Virtual Empathy: Usability and Immersivity of a VR System for Enhancing Social Cohesion through Cultural Heritage

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In this article we describe and evaluate a VR application, designed with a novel approach that allows personalized interaction and a more immersive virtual experience. This VR system uses both a user-based methodology in which the user expresses his/her emotions by interacting directly with the environment; and an artificial intelligence-driven methodology that is based on automated language systems able to detect user emotion and moral values from verbal speech. In this study we evaluated the usability and immersivity of our system on a sample of 30 museum visitors. The results indicate that our application is easy and pleasant to use for visitors, and that positive assessments are significantly associated with the level of immersion and realism experienced within the virtual environment. Additionally, we found a low incidence of motion sickness among users.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**; **Virtual reality**; • **Applied computing → Arts and humanities**;

Additional Key Words and Phrases: Virtual Reality, Social Cohesion, Cultural Heritage, Usability

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1 Introduction

The term **virtual reality (VR)** was used for the first time by the scientist and philosopher Jaron Lanier in 1988 [1]. After a period in which it has not been intensively researched, today VR is used as a new research methodology

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that allows subjects to experience imaginary situations in a highly realistic context [2]. Its power mainly consists of two principles: "sense of presence" and "virtual embodiment" [3].

The first principle requires feeling present in a virtual world similarly as in the real world. The sense of presence depends on the knowledge of the world around us, which derives from data collected by our sensory system (vision, sound, smell, taste, touch), as well as from our previous knowledge of the world [3]. Stark [4] demonstrated that the cognitive-spatial models that control perception and imagination by providing the sense of presence in the real world are also activated in the perception of virtual environments, giving the subject the feeling of being inside the environment, which leads to the feeling of "telepresence."

The sense of presence is also given by using our body in a naturalistic way within the simulated environment that should enable a subject to behave as in a realistic context [5, 6], eliciting realistic bodily responses [7]. For example, bringing a person into a stressful virtual situation leads to an increase in his/her psychophysiological response approximating a stressful situation experienced in the real world [2].

The second principle is related to "virtual embodiment," which can be understood as the ability to "dress another body," i.e., the process of replacing a person's body by a virtual one, and therefore the ability to shift the body ownership into an external object [3]. The relevant research in virtual embodiment of Botvinick and Cohen [8] demonstrated that intermodal correspondence (visual and tactile) influences the properties of the body, using their well-known rubber hand illusion paradigm. They showed that a rubber hand stimulated in synchrony with a real hand leads users to believe that the fake hand is actually their hand, therefore a part of their body.

About immersive virtual environments, Jaron Lanier [9] was the first scientist to discover "homuncular flexibility," i.e., that our brain is able to easily manipulate different configurations of a virtual body.

Pavone et al. [10] showed that dressing an avatar's body during a movement task activates specific components of the action tracking system in the user's brain, even when the user's real body is not in movement.

The principle of virtual embodiment is associated with the well-known "Proteus Effect" discussed by Yee and Bailenson [11], i.e., the ability of a virtual body to influence our identity. Within virtual environments, an avatar is not just a uniform to wear, but represents our entire identity, thus quickly shaping (in minutes) our self-representation, our behavior and our interaction with others.

Based on the Proteus effect, in previous studies Osimo et al. [12] used a virtual environment to make patients embody Dr. Sigmund Freud in a self-counseling process, demonstrating an increase in patients' positive emotions. Also, Banakou et al. [13] used VR to stimulate planning and problem-solving skills by dressing the body of Albert Einstein, demonstrating that when users dress Einstein's shoes, they perform better than wearing their own personal shoes. The influence of Einstein's body increases their cognitive performance and decreases their prejudice toward elderly people.

In psychology, virtual embodiment could be understood as an advancement of the well-known paradigm of "Morenian Psychodrama" [14], this method is based on the idea that the identity of a human subject is strongly influenced by social relationships with others. In this paradigm, the subject is invited to play different roles in a dramaturgical context to understand the feelings and behaviors of others as well as to improve interpersonal relationships.

Today, thanks to immersive VR technologies, it is possible to play the role of another subject in a more realistic way. For this reason, the possibility of using VR to ensure empathic behavior has become a relevant topic in recent literature from various fields. For example, Bujic et al. [15] talk about an "empathy machine" by using VR to increase empathy in the journalism domain. Immersive journalism replacing the 2D screen allows a user to live sensations and experiences that could be far from him/her, increasing emotional involvement. In the gamification domain, Saleme et al. [16] investigated the proof of concept of a gamified social marketing program to promote empathy, demonstrating that augmented reality technologies are valuable tools to promote behavioral changes in young people.

In cognitive science, other studies have shown that playing the role of a virtual avatar can reduce racial prejudice [17, 19], can increase social cohesion among people, and can reduce aggressive behavior, e.g., in domestic violence [20].

Based on the power of virtual embodiment, in our previous work [21, 22] we used it in the context of Cultural Heritage, in order to understand whether dressing the shoes of another person can influence our emotional and moral-driven interpretation of artworks using **Artificial Intelligence (AI)** tools in combination with VR systems. In this article we investigate the power of our tool in terms of immersivity, that allows to generate immersion[1], **motion sickness (MS)** (a typical side effect of VR) and user experience.

2 Our Experimental Study on Empathy

In our previous study [21] we used virtual embodiment to make people live experiences in other people's shoes, during the fruition of cultural heritage. The use of VR in the realm of cultural heritage is an expanding field, for example other studies [23, 24] used VR systems in order to help communities to share their interpretations about artworks and other museum objects. On the same line recently researchers [25, 26] used an hybrid **extended reality (XR)** experience in order to develop a collaborative experience, using gamified narratives.

In our experimental study we simulated a visit in a virtual museum, using a sample of $N = 44$ subjects, divided into two subgroups ($N = 22$) testing three different artworks for each group [21, 22]. We gave our subjects the opportunity to visit a museum with other people (represented as avatars), to discuss their emotional and moral interpretation of artworks. We recorded interpretations both when they dressed their own shoes, as well as when they dressed the shoes of an avatar they interacted with. Specifically in our experimental design we used a four-point timeline: at time 0 (baseline) the user dresses his/her shoes and explains his/her personal feeling about the artwork; at time 1 (listening) the user listen the emotional interpretation provided by the avatar-visitor that share the scene with him/her. At time 2 (perspective taking) the user dresses the shoes of the avatar-visitor and he/she is invited to provide again his emotional and moral-driven interpretation. At the last time 3 (reflection) the user is invited to provide a verbal reflection dressing his personal shoes (see Figure 3).

Iin the first experimental group the reflection phase follows the perspective taking, while in the second one the reflection phase is followed by the perspective taking, this allow us to have a control condition about the virtual embodiment.

We used the Ekman's model [27] to record basic emotions (sadness, happiness, anger, fear, disgust and surprise) and Haidt's model [28] to record moral values (care/harm, fairness/cheating, loyalty/betrayal, authority/subversion, sancity/degradation). We used a total of six artworks with six avatars, balanced by age, gender and nationality.

For our analysis, we evaluated the degree of empathy, using both self-report questionnaires (empathy components questionnaire [29] and interpersonal reactivity index [30]), before and after the virtual experience, and by comparing the users' emotional and moral interpretations in the two phases (baseline and perspective taking) using automated **natural language understanding (NLU)** systems: an unsupervised language model (Zero-Shot [31]), and a knowledge extractor from text (FRED, [32, 33]).

Using Pearson's correlation, our results show that cognitive empathy increases in relation to the realism of the virtual environment and of the verbal input ($r = 0.375$; $p = 0.012$), while affective empathy increases in relation to haptic sensation, i.e., touching one's body during the virtual embodiment phase ($r = 0.339$; $p = 0.025$). Furthermore, through a categorical analysis, our results show that the percentage of empathic people is higher than non-empathic people.

In both experiments it is possible to distinguish between (Figure 1):

- Totally empathic people: People that during the perspective taking (virtual embodiment) change their emotions and moral value according to the emotion and moral value expressed by the avatar-visitor
- Partially empathic people: People that during the perspective taking (virtual embodiment) change their emotion or their moral value according to the emotion or moral value expressed by the avatar-visitor
- Non-empathic people: People who don't change their emotion and/or moral value during the perspective taking phase (virtual embodiment)

[1]Based on the definition of Freitag et al. [43] we consider "immersivity" as the quality of objects and imagined spaces that allow to generate immersion. For more detail see Freitag et al. [43].

3 Our VR Application

Based on the results of our experimental study, we have designed a system capable of modifying an avatar's profile in real time based on the visitor's verbal responses, through a communication between user, server and the VR interface. Inline with the (minimal) literature on using AI and **knowledge graphs (KGs)** for augmenting XR functionalities [34], we have integrated the social cohesion, participation and inclusion through cultural engagement DataHub [35] and two AI and KG-based automated classifiers [22] with Unity.

Our application consists of a virtual museum, designed with Unity Engine **three dimensional (3D)**[2], using a specific environment (Blu Dot Studies—Art Gallery). The scene has been adapted to include artwork from the **modern art gallery (GAM)** Museum in Turin, Italy.

Our virtual environment consists of a total of 13 artworks, created by painters from abstract, real and figurative art movements, and avatars representative of the world's population, which are classified based on gender (male, female and no gender), age (childhood, adulthood, elderly) and nationality (European, Asian, African), resulting in 27 ($3 \times 3 \times 3$) avatars. We built our avatars using Ready Player Me[3] for the human characters and Mixamo.com[4] for the animations.

For our application, we used an immersive VR tool consisting of a headset and joystick (Oculus Quest 2), equipped with rotation, position, body tracking sensors and integrated headphones that provide a 3D sound effect [20].

Our application implements three different methods:

- AI-based: the visitor's verbal response is recorded and saved on an external server, in which a emotions and moral values are detected using NLU systems
- User-based: the visitor can choose an own emotion and moral value directly from within the virtual environment. Each artwork is accompanied by a list of basic emotions [27] and moral values [28]. About basic emotions we used the well-known Ekman's model [27] based on six emotions (Happiness, Sadness, Surprise, Anger, Fear, Disgust) and about the moral values we used the Haidt's model [28] based of five values (Care/Harm, Fairness/Cheating, Loyalty/Betrayal, Authority/Subversion, Sanctity/Degradation)
- Random: it fires in the worst case, when the visitor is not able to explain and/or choose a specific emotion and moral value. This ensures that a specific emotion or value is able to activate the profiling of a user, and the selection of an appropriate avatar.

In the first method, the interaction between user and the avatar-guide occurs verbally. Our avatar-guide is equipped by a prerecorded human voice that welcomes to the user, and then asks for his/her personal feeling about the artworks. Here the verbal answer of the user is recorded and analyzed in an external server, in order to detect a specific emotion and/or moral value. The detected emotion/moral value is sent to the virtual environment, where an avatar-visitor appears featuring another personal emotion and moral value. The avatar-visitor has a prerecorded human voice (in the previous experimental study we recorded a total of 365 verbal interpretations of the artworks, for more details see [22]).

In the second method there is a verbal interaction between user and the avatar-guide, that through a human prerecorded voice invites the user to choose (by pressing on a specific button in the virtual environment) an emotion and a moral value about the artwork. As in the first case, this information triggers the avatar-visitor to appear in the virtual environment. The avatar-visitor has a different personal interpretation (emotion and moral value) about the artwork.

[2]Unity Engine 3D: https://assetstore.unity.com/
[3]ReadyPlayerMe: https://readyplayer.me/it
[4]Mixamo: https://www.mixamo.com/#/?page=1&query=idle&type=Motion%2CMotionPack

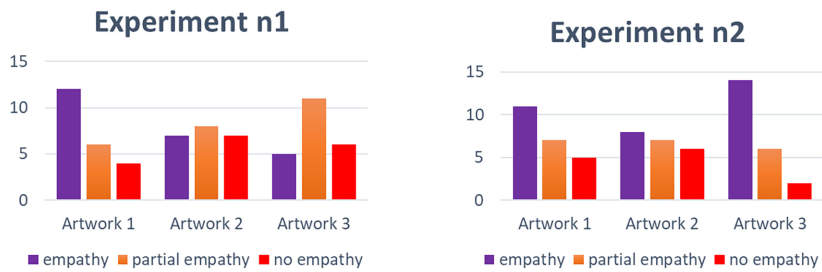

Fig. 1. Distribution of our participants, divided in three categories. Experiment n.1 Chi-square within subjects p-level 0.007; experiment n.2 Chi-square within subjects p-level 0.016; Chi-square between subjects p-level 0.018.

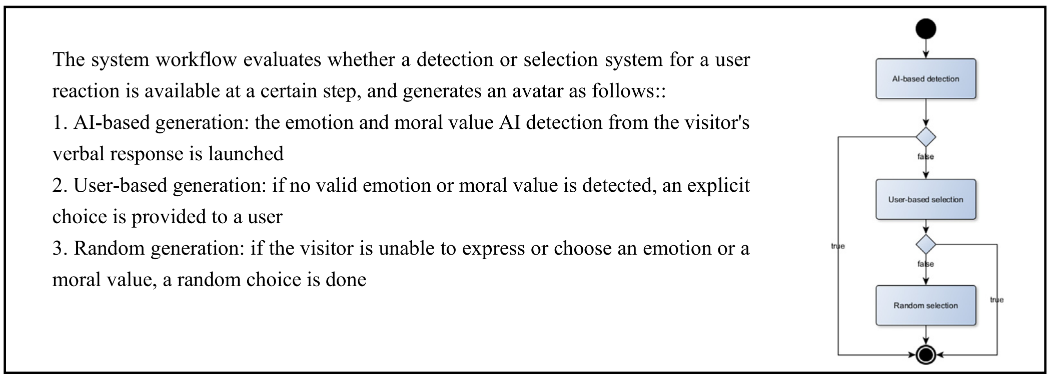

Fig. 2. Visual representation of the avatar generation workflow.

In both methods the appearance of the avatar-visitor depends on the emotion and moral value that is detected. For example, if the emotion detected is "happiness" the system will make an avatar-visitor appear, expressing a different emotion, e.g., "sadness."

The third method is triggered when the system is not able to detect an emotion and/or moral value (method 1), or the user is not able to choose an emotion and/or moral value (method 2). In this case, the system will make a random avatar-visitor appear, in order to avoid breaking the VR experience.

See Figure 2 for a schematic representation of the avatar generation workflow.

4 Materials and Method

4.1 Participants

We tested our application on a sample of 30 visitors to the GAM Museum in Turin, Italy. Our sample is composed of 8 males and 22 females with a mean age of $M = 30.1$ (SD: 12.70). Participants are students ($N = 13$) and workers ($N = 17$) who have no previous experience of VR ($M = 0.7$ from 0 = not at all, to 3 = always). The informed consent form was signed by all participants. This research was approved by the Ethics Committee of the Department of Cognitive Sciences of the University of Messina (protocol number COSPECS_05_2022).

4.2 Procedure

At the end of their visit to the real museum, we ask the participants to try out our VR application. We record visitors' personal information, such as age, gender, occupation and their previous experience within VR interfaces. Then, we ask users to enter our virtual museum with the aim of looking at a specific work of art. (Figure 3a1). At

Fig. 3. Our virtual museum with the avatar-guide that explains to the visitor how to interact within the environment (a1). The user can express his interpretation both verbally than interacting with buttons inside the virtual world (a2) Time 0; The avatar explains her personal point of view to the visitor (b1) Time 1, then the visitor dresses the shoes of the avatar (b2) Time 2/3.

the beginning of the VR experience the user is located in the backyard of the museum. From here, by using the joystick, the user can navigate into the museum and look artworks present inside. Each artwork is accompanied by an avatar-guide who provides the visitor with verbal instructions to interact with the virtual environment. Within the virtual world the visitor can (1) look at specific works of art and express his personal point of view, both verbally than choosing a specific emotion [27] and moral value [28] through buttons placed inside the virtual world (Figure 3a2); (2) he can listen to the interpretation provided by an avatar, that is a visitor who visited the museum at another time(Figure 3b1); (3) he can dress the avatar's shoes and talk about his/her emotional and moral interpretation (Figure 3b2).

After the VR experience, we ask visitors to answer three self-report questionnaires related to the evaluation of: Presence, MS, and Usability of our system.

—Presence

The concept of presence is related to the possibility of behaving and feeling as in the real world [5]. To test it, we used the **Presence Questionnaire (PQ)** test [36] that consists of 24 items on a 7-point Likert scale, from "not at all" to "quite" and "completely," organized in seven subscales that evaluate different aspects of the virtual world: realism (subscale 1), possibility of action (subscale 2), interface (subscale 3), ability to examine (subscale 4), self-assessment of performance (subscale 5), sounds perception (subscale 6) and haptic sensation (subscale 7).

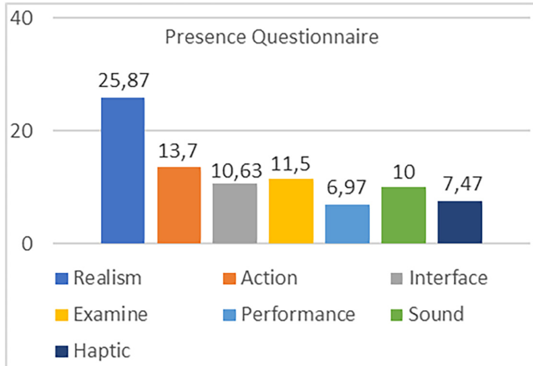

Chart 1. This chart shows the mean score for any subscale of the PQ.

—MS
MS is a typical side effect of VR due to a mismatch between the visual stimuli of the movement and the real movement of the body [37]. We used the **simulator sickness questionnaire (SSQ)** [38] which allows to record the degree of the main symptoms of MS using 16 questions on a 4-point Likert scale from 0 = "not at all" to 3 = "totally." The symptoms investigated by the SSQ are related to three diseases which are: (1) nausea, characterized by general discomfort, increased salivation, sweating, difficulty concentrating, awareness of the stomach and belching; (2) oculomotor disorders, characterized by fatigue, headache, eyestrain, difficulty concentrating and blurred vision; (3) disorientation, characterized by difficulty focusing, fullness of head, blurred vision, dizziness with eyes open, dizziness with eyes closed, and vertigo.

—Usability
Usability can be defined as the interaction between the user and the system, that can be measured by assessing the user performance, satisfaction and accessibility [39]. In our study we used the **usability scale system (SUS)** [39] that consists of 10 items on a 5-point Likert scale (from 1 = "strongly disagree" to 5 = "strongly agree").

5 Results

5.1 Presence

About the degree of presence and immersion, tested using the PQ test [36], our results show a good level of immersion and presence experienced by the subjects within the virtual world (PQ total score: M = 86.13). In particular, there is a higher score on the realism subscale (M = 25.87). It means that our virtual museum is understood by the visitors as a realistic museum (subscale 1) and they are able to act (subscale 2) and examine it (subscale 4) in a natural way. The sound score (subscale 6) is related to the voice of the avatar that a user can hear within the virtual environment. We have chosen not to use vocal synthesis systems, in fact all the voices attributed to the avatars are human voices previously recorded on other museum visitors, while the voice of the avatar-guides was recorded on other researchers—Chart 1.

5.2 MS

We verified the presence of cybersickness in users after the virtual experience through the SSQ test [38]. Our results show that only 5 out of 30 participants (16%), that is 3 females and 2 males with an average age of M = 30.01 years, experienced a sensation of MS. Among the main symptoms, the visitors experienced nausea with an average of M = 5.72; oculomotor diseases with an average of M = 9.34; and disorientation problems with an average of M = 11.6—Chart 2. According to the test, the score <5 indicates negligible symptoms, between 5 and 10 are minimal symptoms, between 10 and 15 are significant symptoms, 15 and 20 are important symptoms

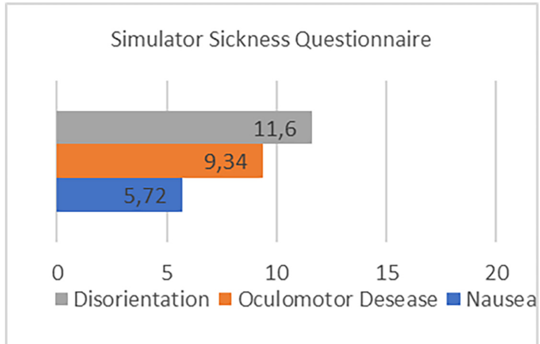

Chart 2. This chart shows the mean score for any subscale of the SSQ. Only 5 out of 30 participants report feeling MS.

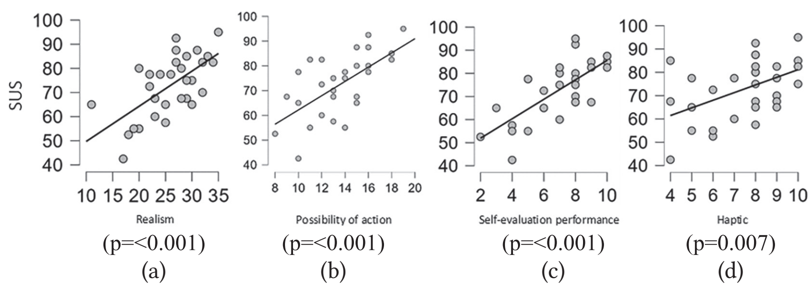

Fig. 4. Scatter plot of the Person's correlations related to significant correlation between SUS and the PQ test subscales. (Realism (a); Possibility of action (b); Self-evaluation of performance (c); Haptic perception (d).)

and >20 are negative symptoms [38, 41]. Our study show significant symptoms ($M = 11.6$) just in the disorientation subscale, it is due to mismatch between the virtual movement of the body and the real one.

Overall, our results show that our virtual application does not lead to serious side effects. MS manifests itself in a non-invaliding way with minimal symptoms recorded for nausea and oculomotor disturbances (between 5 and 10) and significant symptoms recorded for disorientation (between 10 and 15), in a low percentage of the sample (16%).

5.3 User Experience

We tested the usability of our application using the SUS test [40]. Over a range from 0 to 100 our total score is $M = 72.83$. The mean of the SUS test is 68, meaning that scores <68 are below the mean while scores >68 are above the mean [41, 42]. We also recorded the user's intention to recommend our VR application to other people, using a Likert scale from 0 (not at all) to 10 (totally). Our results show that users recommend our system to others with an average of $M = 7.46$.

Correlation analysis (Pearson's correlation) shows that there is a significant relationship between the total SUS score and the degree of immersivity in the virtual world. In this sense, the usability of our application increases as increases the realism of the virtual world ($r = 0.639$ $p = <0.001$), the possibility of action ($r = 0.643$ $p = <0.001$), the self-assessment of performance ($r = 0.724$ $p = <0.001$) and the haptic perception ($r = 0.481$ $p = 0.007$)—Figure 4.

These results show that the usability of our application is strongly related to the degree of immersion and presence experienced in the virtual world. There are no significant results regarding a possible relationship between SUS and MS (nausea $r = -0.225$, $p = 0.231$; oculomotor disease $r = -0.308$ $p = 0.098$; Disorientation $r = 0.206$ $p = 0.274$).

6 Conclusion

Based on positive results of our previous work [21] related to the possibility of increasing social cohesion through the sharing of cultural heritage using virtual embodiment, we have built an application that allows visitors to interact with other people in order to discuss their emotional and moral interpretations of specific works of art. The main novelty of our application concerns the development of a real-time system that allows visitors both to know the feelings of others, and to assume another point of view through virtual embodiment. The avatar profile is based on the visitor's verbal responses through a real-time communication between a user, a server and the VR interface.

In this article we investigated how this application can be used by the users, giving relevance to the degree of immersivity and therefore immersion, MS and usability. For this study we tested a sample of 30 museum visitors, giving them the possibility to use our application after their visit to the GAM museum.

Our findings show that visitors deem our application easy to use and recommend it to others. Another interesting result of our study is the relationship between the degree of immersion and presence experienced in the virtual world, and the degree of usability of our application. A higher level of realism of the system makes the visitor feel immersed in the virtual world, and to use our application easily and in a pleasant way.

Based both on our previous experimental results, and on our usability results, we believe that our application represents an innovative tool based on the integration between VR and AI system, capable of building real-time situations that can be personalized for the users. Our application was used in order to promote social cohesion but it can be easily adapted to other contexts.

In conclusion, the good results obtained in terms of usability and immersion, together with the low presence of MS, entitles us to say that this application can be installed in museums or schools, to foster social cohesion through a friendly virtual experience.

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