significant differences between the museums a t-test was conducted. The museums were tested by pairs. The results show that with strictest cut-off point for significance level (0 .01), the pairs of museums that have statistically significant differences between them are the following:

- M1 significantly higher presence than M3,
- M1 significantly lower presence than M4,
- M2 significantly lower presence than M4,
- M3 significantly lower presence than M4,
- M3 significantly lower presence than M5,
- M4 significantly higher presence than M5.

4. Discussion and conclusions

The statistical results indicate that the virtual museum of Van Gogh virtual museum (M4), which uses Web3D technology and offers real-time navigation in three-dimensional space, has evoked a high level of perceived presence. While interacting with M4, the virtual visitor could view each cultural object from different angles based on its context, and, therefore, complete and documented mental models are evoked realizing the full potential of the virtual museum [23]. In M4, the virtual visitor can acquire the same or even additional information compared to the experience of visiting the physical museum. The virtual visitor is able to dynamically interact with the virtual museum, wonder freely in the 3D space, ‘stand’ in front of the exhibits and get information about them and their context. Potentially, perceived presence after being

exposed to the Van Gogh virtual museum could have been even stronger. The technical flaws of the virtual museum application and its requirements in terms of Internet speed affected the experience of the virtual visitors, as well as the feeling of presence in the 3D interactive environment. The experimental process showed that the 3D virtual tour of the museum suffered certain usability issues. For instance, in order to have access to the virtual museum, the user initially would have had to create an account. A number of participants reported that despite the fact that they had followed the instructions provided, they faced difficulties while navigating the virtual museum. After creating an account, the visitor was instructed to install the standalone virtual museum application. In some cases it was reported that the installation caused confusion, delays and problems for certain participants who had limited Internet experience. For the application to properly function, an easy-to-follow procedure and constant speed Internet connection was a prerequisite. The application required fast network access to the server of the museum in real time, in order to receive the data requested by the virtual visitor, for instance, specific information about a painting. In three cases, participants complained that here were either delays or failure of data mining the virtual museum exhibits because of a slow Internet connection.

A broader look at the results of this study shows that virtual visitors feel present in a virtual museum when they can dynamically interact with the environment while being exposed to multimodal (tactile, visual and aural) interaction while navigating through it. Based on the statistical analysis presented in the previous section, it can be concluded that interacting with text, scalable images and 3D models in a virtual museum website, such as the Metropolitan Museum of Art in New York (M2), results in high levels of perceived presence. Multimodal interactivity enhances the feeling of being there in a technologically facilitated environment, such as a virtual museum interface. Our results revealed that the experience of browsing through virtual museum space and the ability to select exhibits to view enhances visitors' sense of presence by making them feel part of the virtual museum. The direct interaction with dynamic objects contributes to the visitors' sense of immersion and allows them to be absorbed by the presentation of the virtual exhibition.

The text and Quick Time Virtual Reality (QTVR) technology virtual museum that imitates reality (M1) received high scores. As other researches pointed out QTVR technology can provide a sense of presence [24, 25] and give the sense of exploration of the museum scene.

As shown by the presence scores, certain technologies of personalized exploration of a video archive, as used by the Virtual Silver Screen of the Canada Library and Archives website (M5), contributed significantly to visitors' sense of presence. The user's interaction with the virtual museum environment enhanced their sense of presence providing a low-cost and user-friendly solution of wide acceptance which induces satisfactory level of perceived presence in a virtual museum.

The Museum of Modern Art MOMA (M3), which uses a searching utility for images and texts, induced the lowest level of presence in relation to the remaining virtual museums of this study. M3 did not intrigue the visitor's interest by providing limited information about the exhibits and did not encourage the virtual visitor to actively participate in the museum experience. Presence and enjoyment have been shown to be positively correlated and can play an essential role in the virtual museum experience [4]. The common approach of employing a thumbnail gallery leading to high resolution images was proved to be inadequate in terms of visitors' expectations as well as failed to provoke feelings of presence in a virtual museum environment.

More research is necessary to further identify the correlations between users' learning and the usability of virtual museums interfaces. Future research will investigate if and how they are influenced.

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