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Virtual reality supports perspective taking in cultural heritage interpretation

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ABSTRACT

Our research proves that virtual reality (VR) technology can be used to encourage users to adopt an alternative point of view through a virtual embodiment. Our results extend previous studies showing that emotional responses are evoked in virtual environments (Meuleman and Rudrauf, 2018) and arouse the sense of empathy (Ventura et al., 2020).

To this end, we built a virtual museum, where different avatars can interact with experimental subjects to discuss emotional and value-driven interpretations related to artworks, aiming at bootstrapping user's *interpretation-reflection loops* (IRL) (Daga et al., 2022). IRL consists in encouraging the user to (a) provide a point of view, (b) to know about another point of view, and (c) to possibly take a different perspective.

In line with recent literature, our results are based on the analysis of dialogue, and on the psychophysiological response of the users, showing that a VR-driven methodology can both develop a sense of embodiment, and maximize the human capacity to take another's point of view. Results also confirm that the use of immersive VR can be a valid tool to promote empathy through an embodied experience.

1. Introduction

Although humans are evolutionary social animals, dedicated to teamwork, collaboration and prosocial behavior (Tomasello, 2014), today there is apparently a decrease in the quality and quantity of social relations in industrialized societies (Holt-Lunstad et al., 2010; McPherson & Smith-Lovin, 2006; Putnam, 2000), and these data point at a potential danger for human life. Indeed, in a meta-analytic report, Holt-Lunstad et al. (2010) reported that social relationships significantly predict mortality: there appears to be a 50% increase in the chances of survival in relation to social relationships (Holt-Lunstad et al., 2010).

Already in 1988, in an article published in Science, House et al. state that "Social relationships, or the lack thereof, constitute a major health risk factor, rivaling the effect of established health risk factors such as cigarette smoking, blood pressure, blood lipids, obesity and physical activity" (House et al., 1988).

Recent studies show that in older people social isolation is related to a 29% increase in risk of death (Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015), 29% increase in heart disease and 32% increase in risk of stroke (Valtorta, Kanaan, Gilbody, Ronzi, & Hanratty, 2016). In middle-aged communities, social isolation appears to be an added risk factor of death and morbidity (Naito et al., 2021).

Social exclusion, and therefore social isolation, can be understood as the perception of being physically and/or emotionally distant from others (Wesselmann et al., 2016), and it is mainly characterized by rejection (being denied) or by ostracism (being ignored). In both cases, social pain has a strong impact on people's thoughts, emotions, and behaviors (Riva & Eck, 2016) increasing the desire for aggression (Riva, et al., 2011).

In this direction, our research uses Virtual Reality (VR) as a new tool to encourage users to adopt an alternative point of view through a virtual embodiment, in order to increase social cohesion. Today, digital technologies are increasingly at the center of people's lives, and influence their individual experiences and social interactions. This is an emerging field of study on facilitating social interactions and promoting the psychological well-being of people in social contexts (Pancani,

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2020).

In particular, the use of immersive virtual environments has proved very useful in psychology with respect to social interaction (Blascovich, et al., 2002; Loomis et al., 1999), in which VR allows users to live safe experiences that evoke feelings as in the real life (Lucifora et al., 2021).

For example, the study of Osimo et al. (2015) used VR in a self-counseling process, where users dress both their shoes and the shoes of Dr. Sigmund Freud's. Participants were invited to talk about a personal problem, switching from their virtual body to Sigmund Freud's one. The results have shown an increase in the positive emotions of participants when they dress Freud's body, explained by the power of virtual embodiment to foster a *detachment* from one's personal thinking.

Another study by Gonzalez-Liencres et al. (2020) has tested VR in an innovative clinical approach to rehabilitate men responsible for domestic violence. In this study, subjects not accused of violence took part in an aggressive scene against a woman, experienced in the first and third person.

Results showed a correlation between female avatar identification and decreased prejudice against women. In particular, the condition in the first perspective generated a strong feeling of fear, helplessness and vulnerability, highlighted by behavioral and physiological reactions.

In the Cognitive Science field, recent studies have shown that virtual reality can increase prosocial behavior (Schutte & Stilinović, 2017), and arouse empathy among users (Ahn et al., 2013, 2016).

For example, Ahn et al. (2013) used embodied experience to elicit favorable attitudes towards people with disabilities. Here, participants were exposed to a first-hand colorblind virtual situation, and results have shown that participants increased their positive behavior towards colorblind people in both virtual and real life.

Asher et al. (2018) used virtual reality to elicit a sense of empathy towards homeless people. In this study, participants dressed the shoes of a homeless person, living their daily experiences, including facing adversity. The study intended to make people sensitive to difficult situations. The results have shown an increase of empathy and personal distress immediately after the VR experience, and an increase of personal attitudes toward homeless people eight weeks after.

In this line, the recent research of Kishore et al., 2019, related to the study of implicit prejudice and aggressive racist behavior, shows that exposure to VR operating at the implicit level can combat the aggression rooted in implicit prejudice. Here the authors tested a sample of 38 officers in a US police department, simulating an interrogation between a racist policeman and an African American suspect. The control group experienced the situation as a third-person observer, while the experimental group experienced the situation as the victim. Some weeks later, both participants were exposed to an aggressive scene between a policeman and an African American man in a bar. The results showed that the experimental group performed helpful actions towards the victim.

1.1. Research hypothesis

Our study emerges from case studies in the H2020 SPICE project (Social Cohesion, Participation, Inclusion through Cultural Engagement), which has developed suitable technologies to share the interpretations of artifacts and other museum objects. Our research aims to encourage the user to discuss emotional and value-driven interpretations related to works of art, bootstrapping user's *interpretation-reflection loops* through a virtual embodiment experience.

As seen in the recent literature showing the power of virtual embodiment in modifying cognitive and behavioral assets of people (Osimo et al., 2015; Kishore et al., 2021; Banoku et al., 2018), we work on cognitive and affective empathy to make people closer to the feeling and thinking of others, eventually reducing ostracism.

Social exclusion is characterized by an explicit *rejection* that can be understood as violent behavior or verbal aggression, but also by *ostracism*, which can be defined as the "power of silence" (Williams, 2002), and increases negative emotion, social and physical pain (Poon et al., 2020).

For this reason, we have built a VR paradigm that allows users to talk with strangers about their personal emotions related to artworks, and to stay in others' shoes through virtual embodiment. We focused on the sharing of cultural heritage because artworks represent a class of visual objects that are able to convey different emotions based on our personality, cognitive process, expertise and curiosity (Palumbo et al., 2023).

Our research question is about *using virtual embodiment as a tool to sensitize people to different thinking and feeling*. The hypothesis is tested in two different conditions: i) an experimental condition, in which participants can take a different perspective (perspective-taking) and ii) a control condition, in which participants have to provide a verbal response to others' thinking, while keeping their own perspective (verbal response).

In order to exclude a possible influence due to the specific character of the avatars as well as the specific character of the works of art, we used different avatars and artworks for each experiment, balancing the main variables, which include age, gender, and nationality (users), as well as abstract, figurative and realistic art movements (works).

2. Material and methods

2.1. Participants

Our experimental sample consists of university students. The sample is made up by 44 subjects, divided in two groups of 22 subjects. The size of our sample is based on the recent literature about the use of virtual reality in relation to the empathy and virtual embodiment (eg. Schutte et al., 2017; Slater et al., 2010; Osimo et al., 2015).

The first group is made up by 6 males and 16 females with an average age of 26 years old, while the second group is made up by 7 males and 15 females, with an average age of 27 years old.

On a total sample of 53 subjects, 9 were excluded for missing data due to a system error. All subjects participated voluntarily, and their data were collected anonymously. The Ethics committee of the Department of Cognitive Science approved the protocol (number: COSPECS_05_2022).

2.2. Instruments

In our experimental design we have recreated an immersive virtual environment to simulate a visit in a Museum of Art. We used immersive virtual reality, which isolates the user's perceptual channels to induce feelings of telepresence (Steuer, 1992), given by the possibility of performing real movements (e.i. walking, touching, interacting with people and/or objects), and placing one's body as an active part of the virtual world.

To this end, we used a VR headset made by Oculus, namely Oculus Quest2, equipped with rotation, position, and body tracking sensors, as well as integrated headphones that provide a 3D sound effect.

We built the virtual environment using the computer graphics platform Unity Engine 3D, based on the "Blue Dot Studios- Art Gallery" scenario. We have added to this scenario, specific works of art from the Gallery of Modern Art (GAM) Museum in Turin.[1] About the avatars, we created them using "ready player.me" and used "mixamo.com" for the animations.

To record the personal interpretation of the subjects, we used a Zoom H2n audio recorder, and transcribed the dialogue using a semi-automatic "speech to text" methodology.[2]

Furthermore, for the study of empathy we used an equipment for

[1] https://www.gamtorino.it/en/welcome/.

[2] We are implementing an automatic speech-to-text methodology.

Fig. 1. On the left: Virtual Reality environment (using Art Gallery - Unity Engine 3D). On the right: Experimental setup (using BiosignalPlux kit and Oculus Quest 2).

physiological detection (Biosignal Plux Kit), which records the electrodermal activity (EDA) related to the skin micro-sweating, as a direct and immediate manifestation of a state of personal arousal (Bouscein, 2012) - Fig. 1. We recorded the skin conductance response to record changes in sweat secretion activity as a result of the change of the sympathetic nervous system activity. We used 2 AgCl electrodes placed on the index and middle fingers at 1000Hz sampling rate.

We did not record heart rate and respiratory rate because of surrounding noise due to users speaking and movement, which would invalidate the measurements.

On the other hand, to measure both cognitive and affective empathy, we administered the Interpersonal Reaction Index (IRI) and the Empathy Components Questionnaire (ECQ) in a counterbalanced manner.

The IRI test (Davis, 1980) consists of 28 questions on a 5-point Likert scale. It consists of four scales: Fantasy (tendency to transpose oneself in an imaginative way into fantasy situations), Perspective Taking (tendency to spontaneously adopt the psychological point of view of others), Empathic Concern (exploits feelings of warmth, compassion and concern for others), and Personal Distress (evaluates feelings of self-directed anxiety and discomfort resulting from interpersonal contexts).

The ECQ test (Batchelder, et al., 2017) is made up by 27 items, based on a Likert Scale from 0 (totally in disagree) to 4 (totally agree) and assess the cognitive ability, cognitive drive, affective ability, affective drive and affective reactivity.

Furthermore, we measured the personal degree of alexithymia, understood as "the absence of words for emotions" (Nemiah & Sifneos, 1970), which is a stable personality characteristic related to an affective processing disorder (Taylor & Bagby, 2012). For this purpose, we used the Toronto Alexithymia Scale TAS-20 (Taylor et al., 1992) consisting of 20 questions on a 5-point Likert scale.

Finally, based on what has been denoted by previous studies (Van Loon et al., 2018) regarding the positive relationship between empathy and immersion in the virtual environment, we used the Presence Questionnaire PQ (Witmer et al., 2005), consisting of 24 questions on a 7-point Likert scale, aimed at understanding the degree of perceived immersion. All these tests have been recreated and administered via an online Google Form.

2.3. Procedure

2.3.1. Design guidelines

First, in order to ensure social cohesion, we collected the emotional and value interpretations provided by visitors at the GAM Museum.

We interviewed 37 subjects from 7 to 70 years old, parameterized on age, gender and nationality. To avoid collecting invalid information, we asked specific questions to the visitors, two with open answers (Q1 and Q2) and two with closed answers (Q3 and Q4) relating to the emotions and values that a specific work of art can arouse (See Table 1). For emotion categories we used the well-known Ekman's model (Ekman, 1999) with six universal emotions concerning happiness, sadness, disgust, fear, anger and surprise; while for value categories we used the standard classification of Haidt (2012) including Care/Harm, Fairness/Cheating, Loyalty/Betrayal, Authority/Subversion, Sanctity/Deg radation.

We interviewed visitors on 9 works of art dating back to the 1900s, parameterized into abstract, figurative and realistic works (See Table 2). The visitors' emotional and value-driven interpretations, combined with their metadata (age, gender, nationality) were used for the creation of virtual avatars.

Among all the works of art tested at the GAM, we included in the virtual environment those with a strong emotional interpretation. Therefore, we excluded "The Gibigianna III ″ and "The Gibigianna VIII" because they did not collect relevant answers and "The three windows" because they did not arouse relevant emotional interpretations. Table 3

Table 1
Questions posed to the visitor during data collection at the GAM Museum.

N	Questions
Q1	How does this work of art make you feel?
Q2	What moral value does this work of art inspire you?
Q3	Among these emotions (Ekman's model) which do you think the work of art arouses?
Q4	Among these moral values (Haidt's model) which do you think the work of art arouses?

Table 2
Works of art used for the data collection at the "GAM" Museum.

N	Title	Author	Classification
1	The three windows	Jessie Boswell 1924	Realism
2	Summer	Felice Carena 1933	Realism
3	Angles	Jean Faurtrier 1958	Abstract
4	Composition	Mario Mafai 1932	Figurative
5	Self-Portrait in the form of an owl	Alberto Savinio 1936	Figurative
6	In my country	Marc Chagall 1943	Abstract
7	Red head woman	Amedeo Modigliani 1915	Realism
8	The Gibigianna III	Giuseppe Gallizio 1960	Abstract
9	The Gibigianna VIII	Giuseppe Gallizio 1960	Abstract

Table 3
Works of art used in the virtual environment, with related avatars, emotions and values.

Artwork	Avatar (nationality, age, gender)	Emotion	Moral Value	Experiment
Angles (Faurtrier, 1958)	Italy, 21 male	Sadness	Purity/ Degradation	1
Composition (Mafai, 1932)	Brazil, 30 male	Happiness	Fairness/ Cheating Loyalty/ Betrayal	1
Summer (Carena, 1933)	Italy, 7 female	Sadness/ Happiness	Care/Harm	1
In my country (Chagall, 1943)	Italy, 50 female	Surprise/ Sadness	Care/Harm Purity/ Degradation	2
Self-portrait (Savinio, 1936)	Morocco, 18 female	Surprise/ Fear	Authority/ Subversion	2
Red head woman (Modigliani, 1915)	Italy, 40 male	Sadness	Purity/ Degradation	2

Fig. 2. This figure shows the virtual embodiment phase. Here the subject can touch and look at his/her new body and look at it in the mirror. There is a synchronization between the virtual and real movements of the body.

shows the works of art that were included in the experimental phase, their avatars and the emotional and value interpretations provided by the visitors at the GAM museum. We used a total of 6 artworks accompanied by 6 avatars distributed in two experiments.

2.3.2. Experimental study

The experiment required participants to visit a virtual museum with the aim to give their personal interpretation on three works of art. The order of presentation was randomized for each group.

Before the VR experiment, the user was asked to complete the TAS-20 and one of the empathy tests (IRI or ECQ) and to provide his personal information like age, gender, and nationality. After the VR test, the user was asked to complete the other empathy test (IRI or ECQ) and the PQ test.

Inside the virtual museum, the user meets other visitors (virtual avatar) and can listen to their interpretation. The task is based on "perspective giving" related to a verbal and explicit reflection on the other's thought and on "perspective taking" related to the possibility of adopting the other's point of view, embodying the avatar (Fig. 2).

We conducted two different experiments, in order to understand how the assumption of perspective can influence the interpretation-reflection loop of the subjects. While in the first experimental group perspective taking is anticipated by the verbal reflection of the user about the interpretation of the avatars, in the second experimental group the verbal reflection follows perspective taking. This allows us to have a control situation (reflection phase) that happens before (exp. 1) and after (exp. 2) virtual embodiment (Fig. 3).

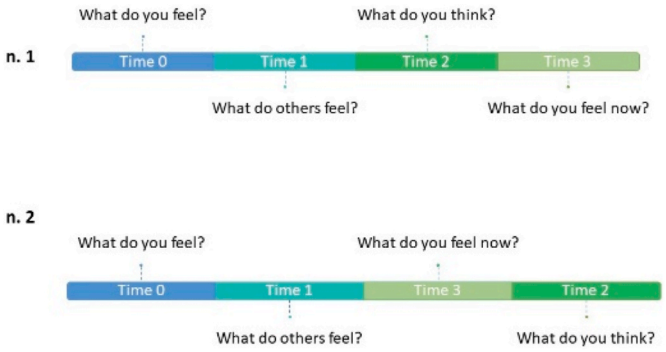


Fig. 3. Flowchart of our experiment. Experimental condition (perspective taking) vs Control condition (reflection phase), counterbalanced in our experimental groups.

Furthermore, to exclude a possible influence due to the specific character of the avatars, as well as the specific character of the works of art, we used different stimuli for each experiment, balancing the main variables of age, gender and nationality, or abstract, figurative and realistic art movements.

Experiment n.1.

The first experimental group was subjected to the condition "*from reflection to perspective taking*".

First, we asked the user to complete the TAS-20 and an empathy test (IRI or ECQ counterbalanced).

Then, the user was placed inside the virtual museum with the task of observing three works of art, and providing the researcher with its personal interpretation (time *t0*). As in the real recording at the GAM museum, here the researcher asked the 4 questions to the users (see Table 1). At the following time *t1* (listening), each work of art was given the emotional interpretation provided by other users (recorded at the GAM museum in Turin) expressed verbally by the avatar present in the scene.

At time *t2* (reflection), the user was invited to discuss with the avatar, providing a further interpretation of the artwork. And at the last time *t3* (perspective taking) the user "dresses the shoes" of the avatar. Here the researcher asked again the personal interpretation of the subject following the four questions, as explained above (Fig. 4).

At the end, the user was asked to complete the ECQ or IRI test and PQ test.

In this experiment we used three works of art with three avatars, which are detailed in Table 4. All the works of art were administered in a random way to avoid a possible influence related to presentation order.

Experiment n.2.

The second experimental group was subjected to the condition "*from perspective taking to reflection*".

Before the virtual task, the user was asked to complete the TAS-20 and IRI or ECQ test (counterbalanced).

In this case, the procedures of group 1 are kept stable at time *t0* and *t1*, while at time *t2* the user was invited to provide a further interpretation of the work of art, finding himself in the role of the avatar. At the last time *t3*, the user was invited to give feedback to the avatar, and provide his personal reflection on the artwork. At the end, the user completed the IRI or ECQ test and PQ test.

In this experiment we used three works of art with three avatars, explained in Table 5. As in the first experiment, works of art were randomly administered.

Each avatar has only one emotional and one value interpretation. This a-priori interpretation (obtained from previous interviews) is

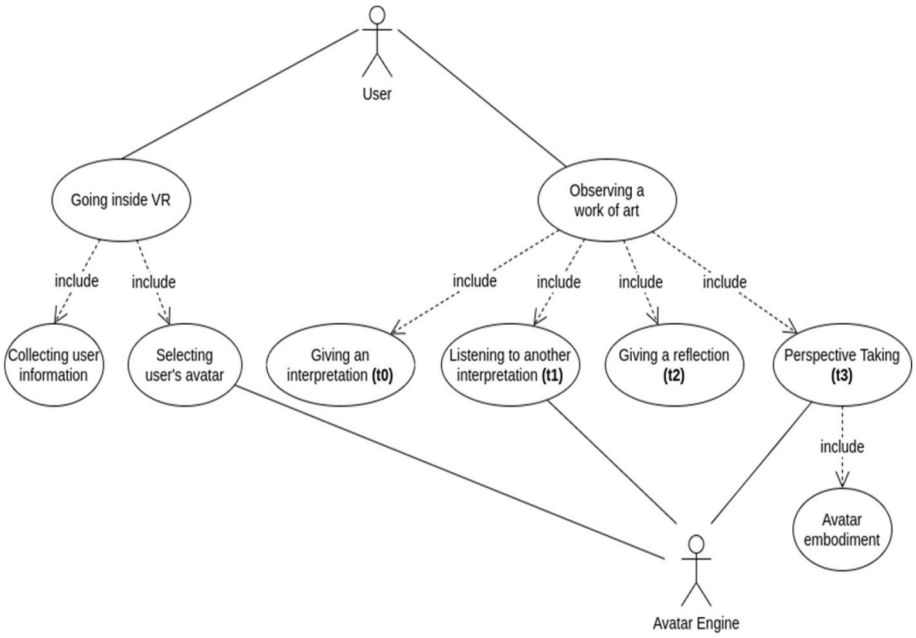


Fig. 4. Use case diagram of our experimental procedure.

Table 4
Stimuli (artworks and avatars) administered in the first experiment. Each avatar has only one emotional and one value interpretation. This a-priori interpretation (obtained from previous interviews) is shown in the table.

Work of art	Avatar	Metadata	Emotions	Moral Values	Interpretation
 ANGLES (Jean Fautrier 1958)		Italy 21 Male	Sadness	Sanctity/Degradation	It gives me coldness because there is a few of color. It gives me coldness and distance
 COMPOSITION (Mario Mafai 1932)		Brazil 30 Male	Happiness	Fairness/cheating Loyalty/ Betrayal	I'm curious because they play naked and seem calm. I am happy, I would like to be with them
 SUMMER (Felice Carena 1933)		Italy 7 Female	Sadness Happiness	Care/Harm	I think maybe she was wrong and was punished, but she also reminds me of fairy tales and fantasy

shown in the table.

3. Results

In order to understand whether a VR-driven methodology can induce a sense of embodiment and maximize the human capacity to take another's point of view, we performed an empathic analysis of the dialogue, comparing the interpretation at time t0 and t2/t3, as well as the biopsychological response (EDA) as an index of empathic involvement.

Our results derive from five methods, summarized as follows.

1. First, categorial analysis helps us distinguish three categories of subjects (empathic people, partially empathic people and non-empathic people) in both experimental groups, and confirms the power of virtual embodiment in arousing empathy among users (Section 3.1)
2. Automated speech analysis reveals that automated language inference systems are able to detect emotions and moral values from the verbal speech of the users (Section 3.2), enabling a comparison between direct classification, and the possible classification implied in discourse
3. Verbal reaction time analysis lets us hypothesize a correlation between virtual embodiment, and fast thinking related to self-reflection (Section 3.3)
4. Psychophysiological analysis related to the electrodermal activity shows a significant correlation between the emotional involvement of the users and their empathic attitude (Section 3.4)
5. Correlation between self-report questionnaires related to empathy and the perception of presence in the virtual embodiment confirms the Proteus Effect and its connection to cognitive and affective empathy (Section 3.5)

3.1. Categorial analysis

Concerning the interpretation-reflection loop, based on the

Table 5
Stimuli (artworks and avatars) administered in the second experiment.

Work of art	Avatar	Metadata	Emotions	Moral Values	Interpretation
 IN MY COUNTRY (Marc Chagall 1943)		Italy 50 Female	Sadness Fear	Sanctity/ Degradation	It has a dreamlike sense. It gives me a sense of protection because I see two people hugging
 SELF-PORTRAIT IN THE FORM OF AN OWL (Alberto Savino 1936)		Morocco 18 Female	Surprise Fear	Authority/ Subversion	it seems that the author wanted to represent himself and his interior with something external
 RED HEAD WOMAN (Amedeo Modigliani 1915)		Italy 40 Male	Sadness	Sanctity/ Degradation	I see hypocrite because it has an asymmetrical gaze, one that observes and the other that does not want to see

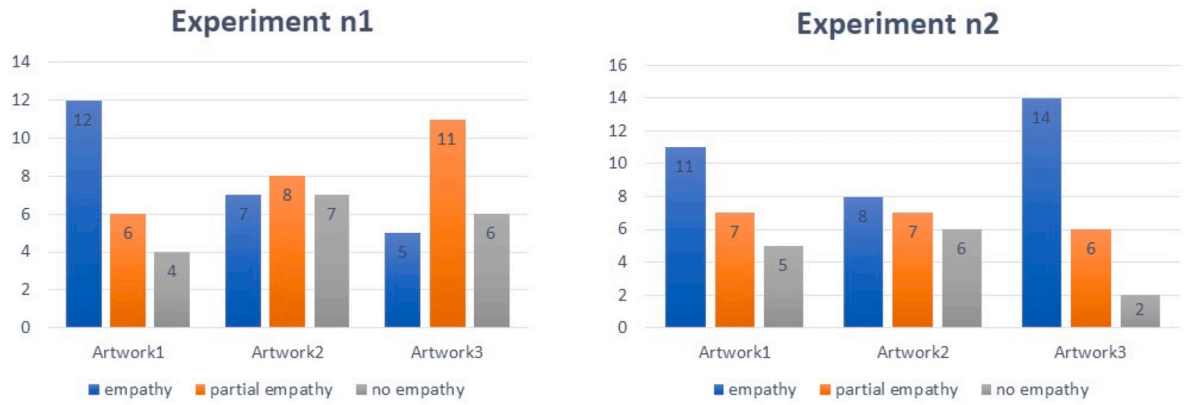


Fig. 5. This chart shows that in both experiments the percentage of those who empathize with the emotional-value interpretation of the avatars is higher than those who don't empathize. These differences are statistically significant.

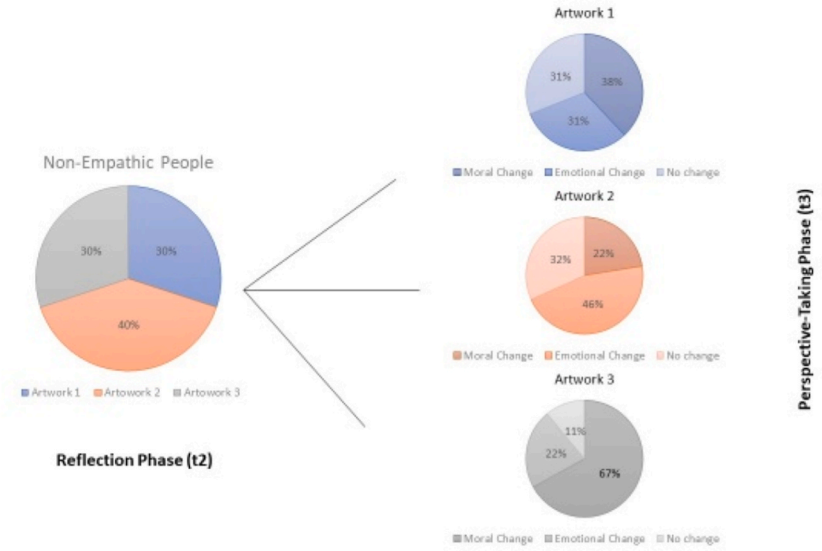
emotional and value categories provided by the users during the VR experience, we considered all the interpretations at time *t0* and *t2/t3*. We compared the answers to Q3 and Q4, related to the classification of emotions and values and the personal interpretation/reflection.

Our results show that in both experimental groups it is possible to distinguish three types of subjects, which either change or not their

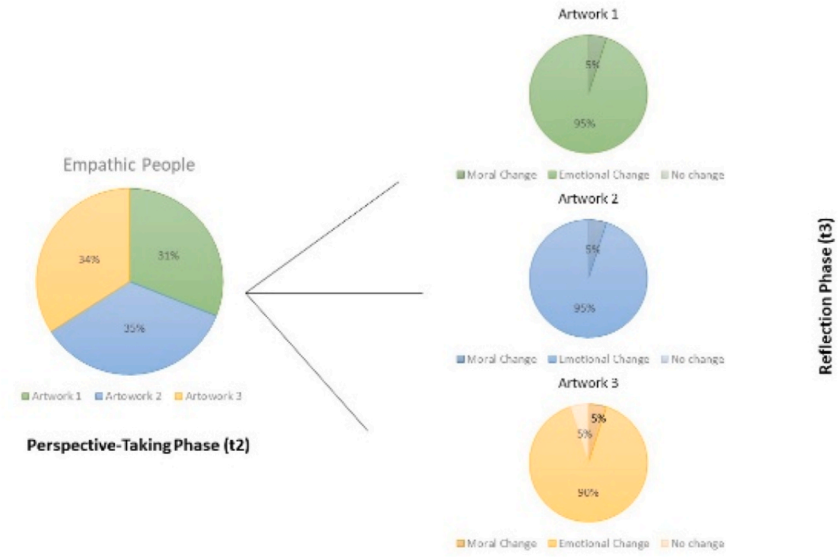
Table 6
The emotions (A) and moral values (B) that we have extracted from dialogue is marked in red. The percentages indicate the degree of agreement of the users.

Group 1							
Artwork	Sadness	Happiness	Anger	Fear	Disgust	Surprise	None
1	31%	6%		19%	19%	19%	6%
2	9%	37%	18%	9%		27%	
3	33%	17%		33%		17%	
Group 2							
1	36%	29%				36%	
2		15%	23%	15%	31%	15%	
3	60%		13%	7%		20%	
A							

Group 1						
Artwork	Care/Harm	Fairness/Cheating	Loyality/Betrayal	Authority/Subversion	Sancity/Degradation	None
1	9%	18%	9%	18%	36%	
2		30%	40%	20%	10%	
3	56%	6%	12%		29%	
Group 2						
1	46%		38%	8%	8%	
2		37%	25%	12%	25%	
3	29%	21%	7%	29%	14	
B						



A: Experimental Group n.1



B: Experimental Group n.2

Fig. 6. (A) Experimental group n.1, including only *non-empathic people*: this chart shows the percentage of people in the reflection phase at *Time 2*, versus the percentage of people that change their emotions and/or moral values in the perspective-taking phase at *Time 3*.(B) Experimental group n.2, including only *empathic people*: this chart shows the percentage of people in the perspective-taking phase at *Time 2*, versus the percentage of people that change their emotion and moral value at the following reflection phase at *Time 3*.

interpretation when they dress another person's body.

(1) Non-empathic: subjects that don't change their interpretation, as well as their emotions and values
(2) Moderately empathic: subjects who only change the value, or the emotion
(3) Empathic: subjects who totally change their interpretation, including emotions and values.

In both experimental groups the percentages of empathic subjects (totally or partially) are equal or greater than non-empathic subjects (Fig. 5).

The Chi-square analysis within subjects shows a significant difference in both experiments (experiment n.1 $\chi^2 = 9.87$ p = 0.007; experiment n.2 $\chi^2 = 8.21$ p = 0.016). The frequency of empathic people is higher in the experiment n.2, in which perspective taking takes place immediately after the listening phase.

In addition, concerning the emotion/value that is implied in the avatar's discourse, the subjects present a high degree of agreement for each artwork (Table 6AB). In fact, the avatar speech can be related to specific emotions and moral values, which are not explicit in the dialogue. The differences between shared and not shared emotions and values is statistically significant (Emotions Chi-Square $\chi^2 = 11.62$ p= <0.001; Moral values Chi-Square $\chi^2 = 18.80$ p= <0.001).

This result indicates that our participants are empathic people. This conclusion is based on the direction of (possible) change: if the emotion has not changed in the same direction as that implicitly expressed by the avatars, virtual embodiment has been useful in changing one's interpretation, but not in bringing people closer to each other. For example, we can consider the artwork "Summer," where the avatar expresses a sense of sadness. If an experimental user changes its initial emotion to align with sadness, we can infer that (s)he empathizes with the avatar.

Table 7
This table shows the F1-score for irrelevant, incoherent and coherent/relevant speech at each phase (t0, t2, t3), related to the detection of emotions and moral values, by the Zero-shot Transformer (A) and FRED (B).

Emotions (A)					
Group n. 1			Group n. 2		
t0	t2	t3	t0	t2	t3
Relevant	0.72	0.62	0.70	0.56	0.56
Irrelevant	0.26	0.05	0.26	0.11	0.20
Incoherent	0.19	0.18	0.13	0.06	0.25
Moral Values (A)					
Group n. 1			Group n. 2		
t0	t2	t3	t0	t2	t3
Relevant	0.48	0.49	0.35	0.38	0.32
Irrelevant	0.09	0.30	0.42	0.18	0.10
Incoherent	0.27	0.30	0.33	0.18	0.32
Emotions (B)					
Group n. 1			Group n. 2		
t0	t2	t3	t0	t2	t3
Relevant	0.38	0.37	0.35	0.47	0.45
Irrelevant	0.17	0.01	0.00	0.19	0.03
Incoherent	0.11	0.05	0.24	0.12	0.00
Moral Values (B)					
Group n. 1			Group n. 2		
t0	t2	t3	t0	t2	t3
Relevant	0.02	0.20	0.20	0.07	0.18
Irrelevant	0.00	0.02	0.00	0.03	0.02
Incoherent	0.11	0.07	0.03	0.00	0.10

On the contrary, if its emotional response shifts towards other emotions, we cannot attribute this change to an empathic behavior. Table 6 shows the percentage of participants who change their emotional state to align with the avatar's emotion.

In a general speech analysis, we compared the interpretations of the subjects at all phases (t0, t2, t3). We notice an interesting result on non-empathic people, related to the difference between the reflection phase (t2) and the perspective taking phase (t3) in the first experimental group. Here, in the perspective taking phase, the people who do not change their interpretation are fewer than the people who affirm a non-empathic interpretation in the reflection phase (Fig. 6). This means that the power of virtual embodiment allows the user to change their interpretation even if they don't change interpretation in the preliminary reflection phase. This data is present only in one case in the second experimental group, in which perspective taking occurs before reflection, where the number of non-empathic subjects is lower. This result confirms that the virtual embodiment has a strong influence on the interpretation-reflection loop.

This is a major achievement that shows the power of virtual embodiment. The first experimental group shows that listening to another person's interpretation is not enough to change one's personal interpretation. To change it, it is necessary to play the avatar's role.

The second experiment confirms this result, because, conversely, the user's interpretation changes when it dresses the avatar's shoes, and keeps it during the following reflection phase.

3.2. Automated speech analysis

We performed an emotion-value detection on Q1 and Q2, using two automated language inference systems: a Zero-Shot Transformer, and a Knowledge Graph Extractor, FRED, with the aim to detect emotions and moral values implied in the speech of the users.

The Zero-Shot Transformer is an unsupervised language model (Asprino et al., 2022, pp. 33–41), trained to make inferences starting from a prompt acting as inferential premises. In practice, given a pre-trained model, the users' speech is used as a prompt to the model, which infers emotion and value categories based on the weights learnt by the model (an artificial neural network).

The FRED machine reader (Gangemi et al., 2017; Gangemi & Presutti, 2022) extracts knowledge graphs from text, and links the nodes and arcs of the graphs to public knowledge graphs such as DBpedia, WordNet, FrameNet, etc.[3] Specialized knowledge graphs developed in the SPICE project (the Emotion Frame Ontology and ValueNet)[4] have been used in this experiment (De Giorgis et al., 2022). A FRED knowledge graph allows to abstract from the specific words of a text, disambiguating them, and enabling emotion and value inferences in a causally traceable way.

Here we divided our samples in three categories, that are.

- Irrelevant: subjects that in Q1 and Q2 don't give information related to emotions or values
- Incoherent: subjects who state a specific emotion or value in Q1 and Q2 but annotate another one in Q3 and Q4
- Coherent and Relevant: subjects with a clear emotion/value interpretation both in Q1/Q2 then in Q3/Q4

Our results show that, for relevant and coherent positions in speech, both automatic language systems are able to detect emotions with fair to good accuracy, and to detect moral values with bad to fair accuracy (Bulla et al., 2023).

This result (see Table 7) is confirmed in all phases (*t0, t2, t3*) in both experimental groups. The Zero-Shot Transformer is more accurate, as expected due to its coverage resilience (large language models are trained on huge amounts of linguistic forms), also considering the difficulty of detecting emotions and especially values when no explicit names for them are provided. This is evident in the case of value detection with FRED, which is bad due to the minimal recall (knowledge graph extraction is mostly based on explicit linguistic traces).

This result confirms the possibility of using an automatic system to detect emotions and moral values from the speech of the users, and to integrate that detection in an AI-enhanced VR environment (ongoing research), although further work should be dedicated to optimize the detection of moral values in the absence of direct linguistic traces.

3.3. Verbal reaction time analysis

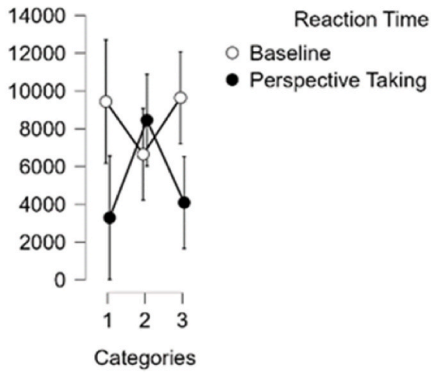
Finally, we analyzed the verbal reaction time index (RT) for each participant to understand if empathy is linked to rapid response from the participants, or if, on the contrary, empathy is expected to take more time.

We analyzed the reaction time for each artwork, for each participant, using ELAN 6.4. as software. Then we extracted an index related to the difference between t0 and t2/t3. We excluded outliers over 2.5SD from our analysis.

Our results show that the reaction time is not linked to the ability to change one's own personal interpretation, but it is linked to the virtual embodiment. In fact, to take another point of view before a verbal and explicit reflection on it (experiment n.2) leads to an immediate response that significantly reduces the verbal reaction time in both no-empathic then empathic people (*t*-test analysis shows significant differences in category 1: $p = 0.007$ and category 3: $p = 0.001$). Instead, to be partially in agreement with the feelings of others requires more time, which increases the verbal reaction index in the perspective taking phase (this result is obtained by subtracting the perspective taking phase to the baseline of each participant. Repeated measures ANOVA reaction time * categories $F = 5.296$ $p = 0.008$ $\eta^2 = 0.079$) Fig. 7.

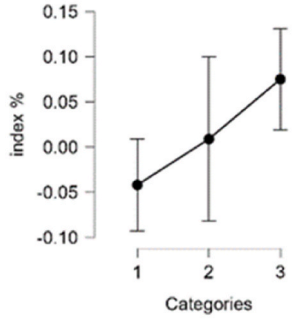
These results are confirmed by the *t*-test analysis on all participants, which shows that reaction time decreases significantly for the second experimental group in the perspective-taking phase compared to the baseline (p-level 0.036). This is not confirmed for the first experimental

[3] https://github.com/framester/Framester.
[4] https://spice-h2020.eu/document/deliverable/D6.5.pdf.



Reaction Time	Categories	Mean	SD	N
Baseline	1	9438.889	5855.338	9
	2	6649.474	2981.020	19
	3	9642.258	7901.840	31
Perspective-Taking	1	3291.111	2054.388	9
	2	8456.316	7179.397	19
	3	4092.258	4820.382	31

Fig. 7. Repeated measures ANOVA within-subjects effect show that verbal reaction time in the experiment n.2, increase in moderately empathic people (category 2) and decrease in empathic people (category 3) and no-empathic people (category 1) in the perspective taking phase.



Categories	Mean	SD	N
1	**-0.042**	**0.105**	**19**
2	**0.009**	**0.194**	**20**
3	**0.075**	**0.123**	**21**

Fig. 8. One-way ANOVA analysis on the arousal index shows that there is a significant difference in the experiment n.1 between the three categories when the perspective taking follows a verbal and explicit reflection of other's feelings.

group, in which there is no-significant decrease in the mean reaction time (p level 0.308). We also observe a lack of statistically significant differences between groups in the perspective taking phase, which points out a similar behavior in the two groups during the virtual embodiment.

3.4. Electrodermal activity analysis

About the EDA, we calculated the difference index between the time of perspective taking and the baseline (time between the beginning and the interpretation phase) of the subjects. Then we converted it into a percentage.

We excluded outliers over 2SD from our analysis.

Our results show that there is a statistically significant difference (one-way ANOVA $F = 3.370$ $p = 0.041$ $\eta^2 = 0.098$) in the values of EDA (personal arousal index) between the three categories of subjects (1 non-empathic, 2 moderately empathic, 3 empathic) in the first experimental group, in which the perspective taking phase is anticipated by the reflection (interpretation-reflection loop).

T-test analysis between the perspective taking phase and the baseline, show a significant difference in category 3 ($p = 0.006$). Here the EDA increases in the perspective taking phase (Fig. 8).

On the other hand, there are no statistically significant differences regarding the EDA signals in the second experimental group in which the perspective taking is followed by the reflection (one-way ANOVA $F = 1.035$ $p = 0.361$ $\eta^2 = 0.032$). T-test analysis between the perspective taking phase and the baseline does not show significant differences. However, descriptive analysis shows that the average of EDA increases in the empathic people (category 3) compared to moderately (category 2) and non empathic (category 1) people.

The personal arousal index, i.e., a physiological measure of emotional involvement, appears to be related to the subject's ability to empathize with others, in fact in both experiments it is higher in category 3 made up by people that totally change their feeling based on others interpretations.

The lack of significant differences in the second experiment, allow us to hypothesize that assuming a conscious perspective through an explicit reflection on other feelings before the virtual embodiment, increases the personal arousal of empathic people. However, a larger sample is needed to better investigate the role of EDA in empathy.

3.5. Proteus effect

Our results are in line with the recent literature on the Proteus Effect that considers avatars able to influence people's perceptions, behaviors, and attitudes in social interactions (Bian et al., 2015). In this sense, the proteus effect occurs when a strong bond is established between the user and the virtual avatar (Kocur, Schwind, & Henze, 2019) and the virtual embodiment becomes able to influence the body ownership (Slater et al., 2010).

Pearson's correlations on our self-report questionnaires show that there is a negative correlation ($r = -0.350$ $p = 0.020$) between the subscale of the TAS-20 "Difficulty in identifying feelings" and the subscale of the PQ "Ability to examine", that is the ability to concentrate within the virtual environment. This result indicates that the greater the difficulty in identifying feelings, the less the ability to feel focused and involved in the virtual environment.

Furthermore, we recorded the cognitive and affective empathy (Davis, 1983) before and after the VR experience, using ECQ and IRI questionnaires. In order to make a comparison between these two different questionnaires, the data were first normalized and standardized on the basis of the mean and standard deviation of the sample itself. Results show no significant differences between questionnaires.

Cognitive empathy is positively correlated to the PQ Sound subscale ($r = 0.375$; $p = 0.012$). This means that cognitive empathy increases as the truthfulness/realism of the verbal input increases. While affective empathy is positively correlated to the PQ Haptic subscale ($r = 0.339$; $p = 0.025$). This means that as haptic perception (the possibility of touching one's own body/avatar) in the virtual environment increases, affective empathy increases.

Furthermore, Proteus Effect is supported by the physiological index. We analyzed possible variations on the arousal index when subjects dress different bodies (i.e. nationality, age, gender). Our results show that there are no significant differences among categories in relation to the specific characters of the avatars (one-way ANOVA: Gender $F = 2.344$ $p = 0.109$ $\eta^2 = 0.107$; Nationality $F = 1.491$ $p = 0.237$ $\eta^2 = 0.068$; Age $F = 2.008$ $p = 0.147$ $\eta^2 = 0.089$). It means that the emotional involvement is highly independent from the personal character of the avatars. This result allows us to hypothesize that a VR-driven methodology may increase empathy among people, and reduce their prejudices.

4. Discussion

We explored the validity of immersive VR-driven methods to develop a sense of embodiment, and ultimately to increase social cohesion among users, also with the help of a data-centric system, based on a communication between virtual reality and artificial intelligence systems (Bulla et al., 2023).

To do this, we conducted an experimental study in order to understand whether embodying a virtual avatar can foster the user's *Interpretation-Reflection Loop (IRL)* (Daga et al., 2022), and therefore the human ability to feel others' thinking and feeling. We have designed a VR tool to reduce ostracism (i.e., a characteristic of social exclusion that can be understood as the feeling of being intentionally ignored), eliciting cognitive and affective empathy.

For this purpose, we have built a virtual environment, in which avatars representative of specific people can interact with the experimental subjects to discuss emotional and value-driven interpretations related to works of art. We focused on cultural heritage, because artworks are a specific class of visual objects that evoke different emotions based on one's own personality, cognitive processes and experiences (Palumbo, et al., 2023). We conducted two different experiments between subjects, using an experimental condition (perspective taking) and a control condition (verbal reflection) to understand how the virtual embodiment is able to encourage prosocial behaviors.

We placed emphasis on the speech analysis in relation to the *IRL,* and, in line with the recent literature (Hamilton-Giachritsis et al., 2018; Kishore et al., 2019; Osimo et al., 2015), our results show that VR methods can develop a sense of embodiment and maximize the human capacity to take another's point of view. We found that the percentage of people that change totally or partially their personal interpretation when they dress another body often exceeds the percentage of those who don't change it. For these analyses, we used (a) a manual speech-to-text methodology in order to compare the specific annotation of emotions and moral values before and after users' perspective taking; and (b) an automatic language inference system to detect emotions and moral values in the verbal speech of the users. Furthermore, related to virtual embodiment, our results show that dressing the avatar encourages the user to change their interpretation, even when, in a preliminary reflection, the users distance themselves from the avatar's interpretation. This result is in line with previous studies that show how the egocentric perspective in an immersive VR leads to a strong feeling of embodiment towards an artificial body (Casula et al., 2022), as well as leading the user to be more empathic in relation to feeling like pain and pleasure (Fusaro et al., 2016).

These results entitle us to hypothesize that *IRL* through virtual embodiment involves a third element, which we classify as self-reflection, which increases empathic sharing between the subjects. VR-induced self-reflection might correspond to Kobriskii's (2017) *fast reflection*, a non-traditional type of reflection responsible for not consciously controlled and rapid human responses. In this sense, our analysis of verbal reaction time confirms that having an experience in the body of other people leads to reflection guided by fast thinking, or System 1 (Kahneman, 1982, 2011), which could be understood as non-traditional reflection (fast and self-referential) opposed to traditional verbal reflection attributable to slow thinking, or System 2.

Then, we analyzed the index of emotional involvement, through the *EDA*. In accordance with other studies (Jackson et al., 2015; Meuleman and Rudrauf, 2018; Ventura et al., 2018, 2020), our results show an increase of electrodermal activity when empathic users dress another avatar's body, indicating a highly affective response. This result appears to be only significant when a user reflects verbally on another point of view before the virtual embodiment. However, a larger sample is needed to confirm this data.

Finally, our research confirms the importance of the Proteus effect (Van Loon et al., 2018) in the development of empathy inside a virtual world. We found two important correlations related to (i) affective empathy as the ability to experience affective reactions to observed experiences (Davis, 1994), and (ii) cognitive empathy that involves perspective taking and theory of mind (Davis, 1994; Eslinger, 1998). First, affective empathy increases with a higher haptic sensation, i.e., the possibility of touching one's virtual body and seeing it in the mirror with a specific synchronization between real and virtual movement facilitates the affective sharing of emotional states of other people. Second, cognitive empathy increases with a higher auditory perception, i.e., the realism in the avatar's voice increases the ability to understand the perspectives and intentions of others. In addition, Proteus Effect is also confirmed by the *EDA*. In this sense, there are no significant variations of the emotional involvement due to the specific characters of the avatars. This means that virtual embodiment is not bound by the specific attributes of the avatars, e.g., age, gender and nationality.

In line with other scholars (Slater et al., 2010; Kishore et al., 2019), we believe that VR can rapidly change the personal perception of one's body, and probably reduce prejudice across different people (Yee & Bailenson, 2006) as well as social and cultural differences (Christofi & Michael-Grigoriou, 201 7, October). In other words, we feel entitled to claim that experiencing another body increases social cohesion, since individuals show themselves closer to the emotional interpretations of others. Approaching the thought of another subject when we dress its shoes indicates an increase of interest in its thoughts and feelings, and therefore it can also be understood as a reduction of ostracism.

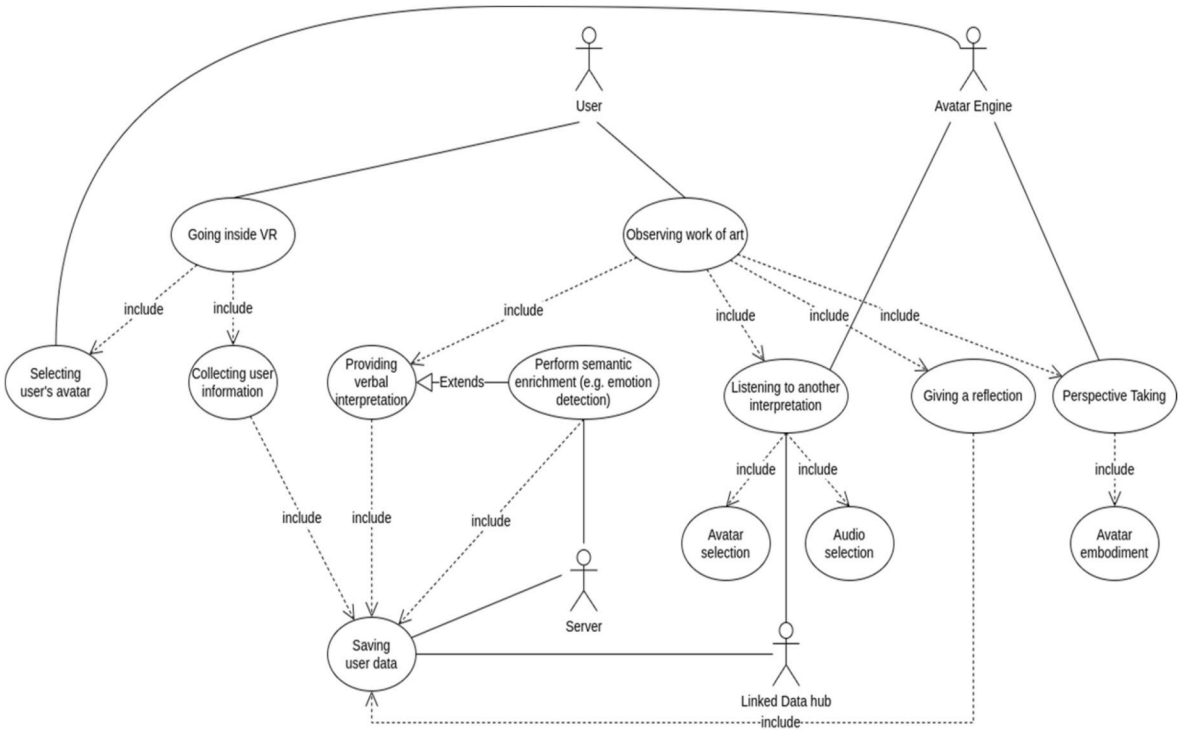


Fig. 9. Use-case diagram of the real-time application.

5. Conclusion

In our experimental study, we employed a Virtual Reality system with the aim to foster human social cohesion through the sharing of cultural heritage. For this reason, we developed a virtual museum where users can interact with different avatars in order to discuss about their emotional and value interpretation related to specific artworks. The aim is to simulate the interpretation-reflection loop by using the virtual embodiment experience.

Our results, which are in line with the literature (Ahn et al., 2013, 2016; Asher et al., 2018) show that immersive virtual reality can be a valid tool to promote empathy through an embodied experience.

Based on our results, future work involves the real-time automated modulation of the avatar profile based on the visitor's verbal responses. This requires communication between a user, a server (including artificial intelligence components), and a VR interface.

Our final application for museums, possibly extended to other domains, is designed as an intelligent system able to record personal interpretations of users, in order to place them in relation to people with different interpretations and/or different characteristics. On the one hand, this could decrease prejudice towards different people, allowing visitors to wear shoes of people with different characteristics such as age, gender or nationality. On the other hand, the avatar can be chosen based on the emotional and moral detection of the visitor's verbal interpretation, improving the sensitization towards the feelings of others.

To do this, we are implementing a system capable of recording verbal interpretations on an external Linked Data hub, and analyzing and enriching them semantically (i.e., by performing automated emotion detection, value detection, etc. (Bulla et al., 2023). The system is

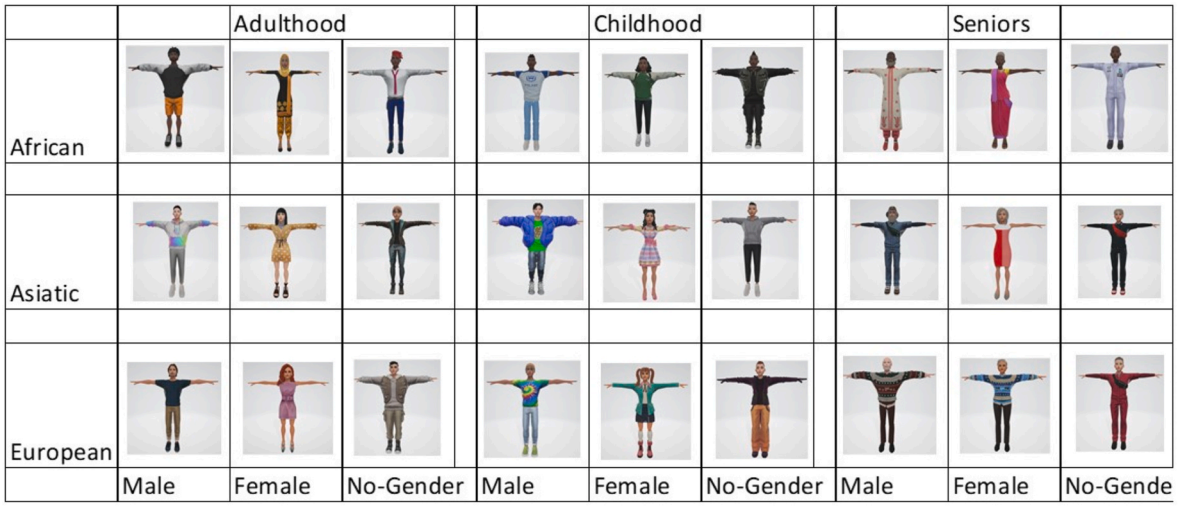


Fig. 10. 27 avatars representative of the whole population.

intended to perform workflow management and speech analysis to guide an avatar engine, e.g., in choosing which avatar to present to a user (Fig. 9).

The user's dialogue is accompanied by an explicit choice of emotions linked to the work of art. In order to maximize immersivity, the choice will be made by manipulating specific objects inside the virtual environment (i.e., the user can interact with tridimensional emoticons).

So far, we developed a total of 27 avatars ($3 \times 3 \times 3$) representative of the whole population, categorized by age (childhood, adulthood, elderly), gender (male, female, no gender) and nationality (European, African, Asiatic) - (Fig. 10), and we are working on the real-time recording of verbal interpretations through the virtual interface.

Credit author statement

Conceptualization: C.L., A.G.; methodology, C.L., M.S.; formal analysis, G.M.G; A.G; C.L., F.P.; investigation, C.L.; writing original draft preparation, C.L., A.G.; writing review and editing, C.L., M.S., A.G., G.M. G.; F.P.; supervision, A.G.

All authors have read and agreed to the published version of the manuscript.

Institutional review board statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee (protocol code COSPECS_05_2022, date of approval: April 12, 2022).

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Aldo Gangemi reports financial support provided by European Union H2020 programme. Aldo Gangemi reports a relationship with European Union that includes: funding grants.

Data availability

Data will be made available on request.

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