ANALYSIS OF THE USER EXPERIENCE (ON SITE VS VIRTUAL REALITY) THROUGH BIOLOGICAL MARKERS AND COGNITIVE TESTS IN MUSEUMS. THE CASE OF MUSEO CRISTO DE LA SANGRE (MURCIA, SPAIN).

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Abstract
Digital technologies have changed almost every aspect of our lives, including the way we access heritage. Following the pandemic caused by Covid 19 and the technological evolution of recent years, museums and institutions, among others, have changed the way they display their collections, taking a greater interest in new technologies, platforms and digital software. This technological boom finds its greatest transformation with the implementation of Virtual Reality (VR) and Metaverse in the museum sector. This article shows the concrete influence of VR/Metaverse in a museum room previously digitised through different techniques. Subsequently, the impact over user experience in the VR scenario versus on-site visit has been measured. In parallel, the measurement of the enzyme alpha-amylase in saliva, a cognitive test and usability test (SUS) were carried out to determine the learning capacity and degree of satisfaction obtained with experience alongside the room of the Museo de la Sangre in Murcia (Spain).

Keywords: Digitisation, Virtual-Reality, Spatial, Alpha-Amylase, System Usability Scale, Metaverse.

1. Introduction:

The pandemic caused by the Covid 19 virus has placed us in an unusual situation, which has made us question and change our habits and customs, to the point of readapting our priorities and most fundamental considerations. Technology, little by little, has been revealed as a great ally to overcome these problems caused by the virus. A set of platforms, tools and software have made it possible to create immersive environments that favour communication and learning to a greater extent, with the aim of generating an interactive paradigm in which users can visualise and/or interact with objects in a way that has never been possible before. We must be aware that Virtual, Augmented or Mixed Reality are far from being exclusive to the videogame industry and are increasingly being used in education, research, experimentation or heritage.

During the period of confinement, we could see how museums reacted by trying to offer in digital format everything they could that was previously done in person, some of them approached the period of closure more prepared than others. With the arrival of the new reopening, museums focused on systematising their routes and applying the necessary measures to ensure a safe opening for their visitors and workers. From that moment until today, the particularity that we are experiencing before these situations has led museums to take a different interest in the digital medium, directing their resources and efforts to create new forms of presence that, without a doubt, direct the museum towards a hybrid format of exhibition, in which virtuality is combined with physical presence (Hyunae 2020).

In this respect, Virtual Reality has much to contribute, being one of the greatest incentives for museums to introduce new ways of attracting visitors as well as to continue to fulfil its mission, as we will see throughout this article, with the case study of the Museo de la Sangre de la Región de Murcia (Spain) which has implemented this technology in a pioneering way. This study shows the results obtained after measuring the enzyme alpha-amylase in saliva, in the visualisation with Virtual Reality glasses of one of the rooms of the Museum to find out the learning capacity and the degree of satisfaction obtained from the visualisation of the Museum's sculptural heritage.

2. Innovative experiences in museum virtualization.

Museums and cultural institutions or entities are at a time when developing digital products and new models of virtualisation to show visitors has become the order of the day. They seek to offer new forms of exhibition that are articulated with their own physical exhibitions to show their contents from the use of new technologies through 360º virtual tours, virtual or augmented reality, etc. Mainly, demanding to reach new audiences anywhere in the world (Shehade et al. 2020).

The first products they offered were the 360º digital tours that have become the basis for the virtualisation of museums through 360º images of their rooms or 360º videos of their tours (Scavarelli 2021). This allows the user to tour the galleries and exhibitions at will and at their own time through any device (web, mobile or virtual reality glasses). In this way, the exhibition reaches any location and public. Examples include the website "Miguel Delibes: Su vida y su obra," hosted by Acción Cultural Española, which provides detailed information about the author, according to the Ministry of Education, Culture and Sport (Acción Cultural Española). On the other hand, Grimshaw's Tate Modern Project is a major architectural effort to expand the museum, according to information from Tate (Tate). The websites are listed in the references section.

Another product that has been widely used in recent years has been websites and microsites, which promote an approach by reaching the public through digital channels, but at the same time offering an incentive to bring them in person to complete the information in the Museum itself (Hamza et al. 2022). Examples are the websites of The Museum of Modern Art presents the exhibition "Julia Phillips" (Museum of Modern Art, n.d.), while the Van Gogh Museum offers a series of stories related to art ("Art and Stories: Stories," Van Gogh Museum, n.d.). The websites are listed in the references section.

Finally, the product currently most in demand by users and with the greatest loyalty and possibilities have been the experiences of realities (virtual, augmented or extended), which have allowed an even closer approach to the spectator, with the 3D digitalisation of their works (Bellido, 2016) and/or augmented reality experiences (Puig 2020), which have brought static exhibitions to life (Yuting 2022). Creating a third dimension, both with the use of Virtual Reality glasses and through virtual applications or platforms, and offering a new, interactive, didactic and different perspective from the traditional exhibition. Examples include the Louvre offering a unique experience with "The Mona Lisa in virtual reality in your own home" (Louvre Museum, n.d.), while the Smithsonian provides a modern perspective on visiting the museum in its blog "Do it for the Gram" (Smithsonian, n.d.). The websites are listed in the references section.

At national and regional level, there are numerous centres in Spain that already have microwebs and 360º digital tours of their museums, such as the National Archaeological Museum in Madrid ("Museo Arqueológico Nacional en Madrid"). Likewise, the Salzillo Museum in the Region of Murcia offers a virtual tour ("Salzillo Museum in the Region of Murcia"). The websites are listed in the references section.

3. Virtualization of "*Museo Cristo de la Sangre*" (Murcia-Spain).

Seeking to offer a completer and more attractive product for spectators and visitors, the Museo Cristo de la Sangre (owned by the oldest of the Holy Week brotherhoods of Murcia) created the virtualisation project of the museum through the digitalisation of the sculptures and the 3D recreation of the architecture of the first room to be viewed in Virtual Reality.

3.1. The "Museo de la Sangre" of Holy Week.

The "*Museo del Cristo de la Sangre*" is a cultural institution of great importance in the city of Murcia. Its existence is linked to the very history of the institution that makes it possible, in this case, the so-called *Real, Muy Ilustre, Venerable y Antiquísima Archicofradía de la Preciosísima Sangre de Nuestro Señor Jesucristo*, whose origins date back to the year 1411. The sculptural heritage treasured by this penitential brotherhood, which dates from the 17th to the 21st centuries, and which is carried in procession through the city every Holy Wednesday, was kept in narrow rooms in the upper part of the church of El Carmen, until 2018, when a new headquarters was opened in an adjoining space. Its museography project was truly innovative, with the sculptures displayed at spectator level and with a lighting project that highlighted the dramatic aspects of images that recreate the Passion of Christ.

Also, since that year, the museum has developed a cultural action programme that has made it more accessible to the public, through innovative temporary exhibitions, conferences and other cultural activities. But, above all, the implementation of a digitisation and virtual reality project to make its artistic heritage more accessible has been of great interest. In particular, the first room of the museum, where sculptures dating from the 17th and 18th centuries are exhibited, linked especially to two artists, Nicolás de Bussy (ca. 1640 - 1706) and Roque López (1747 - 1811), who constitute the alternative to the sculpture of Francisco Salzillo (1707-1783), who has his own museum in Murcia, linked to another brotherhood, the Real y Muy Ilustre Cofradía de Nuestro Padre Jesús.

All the sculptures in this first room have been digitised and from this project, a museum has been recreated in virtual reality. It all began with the most important sculpture of the brotherhood and the museum, the *Cristo de la Sangre* by Bussy, a work from 1693. After its digitalisation, a replica of the bust of this sculpture was created to recreate a visit that allows visitors to develop their sense of touch, sight, hearing and smell, as it transports them to the day on which it goes out in procession at Easter. Likewise, museum users can have an immersive experience by visiting this museum room with 3D glasses, where they can appreciate the polychrome wooden sculptures in great detail, as well as learn about the history of each one of them. This fulfils the mission that every museum should have, as stated by the International Council of Museums (ICOM), in the latest definition approved in Prague in 2022, as these institutions should tend to the participation of communities, "offering varied experiences for education, enjoyment, reflection and the exchange of knowledge" (ICOM 2022).

3.2. Background of the Museum's virtualization project.

The Museum's virtualisation project consists of three distinct phases that have encompassed other studies described in the research cited below.

The first phase consists of the digitisation of a Christ, called Christ of the Blood, using three different digitisation techniques: photogrammetry, laser scanning and structured light scanning, obtaining very positive results, as described in Melendreras et al. (2020), Melendreras et al. (2022a) and Melendreras et al. (2022b). Finally, it was concluded that the combined use of medium- and high-resolution structured light scanners (focused on the digitisation of small elements such as teeth, beard, nose, etc.) offered the best results in terms of accuracy, quality and efficiency. Thus, it was decided to use the structured light technique for the digitisation of the rest of the sculptures in the museum hall. Specifically, a full-length Christ, a small angel, two busts and a third bust created from the scan of the full-length Christ scanned for the creation of a replica for the blind and the subject of study in Melendreras, et al. (2022c) were digitised. However, due to the large size of the sculptures obtained with this scanner (excessive size of the models and the number of polygons), which could not be incorporated into the metaverse software, it was decided to digitise all the sculptures in the room again with an iPhone-type mobile device, using the Polycam application.

In a second phase, a digital tour of the Museum was created by capturing 360º images with the aim of reaching a wider public and distributing them digitally, as the Museum was still under access restrictions at that time, caused by the pandemic.The 360º images were taken with the Xphase® camera and the virtual tour of the Museum was created with the 3D Vista® software, incorporating images of the museum, information points and videos to complete the graphic information offered. The website is listed in the references section.

Finally, the third phase of this article consists of the creation of an immersive virtual environment with the Blender and Spatial software, of the first room of the Museum, seeking to be as faithful as possible to reality and to the digital tour, mentioned above, to be viewed through the Oculus Quest 2 ® Virtual Reality glasses and its comparison with reality through the collection of salivary samples and usability tests that verify the creation of virtual content as a satisfactory means of enjoying the heritage.

3.3. Design of the virtual experience.

The Museo de la Sangre, as described in section 3.1., consists of three distinct rooms, however, due to time and volume reasons, this study has focused exclusively on the creation of the virtual environment of the first room of the Museum, as mentioned above.

The virtual content of the museum was created using Blender® and Spatial® software. Blender software is a free and open-source 3D authoring software that supports virtually all aspects of 3D development. It has a solid foundation of modelling, texturing, rigging, animation, lighting, and a host of other tools for complete 3D creation. All the objects included in the room, such as walls, ceilings, doors, floorboards, lights, etc., were created in this programme. At the same time, points of light were added to the generated lights to recreate the appearance of the real environment. Likewise, special care was taken in the choice of textures to make them as realistic as possible, such as the texture of the floor, which was imported using a .png image with a colour very similar to the real floor of the Museum. The textures of the walls and ceiling were simpler, as they consist of a basic uniform colour, so it was sufficient to apply a uniform matte colour to them by changing the surface of the object, using the *shading editor* tool (fig. 01).

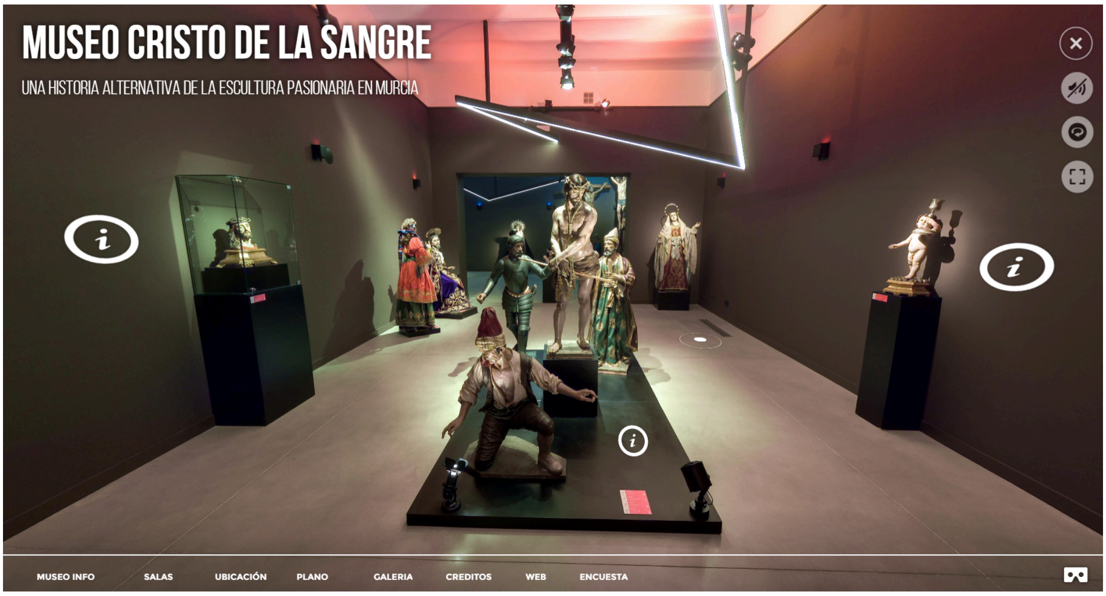


Fig. 01: Virtual Tour 360º Source:
http://www.coloraos.com/index2.php?option=com_wrapper&view=wrapper&Itemid=69)

These textures were imported with resolutions of 2048 x 2048 pixels, without shadows or reflections, in order to try to reduce the size of the global file as much as possible. Since one of the main problems of online virtual rooms is the reduced size that they currently allow. Finally, it was also decided to eliminate the points of light and it was decided to make a bake or fixed texture with the points of light of the spotlights on the walls to give it a realistic touch, although in reality, they were not being illuminated. The final result of the environment created in Blender is shown in the following image (fig. 02).

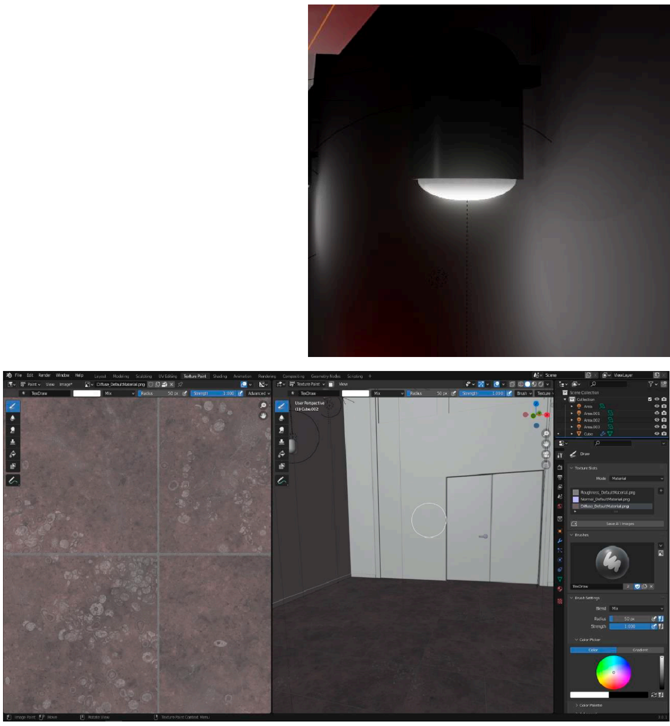


Fig. 02: Creating elements in Blender.

This environment was then exported in .glb for import into Spatial, which is a Metaverse platform, available both on the web and as a mobile application. This platform only supports connection to Meta Quest and Meta Quest 2 VR devices.

Once this room is loaded into Spatial, we proceed to finish importing and modelling the rest of the missing elements. The 3D models of each of the digitised figures are imported and placed on their respective pedestals inside the museum. The labels with their names, created by photographing them in the Royal Museum, are also placed on these pedestals (fig. 03).

Fig. 03: Creation of the Museum room in Blender.

The result obtained, as can be seen in Fig. 04, is quite satisfactory, despite the limitations of quality and size of the files imported into Spatial. The Museum created in Spatial can be visited in the link found in the Web References Section.

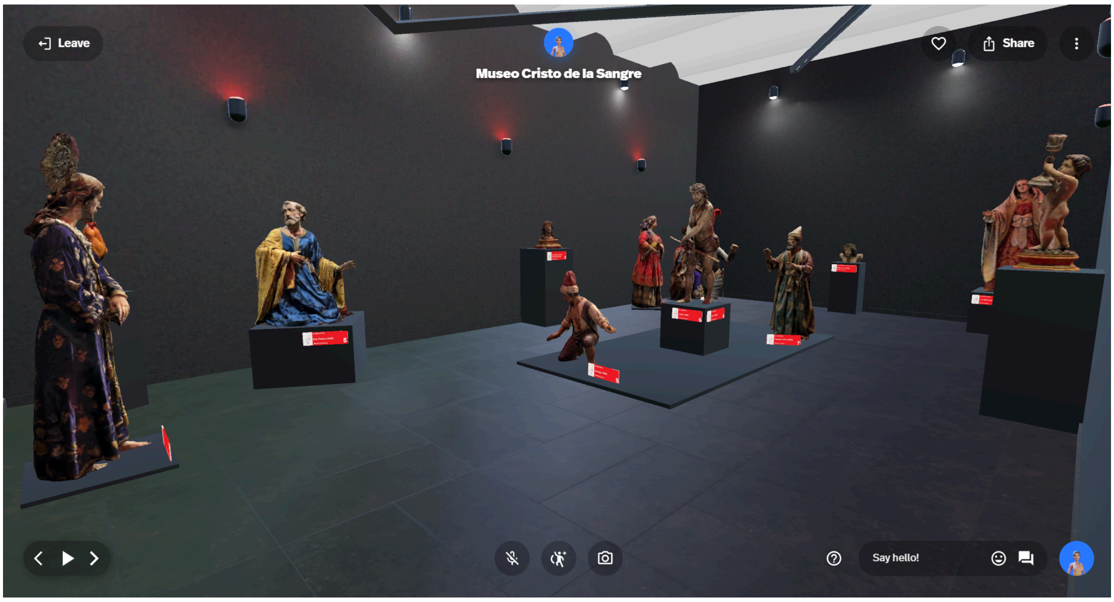


Fig. 04: Virtual room of the Museum created in Spatial.

4. Study methodology

This study aims to measure whether the VR experience really does show significant differences compared to the same experience in person, in terms of user satisfaction, usability and information retention.

To this end, two visits will be prepared with two different groups of people: one group will take the traditional guided tour of the Museum, in person, while the other group will take the guided tour through Virtual Reality. The groups will be made up of people between 18-75 years of age of both sexes and of different academic backgrounds, as regular visitors to the museum and recommended users of VR technologies. These individuals will undergo the following tests:

4.1. Cognitive test: A knowledge and/or learning test is carried out to measure the degree of comprehension, attention and memory after the guided visit or VR experience.

4.2. Biological test: A pre/post saliva test is performed to measure the variation in alpha-amylase enzymes indicative of psychological stress and cortisol levels indicative of physical stress (Informed consent, University Ethics Committee).

4.2.1. Measurement of saliva flow:
Patients were asked to refrain from brushing their teeth or ingesting food or any other substance, e.g., medication or lip cosmetics. Before collecting saliva, each patient rinsed their mouth with distilled water. All samples were collected at room temperature, which was stable. Unstimulated saliva was collected by the drainage method (31), without chewing movements, in dry plastic vials, with the test subject seated in a relaxed position. Approximately 5 ml of unstimulated whole saliva was collected. In all cases, saliva samples were collected in the morning, between 10:00 and 12:00 hours. Unstimulated whole saliva flows were measured in ml/5 min. The presence of blood contamination in the samples was excluded (by visual inspection scale).

4.2.2. Laboratory methods:
Saliva was centrifuged immediately after collection at 3000 g for 10 min. Samples were then placed in Eppendorf tubes and frozen at 80°C for preservation until analysis.

AAS (Alpha-amylase enzyme) was measured using a commercial kit (Olympus®) and the methodology recommended by the International Federation of Clinical Chemistry and Clinical Laboratory Sciences (IFCC). This analysis was performed by a kinetic spectrophotometric study using 4,6-ethylidene (G7)-nitrophenol (G1)-alpha-D-maltoheptaboside (ethylidene-G7PNP) as the enzyme substrate. The hydrolysis intermediate of the substrate is reacted with alpha-glucosidase, producing p-nitrophenol as the final product of the reaction. The rate of p-nitrophenol formation is directly proportional to the alpha-amylase activity of the sample and can be determined by measuring the absorbance at 405 nm. The reagent volumes were adjusted according to the manufacturer's instructions. The assay was adapted to an automatic analyser (Olympus A400®). The method produced an inter-assay CV of less than 3% and a linear regression coefficient of 0.992. The measured concentration results are expressed in International Units (IU) (Roca et al. 2022).

Cortisol was evaluated by a solid-phase, competitive chemiluminescent enzyme immunoassay (Immulite; Siemens, Erlangen, Germany), displaying within-run and between-run imprecision lower than 10%, recovery rates between 92% and 120%, and a limit of detection of 0.2 nmol/l (32, 33).

4.2.3. Statistical analysis:
Data were analysed using SPSS 21.0 statistical software (SPSS Inc., Chicago, IL, USA).

For the general analysis of the study variables, basic descriptive methods were used for qualitative variables, obtaining the number of cases present in each category and the corresponding percentage; for quantitative variables, maximum, minimum, mean and standard deviation-standard deviation values were calculated.

To compare means between groups, the Student's t-test was used to compare means between groups, the Student's t-test was used for normal independent samples with the Kolmogorov-Smirnov test ($n > 30$).

The significance of the results was assessed by calculating the effect size (d) proposed by Cohen (35), where values of 0.2, 0.5 and 0.8 typically correspond to low, medium and high effects. Correlations between variables were performed using Pearson's correlation coefficient. The significance level was set as $P < 0.05$.

4.3. Adaptation test: With the intention of verifying whether the technology is a barrier to the development of the experiment and/or user adaptation to VR, the SUS (System Usability Scale) test is performed to measure the usability of the device in the user experience carried out, and to determine the satisfaction or irritation of using this technological tool. (Brooke 2013).

The SU scale is typically used after the respondent has had the opportunity to use the system being evaluated, but before a briefing or discussion takes place. It consists of a 10-question questionnaire based on a 5-point Likert scale ranging from "strongly agree" to "strongly disagree".

Respondents should be asked to record their immediate response to each item, rather than thinking about the items for a long time. All items should be checked. If a respondent feels that he/she cannot answer a particular item, he/she should mark the central value of the scale, located at score 3.

SUS yields a single number that represents a composite measure of the overall usability of the system under study (Bangor et al. 2009).

To calculate the SUS score, the contributions of each item are first summed. For items 1,3,5,7 and 9, the score contribution is the position on the scale minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the position on the scale. The sum of the scores is multiplied by 2.5 to obtain the overall SUS value. SUS scores range from 0 to 100 (Brooke 1995).

In order to carry out the face-to-face and immersive experience and the tests described above, the following study protocol is established:

1. Preparatory information: Brief information on the protocol for the experience.
2. Biological test: Pre-visit/experience saliva sampling.
3. Experience: On-site visit / virtual visit
4. Biological test: Post-visit/experience saliva sample collection.
5. Cognitive test: Knowledge test of auditory or visual information observed in the experience or visual.
6. SUS test: Usability test on VR devices to VR users during the experience.

The following is a description of how each of the visits was carried out:

<u>On-site visit</u>

35 people met at the Museum, in 5 groups of approximately 7 people and at different times, in order to make the visit in a comfortable and relaxed manner. First of all, the visitors entered the Museum library, where they were informed about what they were going to do and a saliva sample was taken before the experience. After the saliva samples were taken, they were taken to the first room of the

Museum, where they were given a guided tour in the traditional way, providing them with some relevant information about the sculptural heritage they were observing. The visit lasted approximately 15 minutes. At the end of the visit, a post-visit saliva sample was taken again, and they were asked to fill in a test on the computers available in another room on the knowledge they remembered from the visit (fig. 05).

Fig. 05: On-site visit

<u>Virtual tour</u>

35 people were invited in groups of 2. The virtual visit took place in the Virtual Reality Room of the Universidad Católica San Antonio de Murcia, which was prepared and equipped with the appropriate equipment (computer and glasses) for the virtual visit. As in the face-to-face group, a saliva sample was taken before and after the visit and the guided visit was carried out in this case with virtual reality goggles. The visit also lasted approximately 15 minutes (fig. 06).

Fig. 06: Virtual reality visit

In both cases, saliva samples were collected in test sample tubes and stored cold in a cooler with ice blocks. Each of the samples were numbered, as No. A (the pre-samples) and No. B (the post-samples) for further analysis.

The forms of cognitive test after both experiences that were filled out for each group can be found in the Web References section. Also users of the VR experience also took a SUS test, to find out the degree of satisfaction and/or difficulty in using the Virtual Reality goggles and controllers. This form can be found in the Web References section.

5. Results.

The results obtained from the three tests carried out during the study conducted in this article are shown below, with the following data being obtained:

5.1. Cognitive test:

QUESTIONS	ANSWERS	
	ON SITE VISIT	**VIRTUAL REALITY VISIT**
1. Sample nº:	35 samples	35 samples
2. Gender:	Female: 51.4% (18) Male: 48.6% (17)	Female: 48.6% (17) Male: 51.4% (18)
3. Age: Average:	43 years	47 years
4. Had you previously taken a guided tour of a Museum? / 4. Had you put on Virtual Reality glasses before?	Yes: 70.6% (24) No: 29.4% (10)	Yes: 62.86% (22) No: 37.19% (13)
5. To what degree of 1-10 did you like the experience?	8: 17.1% (6), 9: 40% (14) and 10: 42.9% (15).	7: 8.5 7% (3) 8: 8.57% (3), 9: 11.43% (4) and 10: 71.43% (25)
6. Remember how many angels originally accompanied the *Cristo de la Sangre*?	1 angel: 8.6% (3), 3 angels: 5.7% (2), 4 angels: 11.4% (4) and 5 angels: 74.3% (26). Correct answer: 5 angels.	1 angel: 8.6% (3), 2 angels: 14.3% (5), 3 angels: 8.6% (3), 4 angels: 17.1% (6) and 5 angels: 51.4% (18). Correct answer: 5 angels.
7. Do you remember the purpose of the creation of the tactile replica of the *Cristo de la Sangre*?	Replica for the blind: 100% (35)	Replica for the blind: 94.3% (33), Replica for exposure: 5.71% (2). Correct answer: replica blind
8. Do you remember what material the tactile replica of the *Cristo de la Sangre* has been made?	Resin: 100% (35)	Resin: 91.43% (32), Wood: 5.71% (2), Clay: 2.86% (1). Correct answer: Resin.
9. Do you remember the name of the predominant sculptor in the room?	Roque López: 11.43% (4), Nicolás de Bussy: 88.57% (31). Correct answer: Nicolas de Bussy	Roque López: 14.3% (5), Nicolás de Bussy: 85.71% (30). Correct answer: Nicolas de Bussy
10. Do you remember the name of the sculptural group that is in the center of the room?	The Praetorium: 100% (35)	Praetorium: 94.29% (33), Samaritan: 2.86% (1), Denial: 2.86% (1). Correct answer: Praetorium
11. Remember what the Samaritan woman has in her arms?	Saddlebag: 80% (28), Cloth: 20% (7). Correct answer: Saddlebag	Saddlebag: 77.14% (27), Cloth: 20% (7), Rope: 2.86% (1). Correct answer: Saddlebag
12. Do you remember the colour of the walls of the room?	Light-White Tones: 17.1% (6), Dark tones-black/brown: 82.9% (29). Correct answer: Dark tones	Light-white tones: 14.3% (5), Dark tones-black/brown: 85.7% (30). Correct answer: Dark tones
13. Have you been able to move satisfactorily around the room?	Yes: 100% (35)	Yes: 100% (35)
14. Did you find it a valid didactic experience for the knowledge of sculptural heritage?	Yes: 100% (35)	Yes: 100% (35)
15. Did you find the experience appropriate to have more than one person in the room?	Yes: 100% (35)	Yes: 100% (35)

Table 1: Results of cognitive tests - On-site visit test vs Virtual Reality test

The following table shows a summary from the table above of the correct and incorrect answers to questions 6-12 of the cognitive test. The other questions are not included in the table, as they are questions of personal data or personal opinion. Finally, the same table shows the success rate, i.e. the percentage of success for each group. We can see that in all the questions the percentage of success is high in the on-site visit except for the last question.

Test Results On site Visit							
Question No.	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Incorrect	9	0	0	4	0	7	6
Correct	26	35	35	31	35	28	29
% Success On site Visit	**74,3%**	**100,00%**	**100,00%**	**88,6%**	**100,00%**	**80,00%**	**82,9%**
Test Results Virtual Reality Visit							
Question No.	6	7	8	9	10	11	12
Incorrect	17	2	3	5	2	8	5
Correct	18	33	32	30	33	27	30
% Success VR Visit	**51,4%**	**94,3%**	**91,4%**	**85,7%**	**94,3%**	**77,1%**	**85,7%**
Difference % Success	*22,86%*	*5,71%*	*8,57%*	*2,86%*	*5,71%*	*2,86%*	*-2,86%*

Table 02: Summary and comparison results of cognitive tests

As can be seen in all the questions, better results are obtained in the on-site test than in the VR test, except for the last question, which is a visual memory.

The following table has been calculated using the following formula to obtain the transformed mark for each question out of 10 points.

$$Transformed\ mark = \frac{7-A}{10*7}$$

where A = the number of incorrect questions.

0 = no incorrect questions
1 = 1 incorrect question
2 = 2 incorrect questions
3 = 3 incorrect questions
successively

Then, the weighted average of all transformed marks of all questions is taken.

Average grade Test On-site visit	8,98
Average grade VR Test	8,49

Table 03: Final average grade of the cognitive tests.

5.2. Biological test:

The sample consists of 70 people, 53% (37/70) of whom are male and 47% (33/70) female, with a mean age of 45 ± 12 years (minimum 12 and maximum 71 years). Each of the groups is composed of 50% (35 participants) of the sample. No statistically significant differences were found between the two groups in relation to gender or age.

Results for the Museum Group (on-site visit):

Participants in the Museum Group had an anticipatory stress of 143 766 ± 130 325 AAS IU, with a decrease of 39 645 AAS IU, with no statistically significant differences (p=0.136), to 104 121 ± 85 004 AAS IU after the museum visit. With respect to cortisol, anticipatory stress was 0.18 ± 0.13 IU, with a decrease of 0.02 IU, with no statistically significant difference (p=0.466), to 0.16 ± 0.11 IU after the museum visit. No statistically significant differences were found between changes in ASA and/or cortisol and the rest of the variables in the Museum Group.

Results for the Virtual Reality Group:

Virtual Reality participants had an anticipatory stress of 66 397 ± 49 508 IU AAS, with an increase of 14 925 IU AAS, with no statistically significant differences (p=0.307), to 81 322 ± 70 023 IU AAS after wearing the VR goggles. With respect to cortisol, anticipatory stress was 0.13 ± 0.08 IU, with an increase of 0.01 IU, with no statistically significant difference (p=0.478), up to 0.12 ± 0.09 IU after wearing the VR goggles. No statistically significant differences were found between changes in ASA and/or cortisol and the rest of the variables in the VR Group. 97% (34/35) of the participants in this group considered that "they were able to move freely and satisfactorily around the room. 100% of the sample found Virtual Reality to be "a valid didactic experience for learning about sculptural heritage". This can be seen in Fig. 07.

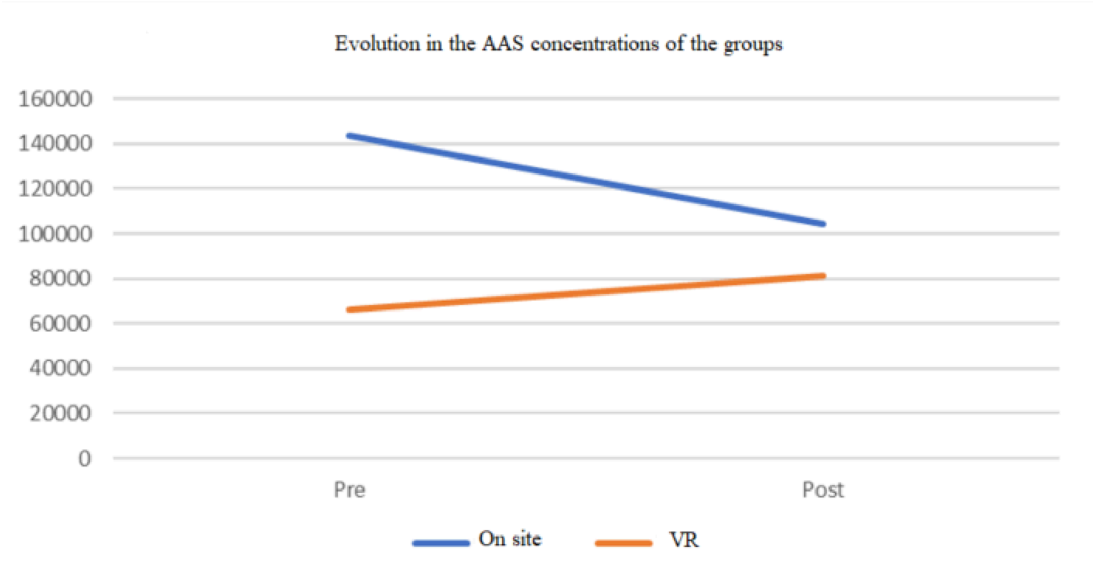


Fig. 07: Evolution in the AAS concentrations of the groups. Mean Values.

Comparison between groups:

In the Museum Group 72 % (25/35) of the participants did have a previous guided tour and in Virtual Reality Group 63 % (22/35) did have a previous experience with Virtual Reality glasses. There were no statistically significant differences between the Museum Group (9.4 ± 1 points) and the Virtual Reality Group (9.25 ± 0.74 points) in the evaluation of the experience. There are no statistically significant differences in the scores between people who had taken a previous guided tour (for the Museum Group) or had used the Virtual Reality glasses (for the VR Group), compared to those who had not.

Anticipatory stress was higher for participants in the Museum Group compared to the Virtual Reality Group, with a mean difference of 77 369 ± 23 564 AAS IU [(95%CI 30 346 -124 392) p = 0.002]. With respect to cortisol there is no statistically significant difference (p = 0.225) between the increases in both groups. In post-intervention stress there are no statistically significant differences neither for ASA (p = 0.085) nor for cortisol (p = 0.217).

The (post-post) increase in ASA was higher for GRV participants compared to GM, with a mean difference of 54 570 ± 23 372 IU ASA [(95%CI 7 930 - 101 210) p = 0.023] (fig. 08). With respect to cortisol there is no statistically significant difference (p = 0.227) between the increases in the two groups.

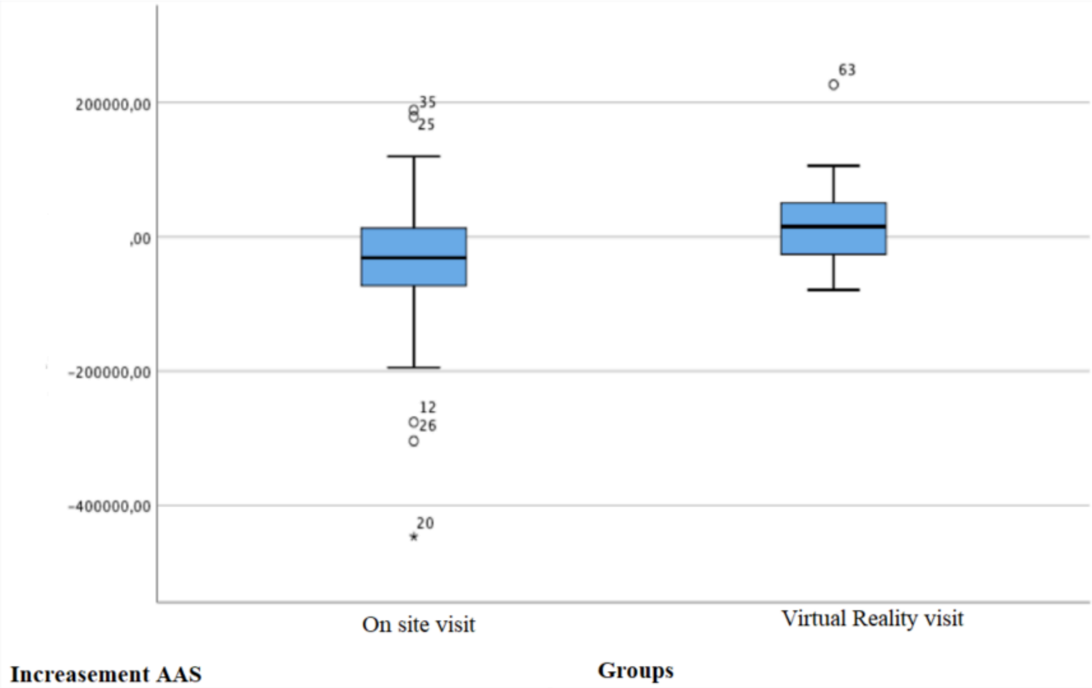


Fig. 08. Box diagram of AAS increases for both study groups.

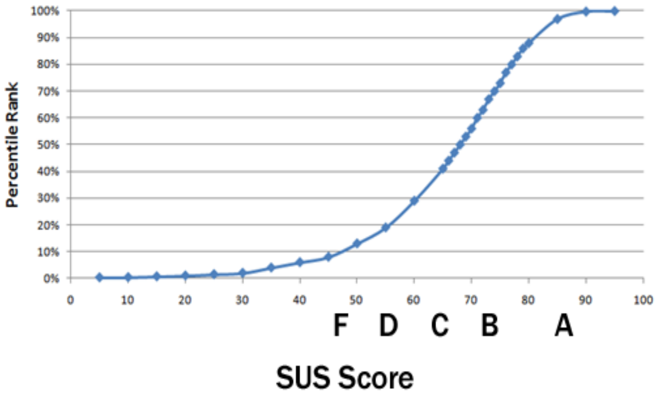
5.3. Usability test:

User	1. I think I would like to use Virtual Reality (VR) frequently.	2. I found VR unnecessarily complex.	3. I thought VR was easy to use.	4. I think I would need the support of a technician to be able to use VR.	5. I found that the various functions of VR were well integrated.	6. I thought there was too much inconsistency in VR.	7. I imagine most people would learn to use VR very quickly.	8. I found the VR very cumbersome to use.	9. I felt very confident using the VR.	10. I needed to learn a lot of things before I could get started with VR.
1	5	1	5	1	4	3	2	1	5	1
2	5	1	1	1	5	1	5	1	5	1
3	3	2	4	3	4	2	4	2	3	2
4	4	2	4	2	4	2	4	2	4	2
5	3	2	4	2	4	2	4	2	4	2
6	1	2	4	4	5	2	4	1	4	3
7	4	1	5	1	4	1	4	2	4	1
8	4	1	4	2	3	2	4	1	4	1
9	4	2	4	2	4	2	2	2	5	3
10	4	2	4	2	4	2	4	2	4	2
11	4	1	4	2	4	2	4	2	2	2
12	4	3	2	4	4	3	2	2	2	2
13	4	2	4	3	4	2	4	2	4	3
14	4	2	4	4	4	2	4	2	4	2
15	5	1	1	1	5	2	5	1	5	1
16	4	2	4	1	5	1	5	1	5	1
17	4	1	4	4	4	3	4	2	5	1
18	5	1	4	2	5	1	3	1	4	2
19	5	1	4	4	5	2	4	2	4	3
20	1	2	3	3	5	2	4	1	5	1
21	4	2	2	2	4	4	4	2	4	2
22	4	2	4	2	4	1	4	2	5	1
23	4	2	4	3	4	2	4	2	4	2
24	4	2	4	1	5	1	4	1	4	1
25	5	2	4	4	5	1	4	2	4	2
26	3	2	4	2	4	2	3	2	3	3
27	5	2	4	2	4	4	5	1	5	1
28	3	2	4	2	4	4	3	2	5	3
29	4	2	4	2	3	2	4	2	3	2
30	5	1	5	1	5	1	4	1	5	1
31	5	1	4	1	3	3	4	2	4	1
32	4	1	5	1	4	2	4	1	4	2
33	5	5	5	2	5	1	4	1	5	2
34	3	2	4	4	4	1	4	2	4	2
35	4	3	4	1	4	2	4	2	4	2
Media	**3,9714**	**1,8**	**3,82857**	**2,22857**	**4,22857**	**2**	**3,8571**	**1,6285**	**4,1428**	**1,8**
		Average of 1,3,5,7,9 =	15,02857143							
		Average of 2,4,6,8,10 =	15,54285714		**SUS Score =**	**76,4285**	**SUS Score =**	(Average of 1,3,5,7,9+Average of 2,4,6,8,10) * 2,5		

Table 04: Results test SUS

SUS yields a single number that represents a composite measure of the overall usability of the system under study. Note that individual element scores alone are not meaningful. To calculate the SUS score, first add up the contributions of each user. For items 1, 3, 5, 7 and 9, the score contribution is the position on the scale minus 1. For items 2, 4, 6, 8 and 10, the contribution is 5 minus the position on the scale. Finally, the sum of the scores is multiplied by 2.5 to obtain the overall SUS value. SUS scores range from 0 to 100.

By obtaining a SUS score of 76.428 (table 04), we can qualify the virtual experience as Good, as it exceeds the 68 points indicated by the method itself as a threshold or average value, which corresponds to a percentile range of 50% (https://measuringu.com/sus) (fig. 09).



SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68 – 80.3	B	Good
68	C	Okay
51 – 68	D	Poor
< 51	F	Awful

Fig. 09: Percentage range of SUS. Source: Jeff Sauro, PhD

6. Discussion of experience and virtualization

With regard to the results obtained in the biological tests, no significant differences in terms of increases in the concentrations of this compound were observed between the VR and in-person groups with respect to cortisol. A priori, in the literature, variations in this hormone are correlated more with effects associated with chronic stress, i.e. due to physical causes. Therefore, the results derived from its analysis in our study are discarded.

On the other hand, as AAS is a hormone closely related to adrenergic stress, it has a more direct correlation with psychic or acute stress situations, based on stimuli, such as the experience of visiting a museum under analysis in the present research.

First of all, it is worth noting that the statistics show that with respect to the sex and age of the volunteers, no significant differences are found in the increases in enzyme concentration in both the in-person and RV groups. Therefore, these variables are discarded, focusing the interest of the analysis on the general set of the groups, containing the totality of their members. At the same time, both groups show a homogeneous composition in terms of number of members, and averages by sex and age.

In this sense, it is worth highlighting, on the one hand, the average anticipatory stress of each of the groups under analysis, which in the case of the on-site group is significantly higher than in the case of the RV (143766 vs. 66297 UI). One possible reason is that the on-site group was objectively familiar with the place of their visit, the object of this test, while the RV group, being in a remote location, and a priori disconnected from the museum space, had a less objective character. In both cases, it was a prerequisite for selection that they had not previously visited the museum.

Precisely because of the disparity between the two levels of anticipation, the interest of the statistical analysis focuses on the variation in the concentration of AAS in each of the two groups, with disparate results being observed in each group. Specifically, the VR group had higher salivary alpha amylase levels with statistically significant differences ($p=0.023$). On the other hand, the in-person group showed a negative mean variation, with the concentration decreasing from 143mil to 104mil IU. The interpretation of this result leads us to describe a state of relaxation or pleasurable sensation, as the level of stress in the members is significantly reduced. In the RV group, on the other hand, the average increase in AAS concentration is positive, increasing from 66,000 to 81,000 IU. Therefore, an objective stimulation of the subjects in this group can be detected, in principle attributable to the use of the technology. However, this is a moderate increase, which, together with the high average score obtained by the group in the cognitive tests and the result of the use of the technology, is the result of a moderate increase in the AAS concentration of the subjects.

In the cognitive test, both groups, face-to-face and virtual, obtained a very high score of 8.98 and 8.49 respectively out of 10. As can be seen in the percentages of the results in table 1, those in the face-to-face visit obtained higher scores in the questions on information retention, that is, they got more questions right that dealt with information that was told to them verbally during the visit. While those in the virtual reality group scored higher on questions with a visual effect, such as the colour of the walls. Although both groups got a large number of correct answers, this difference is observed.
With regard to the SUS test, this was only administered to VR users. The rating obtained according to the scale and its interpretation, together with the results of the increase in enzyme levels, gives validity to the results and detracts from the subjects' adaptation to the technology itself. After analysing all the results, such as those of the cognitive test, we can assure that VR and the use of VR headset do not a priori represent a barrier to access to the experience, regardless of the age of the subjects.

7. Conclusions.

In conclusion, the biological tests conducted as part of this study provided valuable insights into the physiological responses of the participants during the in-person and virtual reality (VR) visits. Although no significant differences were observed between the two groups in levels of cortisol, a hormone associated with chronic stress, analysis of anticipatory stress, specifically salivary alpha amylase (SAA) concentrations, revealed intriguing patterns.

Notably, the level of anticipatory stress in the face-to-face group was significantly higher than in the VR group. This discrepancy is likely due to the face-to-face group's inherent familiarity with the physical location, which may have induced a sense of relaxation or comfort. In contrast, the VR group showed a moderate increase in AAS concentration, potentially attributed to the stimulating nature of the VR technology.

Further investigation into cognitive performance highlighted the remarkable scores of both groups on the cognitive test. While the face-to-face group excelled on questions related to verbal information, the VR group showed their strengths on questions related to vision, such as identifying the colour of walls. This divergence underlines the different cognitive involvement between the two experiences.

The System Usability Scale (SUS) test was administered exclusively to VR users, revealing a favourable rating which, coupled with the physiological findings, reinforces the validity of the results. The combined evidence suggests that VR, along with the use of VR headsets, does not inherently present a barrier to accessing the museum experience, regardless of the age of the participants.

In essence, while cortisol results showed no significant variations, analysis of AAS concentrations and cognitive performance revealed nuanced differences between in-person and VR visits. These results contribute to our understanding of the physiological and cognitive aspects of museum engagement through VR technology, highlighting the potential of immersive experiences to effectively convey information and stimulate participants' senses, ultimately enriching their overall museum experience.

The results shown above highlight the potential of immersive technologies for learning, as well as the innumerable advantages they present, such as sustainability, understood as the reduction in the carbon footprint generated by museums as a result of the pollution and fuel consumption caused by the thousands of visits to museums, the printing of brochures or the departure of collections for travelling exhibitions. On the one hand, it can slow down the deterioration of works of art as a result of their overexposure to the public, especially those that are most affected by environmental factors such as lighting, temperature, etc., or simply minimise the risk posed by their exposure - accidents, vandalism, etc. -.

On the other hand, VR technology democratises access to these resources, providing practically global accessibility, especially for people with disabilities, and also for people with low resources, due to the interconnection of networks and the increasingly affordable cost of immersive technology (VR helmets). Moreover, as an educational resource, the potential is unsurpassed. All of these are particularly relevant factors to take into account when betting on XR technologies, based on the quality of the user experiences they are capable of achieving.

Finally, this study has evaluated the use of the salivary alpha amylase enzyme as a marker of enjoyment or learning using virtualisation techniques to visualise the heritage and different tests: biological, cognitive and adaptation through the SUS test. In this way, new approaches for the dissemination and visualisation of heritage have been implemented by comparing the reaction of a group of visitors to viewing heritage through Virtual Reality vs. the traditional face-to-face visit to a museum. In short, this study has proven with numerical and statistical results the consistency and validity of the tests carried out and ensures that the use of VR glasses is not a barrier or impediment to the proper development of an experience of this type.

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All authors whose names appear on the submission:
1) made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data; or the creation of new software used in the work; 2) drafted the work or revised it critically for important intellectual content; 3) approved the version to be published; and 4) agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
All data generated or analysed during this study are included in this published article.

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