IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received May 12, 2021, accepted May 22, 2021, date of publication May 28, 2021, date of current version June 8, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3084863

The Relationship Between Cybersickness, Sense of Presence, and the Users' Expectancy and Perceived Similarity Between Virtual and Real Places

MARIANA MAGALHÃES[1], MIGUEL MELO[2], MAXIMINO BESSA[2,3], AND ANTÓNIO FERNANDO COELHO[1,2]
[1]Faculty of Engineering, University of Porto, 4200-465 Porto, Portugal
[2]Centre for Information Systems and Computer Graphics, INESC TEC, Campus da Faculdade de Engenharia da Universidade do Porto, 4200-465 Porto, Portugal
[3]Department of Engineering, University of Trás-os-Montes and Alto Douro, 5000-801 Vila Real, Portugal

Corresponding author: Mariana Magalhães (up201100991@fe.up.pt)

This work was supported by the National Funds through the Portuguese Funding Agency, Fundação para a Ciência e a Tecnologia (FCT), under Project UIDB/50014/2020. The work of Mariana Magalhães was supported by the Portuguese Foundation for Science and Technology (FCT) under Doctoral Grant PD/BD/150491/2019.

ABSTRACT This paper aims to explore the impact of sense of presence and cybersickness on the users' expectancy and perceived similarity between virtual and the corresponding real environments. Two virtual reality setups were tested (non-immersive and immersive) to achieve further conclusions. This research encompassed a quantitative analysis using data collection based on questionnaires, applied to a sample of 45 participants. A virtual experience was conducted (to explore users' cybersickness and sense of presence), followed by a visit to the actual real sites (to determine the degree of perceived similarity between the virtual and the corresponding real environment and if their expectations were fulfilled). Our results show a positive correlation between the global sense of presence and perceived similarity and users' expectancy for the non-immersive VR setup. A positive correlation was also found between the global cybersickness on both perceived similarity and users' expectancy for the immersive VR setup. Implications of such results for virtual tourism are discussed.

INDEX TERMS Cybersickness, sense of presence, users' expectations, users' perceived similarity, virtual tourism.

I. INTRODUCTION

The expression "virtual reality" (VR) was coined by Jaron Lanier in 1989 [1], although some attempts of implementing VR systems have started before, for instance, with Sutherland and his team's experiences working on their stereoscopic display in 1968. Since then, VR systems have been extraordinarily improved regarding immersion and interaction between users and the virtual environment. VR applications are vast and increasing [2], making them relevant in many areas/industries [3], notably in tourism [4]. It enables new ways of presenting more efficient, engaging, and consumer-oriented information, from which both the tourism sector and consumers take benefit [1], justifying the increasingly higher interest for tourism researchers.

The sense of presence, widely known as "the sense of being in a place" [1], is an essential concept regarding communication efficiency in VR. It comprises two crucial aspects: the capacity to provide physical immersion (isolation from the rest of the world) and physical presence (users behave like in real-life) [5]. These feelings are dependent on the users' immersion, i.e., the psychological state of being surrounded by something [6], [7]. One of the most critical barriers in providing a consistent sense of presence to the users is cybersickness [2] – an undesirable side effect of VR use [8] that can be defined as a constellation of discomfort symptoms associated with the exposure to VR content [9]. The assumption that technology development will eradicate cybersickness is no longer correct. Instead, recent research

The associate editor coordinating the review of this manuscript and approving it for publication was Xiaogang Jin.

shows increasing cybersickness ratings with the technology improvement, which is likely to increase [10], highlighting the importance of investigation in this context.

In the particular case of virtual tourism, besides sense of presence and cybersickness, satisfaction is an important goal to achieve. It encourages the user to recommend that destination to friends and family [11]–[13] and revisit it [14]. As virtual tourism does not allow physical contact, a precise and realistic image is essential to provide relevant information and help the user form a mental image [15]. In the tourism context, mental imagery can be defined as a person's mental representation of knowledge, feelings, and global impressions about a destination [11]. Thus, it is important to provide a pleasant experience to the user to stimulate the interest to physically visiting it and achieve satisfaction, considering VR as a complementary tool for the tourism industry, as defended by several authors [16]–[20]. It means that the feelings and the emotions felt during "real" visits cannot be replaced by virtual visits, as concluded by Losada *et al.* [18]. Perceived similarity is another important concept regarding virtual tourism and, more specifically, concerning the relationship between virtual and real tourism scenarios, and it is closely related to the concept of mental imagery [21]. For this paper, we describe perceived similarity as a subjective concept related to the likeness between the virtual and the real corresponding destination images. A virtual visit to a particular place will contribute to forming a mental image of that scenario and, consequently, shaping the user's expectations [12] that may match or mismatch the reality, depending on the perceived similarity between both scenarios (virtual and real). The discrepancy between the reality and the user's prior beliefs (negative expectations) results in a psychological conflict that can persuade the user not to travel to that destination [14], emphasizing the vital role of similarity and users' expectations.

Based on the match/mismatch of the users' expectations, we intend to explore if the users' perceived similarity between a virtual and the real environments and/or users' expectations can be affected by the symptoms of cybersickness and/or sense of presence. The research questions (*RQ*) under investigation, according to each VR setup (non-immersive and immersive), are:

RQ1: Is the users' perceived similarity between virtual and the real corresponding environment correlated with the cybersickness symptoms?

RQ2: Is the users' perceived similarity between virtual and the real corresponding environment correlated with the perceived sense of presence?

RQ3: Are the users' expectations, after the virtual and the real corresponding visits, correlated with the cybersickness symptoms?

RQ4: Are the users' expectations, after the virtual and the real corresponding visits, correlated with the perceived sense of presence?

The research team decided to investigate two different VR setups for virtual experiences so our conclusions could be more complex and differentiated. Accordingly, the results are distinguished considering the "non-immersive VR system" (laptop version) and the "immersive VR system" (Head-Mounted Display (HMD) version). Finally, these results will be confronted with the physical visit to the corresponding real places.

Research comparing virtual and real environments is still rare in the literature, as attested by Wagler and Hanus [17], highlighting this paper's contribution. Moreover, despite the increasing opportunities for virtual tourism, little research has assessed such concepts (users' expectations and perceived similarity), especially when it comes to the use of 360° video [17].

II. LITERATURE REVIEW

A. SENSE OF PRESENCE AND CYBERSICKNESS

Multiple definitions and dimensions of sense of presence have been created. Nevertheless, they all share a common feature: a subjective experience of being in a place one is not [2], only quantifiable by the user experiencing it [22]. Like the concept of presence, cybersickness has received several definitions. It is a product of mismatches/conflicts in information across sensory streams, particularly in visual-vestibular conflicts [10], [23], [24]. Cybersickness is polysymptomatic (many symptoms) and polygenic (they vary from one person to another), making it a complex concept to understand and describe. Medically, cybersickness symptoms include nausea, pale skin, cold sweats, vomiting, dizziness, headache, increased salivation, fatigue, eyestrain, and difficulty focusing [10]. This symptomatology shows an increase after 10 minutes of immersion [25] and can persist for several hours [26]. 80 to 95% [25] will experience some level of disturbance during or after exposure to VR, which tends to negatively affect the user experience [27], [28]. The severity of the adverse effects can be emphasized by numerous factors, such as technological (the type of display, the content watched, the task performed and the duration of the immersive experience [29]), and individual characteristics, such as age, gender, ethnicity, and education level, as defended by several authors [1], [2], [8], [16], [27], [30]–[36].

It is common to find "cybersickness" linked to "sense of presence" in literature, mainly due to the typically reported discomfort caused by VR equipment usage, contributing to decreasing the sense of presence. However, finding the factors (individual or technological characteristics) mediating this connection still represents a "significant challenge" [2]. Despite being more engaging, immersive VR is more likely to cause higher cybersickness [37], which can inhibit the users' focus, engagement, and involvement with the virtual environment and, in turn, harm the overall user experience [6], [32], [38]. However, on the one hand, the use of VR equipment, such as HMD, increases users' sense of presence, which is considered a positive effect. On the other hand, the usage of VR equipment presents some inconveniencies, for instance, technical problems such as jitter and lag [26], [39], or concerning physical ergonomics issues (weight, weight distribution, fit, and adjustability) [26], that limit the user moves [2]. Generally, HMD induced symptoms and effects are associated with the adaptation of a new spatiotemporal change (from the real world to the virtual environment) [8]. Moreover, apart from the body discomfort, VR exposure's consequences lead to a lack of enjoyment [8], satisfaction with VR use, and a lowered VE effectiveness [26]. The related constraints may exacerbate the experienced cybersickness symptoms [26]. Hence, it is common to find negative correlations between the sense of presence and cybersickness in literature, considering that higher levels of reported symptoms or discomfort typically decrease the level of sense of presence. First reports of negative correlations between sense of presence and cybersickness found in the literature started in the '90s. Witmer *et al.* [40] demonstrated a large negative correlation between the scores of sense of presence and self-reported cybersickness. Later, during experiments that helped establish the "Presence Questionnaire", Witmer and Singer [6] found that cybersickness can cause distraction, as later supported by Nichols *et al.* [38]. Also, Cooper *et al.* [41] suggest that when users report increased feelings of discomfort, their perceived sense of presence decrease. According to Weech *et al.* [2], this negative relationship seems to derive from factors including vection (the illusion of self-motion [23], [42]), navigation control, and display factors. Their combined power acts on sensory mismatch, which leads to sense of presence and cybersickness to drive in the opposite direction. Also, considering the use of increasingly immersive virtual tools, which is naturally dependent on the technological progress (for instance, the emergence and accessibility of HMD), contributes to turning an experience more immersive. Although the sophisticated equipment provides the user more immersion, it also originates more cybersickness symptoms. This idea clarifies that immersion in VR can bring out the positive effect of higher levels of presence and the negative consequences of cybersickness symptoms.

The balance of evidence favors the thesis that presence and cybersickness are negatively correlated. Nonetheless, a few can be found in literature revealing a positive correlation [43]–[45]. As defended by Weech *et al.* [2], both assumptions are valid and not exclusive. They are dependent on the other studied elements that can influence the sense of presence and cybersickness, such as display factors, navigation control, and individual characteristics. The methodology criteria can also affect the positive/negative correlation between sense of presence and cybersickness, for instance, using different presence questionnaires [46], or using modern/outdated VR headset devices.

1) MEASURING USERS' SENSE OF PRESENCE

Presence measures are often classified into objective and subjective measures. Objective measures assess the participant's automatic responses using physiological indicators/biomarkers or behavioral indicators [47]. Physiological indicators can be obtained from heart rate or skin conductivity, for instance; behavioral indicators include, among others, the assessment of reflexive responses, postural sway, measurements related to task performance. Subjective measures result from an introspection moment, that can be registered either in established presence questionnaires after the virtual experience, or using verbal/written ratings or reports during or after the virtual experience [2]. Despite being so criticized, questionnaires are still the most used measure to assess sense of presence [47], [48]. As previously stated by Sheridan [49], the subjective quality of presence needs a subjective method to be measured. Questionnaires are often used not only because they collect more extensive and comprehensive results, but also because of being easy to apply in various contexts. On the other hand, objective measures of presence provide less depth in measurement, and their use is more limited [47].

2) MEASURING USERS' CYBERSICKNESS

Measurements of cybersickness, similarly to presence, can be subjective or objective. Regarding objective methods, the analysis of physiological markers such as gastric activity, respiration rate, heart rate, and skin conductance are typically used. Subjective methods are the most widely used to assess the severity of cybersickness. Among them, questionnaires are the most common [10], [42], [50], and oldest [10] mechanism used to evaluate the severity of cybersickness and simulator sickness, such as the 16-item "Simulator Sickness Questionnaire" (SSQ) [50]. Although this questionnaire was created to evaluate the effects of aviation simulator displays [50], it was soon adapted to assess human symptoms related to immersive technologies [29]. Even when using supplementary material to determine cybersickness symptoms' severity, such as postural or physiological testing, researchers often use the SSQ [10], [42].

B. THE EFFECTS OF DISPLAY TYPES IN THE SENSE OF PRESENCE AND CYBERSICKNESS

As commented before, immersion tends to cause adverse effects in the user's virtual experience, which contributes to anticipating some conclusions regarding VR setups' effects in the sense of presence and cybersickness. According to the literature, more immersive VR equipment, which tends to provide the users a higher level of presence, will cause higher overall cybersickness symptoms. In general, some of the most reported problems caused by immersive display types are discomfort in the shoulder (possibly caused by the prolonged static posture), discomfort associated with the usage of VR headset, difficulty in using a hand-held input device (when applied), distraction from the VE due to deficits in visual display, and fear of becoming "tangled" in connection cables [26].

For instance, Sharples *et al.* [39], by testing four VR display types (HMD, desktop, projection, and reality theatre), found post-exposure disorientation to be significantly higher for participants who used an HMD than those who used either desktop or reality theatre. The authors also found significantly higher scores for nausea when the users used an HMD than those who used less immersive tools (desktop). Also, the authors' findings show higher overall cybersickness scores for participants who used an HMD than those who experienced reality theatre and desktop. These results are similar to Baños *et al.* [31], whose findings revealed more undesirable effects (dizziness, disorientation, and nausea) when participants wore an HMD compared to those who experienced a PC monitor or rear-projected video wall. Also, Liu and Uang [43] found higher cybersickness scores for HMD compared to a standard monitor. Relatedly, results from Vlad *et al.* [29] and Howarth and Costello [23] demonstrated higher cybersickness levels for HMD than the stereoscopic monitor. Kim *et al.* [51] reached similar results, concluding that the users felt more cybersickness levels for the HMD than CAVE and significantly more for CAVE than the desktop version.

Lately, Xu *et al.* [37] concluded that the players felt sicker (nausea and oculomotor discomfort) when playing with an HMD than a 50-inch TV.

Sharply contrasting with such results, Hakkinen *et al.* [8] found the HMD to cause significantly fewer nausea symptoms than the standard television. The authors postulate that the HMD can make the participants feel better and relaxed in an immersive movie-watching experience, reducing their discomfort.

Lately, researchers have been focusing on how to reduce such adverse consequences, as Monteiro *et al.* [3], who developed and tested a technique (''PlaneFrame'') that can lead to an improvement of the performance and the level of immersion, minimizing the level of simulator sickness with minor effects on users' perceived level of immersion. Besides, it does not require additional external devices, it is not intrusive, and it is easy to adapt and use. This technique was first applied in the first-person shooter games context. However, it might be helpful in other VR applications, such as tourism, allowing the users to be immersed for extended periods (visiting a museum, for instance), as suggested by the authors.

III. METHODOLOGY

A. RESEARCH HYPOTHESES

Taking into consideration the literature review and the research questions stated previously (Section I – Introduction), we believe that higher levels of immersion will lead to a greater perceived similarity between the virtual and the real corresponding environments, consequently meeting the users' expectations. On the contrary, we consider that cybersickness will negatively influence the users' perceived similarity and expectations. Hence, we formulate the following hypotheses:

- H1: the users' perceived similarity between virtual and the real corresponding environment will not be correlated with cybersickness in the non-immersive VR experience. We believe that the provided low level of immersion will not interfere with the user experience. Regarding the immersive experience, we expect that the users' perceived similarity will be negatively affected by cybersickness. The levels of immersion provided are high and, consequently, it is more likely to find reports revealing higher intensity levels of cybersickness. In turn, we believe that high cybersickness levels will prevent the users from focusing on the virtual environment and, consequently, on the task of thinking about the similarity between the two places.
- H2: the users' perceived similarity between virtual and the real corresponding environment will not be correlated with the perceived sense of presence in the non-immersive VR experience, due to the low levels of immersion provided, which we believe will not be enough to affect the user experience. Regarding the immersive experience, we expect that the users will report high levels of presence, which we believe will positively interfere with their perception of similarity.
- H3: the users' expectations after the virtual and the real corresponding visits will not be correlated with the cybersickness symptoms caused in the non-immersive experience, taking into account the low level of immersion provided. Regarding the immersive VR experience, we expect that the users' expectations after the virtual and the real corresponding visits will be negatively affected by cybersickness, similarly to H1.
- H4: the users' expectations after the virtual and the real corresponding visits will not be correlated with the perceived sense of presence in the non-immersive VR experience, once again, due to the low level of immersion provided. For the immersive VR experience, we believe that the sense of presence will positively affect the users' expectations. We believe that the high sense of presence will motivate and engage the users with the virtual environment, contributing to the fulfillment of their expectations.

B. SAMPLE

A convenience sampling based on a non-probabilistic method consisting of 45 volunteer participants (21 male and 24 female) between 18 and 79 years of age ($M = 42.27$, $S.D. = 17.567$) was used. All participants reported normal or corrected-to-normal vision.

C. MATERIALS

This experiment's first purpose was to gather information regarding the users' sense of presence and cybersickness for both non-immersive and immersive virtual experiences. Secondly, we collected the information regarding the users' perceived similarity between the virtual and the corresponding real scenarios and if their expectations had been fulfilled. For this purpose, we have considered a laptop as the non-immersive VR tool and an HMD as the immersive VR tool. These results were collected via questionnaire, as detailed below.

FIGURE 1. Viewpoint of são leonardo da galafura (vila real) – screenshot.

FIGURE 2. Capela nova (vila real) – screenshot.

Two different VR scenarios were created to prevent the boredom of the participants who, otherwise, would have to experience non-immersive and immersive experiences regarding the same location, at the risk of losing their interest. The first group (N = 22) visualized non-immersive "Video 1" and immersive "Video 2", and the second group (N = 23) visualized non-immersive "Video 2" and immersive "Video 1". "Video 1" and "Video 2" correspond to two virtual tours, one recorded in São Leonardo de Galafura, Peso da Régua (Fig. 1), and the other in Capela Nova (Fig. 2), Vila Real, both places located in the North of Portugal. The viewpoint of São Leonardo da Galafura is a recondite space that offers a wide and clear view over the Douro River, at an altitude of 566 meters. Here, people could be spatially dispersed and quietly explore and experience the landscape, mainly surrounded by nature. Capela Nova is located in a small square in the historic center of Vila Real, a frequent crossing point for many people, surrounded by many stores.

D. APPARATUS

For the non-immersive virtual experiment, we provided the participants a laptop (MacBook Pro Retina 13" i5 - 2,6GHz), so they could freely explore the 360° panorama by using an optical mouse to move, zoom in and zoom out in the scene. In the immersive experiment, participants could explore the scenario using a VR headset – Oculus Rift Development Kit 2 (DK2). Both non-immersive and immersive experiments took place in a quiet room, where participants had the real sound experience of the places, by using headphones with superior noise isolation (Audio-Technica M40x). It was intended to give the participants a virtual tourism experience as identical as possible to the chosen locations.

TABLE 1. Questions to measure "similarity" and "expectancy" constructs (translated from portuguese).

Construct	Questions
Similarity	1. I feel like I have already been here before.
	2. I feel like I saw nothing new.
	3. This place looks familiar to me.
	4. I saw some things I had not seen in the virtual experience. (reverse)
	5. I did not observe any differences comparing this landscape with the virtual one.
	6. The virtual experience would have been enough to know this place.
Expectancy	7. The feeling I had when physically visiting this place was greater than during the virtual experience. (reverse)
	8. I felt I had a good spatial perception of the place during the virtual experience.
	9. I think it is more pleasant to be physically in this place than just experience it virtually. (reverse)
	10. If I had not come to this place, I would feel the same.

E. STUDY VARIABLES

A within-subjects experimental study with a quantitative analysis was undertaken. This study's independent variables are the users' "sense of presence" and "cybersickness" (first explored after the virtual experience). The dependent variables are the "perceived similarity" and "expectancy", which data contributed to achieving the comparison between the virtual and the "real" experiences.

F. INSTRUMENTS

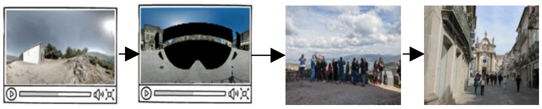
Regarding the measurement of the users' sense of presence, considering that all the participants were Portuguese, a validated Portuguese version of the Igroup Presence Questionnaire (IPQ) was used – IPQ-PT [52]. This version is an adaptation of the original IPQ by Schubert *et al.* [54], and it consists of 14-item with a 5-point Likert-scale provided for responses. It maintains the semantic/conceptual equivalence and content validity.

To assess the users' cybersickness, we used the Portuguese version of the SSQ questionnaire, adapted by Bessa *et al.* [54], which preserves the original content validity.

To explore the discrepancy between the users' expectations (formed during the VR experiences) and the sensation of physically visiting the corresponding places (perceived similarity), we developed a new entire questionnaire as there are no other methods that allow us to achieve such results. The questionnaire is composed of ten questions, six for the "similarity" construct and four for the "expectancy" construct, as shown in Table 1:

These questions were translated from the original version, written in Portuguese, as all the participants were Portuguese.

TABLE 2. Experimental setup.

	Virtual tour		Physical visit	
	Non-immersive experience	Immersive		
N=22	 Location 1	Location 2	Location 1	Location 2
N=23	 Location 2	Location 1	Location 1	Location 2
Collected information	Sense of presence	Sense of presence	Perceived similarity between virtual and real location 1	Perceived similarity between virtual and real location 2
	Cybersickness	Cybersickness	Expectations fulfillment after virtual and real visits to location 1	Expectations fulfillment after virtual and real visits to location 2

During the questionnaire development, we took into consideration a simple and straightforward discourse, with no ambiguous expressions, and the use of an accessible vocabulary, as suggested by Nemoto and Beglar [55]. A 5-point Likert-scale from "Strongly disagree" to "Strongly agree" was provided for the responses.

A pilot study with five students was conducted to assess the questionnaire's performance regarding wording, clarity, and ambiguity, as recommended by Nemoto and Beglar [55]. All the construction was guided by one Ph.D. in psychology with an expertise in psychometrics to ensure the correct measurement of the proposed constructs.

G. PROCEDURE

As mentioned before, 45 participants experienced two different VR systems. All the participants were tested following the same conditions (360° video experience in a laptop, followed by 360° video exposure using VR equipment). Accordingly, this experiment required two different videos. The result consisted of two videos, each with a 4000 x 4000 (top/bottom layout) resolution. It is consistent in the literature that 360° video is a genuine VR technology, fundamental for new content distribution, that can provide high levels of immersion at a reasonable cost [17], [18], [56], [57].

For the experimental setup (Table 2), regarding the non-immersive experience, the first group (N = 22) explored Location 1 with a laptop and a mouse. For the immersive experience, they explored Location 2 with the Oculus Rift. Regarding the non-immersive experience for the second group (N = 23), the participants explored Location 2 with a laptop and a mouse. For the immersive experience, they explored Location 1 with the Oculus Rift. Later, both groups were taken to the real corresponding sites so that they could take their conclusions about their expectations and perceived similarity between the virtual and the real environments.

The experiment was divided into two stages: 1) non-immersive experience and 2) immersive experience, each one performed for as long as the participant sought, at a maximum of 2 minutes. This limit has in consideration findings that reveal no significant evidence between shorter (1 or 3 minutes) and longer (5 or 7 minutes) VR experiences regarding users' sense of presence [58], [59], and cybersickness [58]. The experiment occurred as follows:

1. Explanation of the experiment and general instructions by a member of the research team;
2. The participants read and authorized the "Free, prior and Informed Consent" document, by signing it;
3. The participants filled out the demographic questionnaire;
4. The participants experienced the first VR experience (non-immersive – laptop version);
5. The participants filled out the post-exposure SSQ;
6. The participants filled out the first IPQ;
7. The research team tested the fit of the equipment to the participants for the immersive VR experience;
8. The participants experienced the second VR experience (immersive – with the Oculus Rift);
9. The participants filled out the post-exposure SSQ;
10. The participants filled out the second IPQ;
11. Participants were physically taken to Location 1 (*São Leonardo da Galafura*);
12. The participants answered the questionnaire regarding the comparison between the virtual and the actual visit to Location 1;
13. Participants were physically taken to Location 2 (*Capela Nova*);
14. The participants answered the questionnaire regarding the comparison between the virtual and the actual visit to Location 2.

H. STATISTICAL PROCEDURES

Before the data analysis, the variables were screened for outliers, reducing the total sample size from 45 to 43 participants. Two outliers were detected and removed. After that, we verified the normal distribution of the data, considering Skewness and Kurtosis' values that, according to George and Mallery [60], must range between ±2 to be considered normally distributed. Subsequently, we explored the significant differences between the two videos (Location 1 and Location 2) to check if they could be grouped for the statistical analysis or if they had to be separately analyzed. For this purpose, a Levene's test was run to assess the homogeneity of the variances, and then an independent sample t-test was performed to make the comparisons. The outcome showed no differences between the two videos, so they were analyzed together.

To assess the relationship between the studied variables, we run a Spearman's rank-order correlation between the independent variables ("cybersickness", "sense of presence") and the dependent variables ("similarity" and "expectancy"). The analysis and the results were distinctly made for the non-immersive and the immersive environments, as we also intended to understand if there were any differences between the two VR setups. Thus, summarizing, it was our goal to explore the following correlations:

1. The correlation between the sense of presence and its subscales and perceived similarity, for the non-immersive environment;
2. The correlation between the sense of presence and its subscales and perceived similarity, for the immersive environment;
3. The correlation between the sense of presence and its subscales and expectancy, for the non-immersive environment;
4. The correlation between the sense of presence and its subscales and expectancy, for the immersive environment;
5. The correlation between cybersickness and its subscales and perceived similarity, for the non-immersive environment;
6. The correlation between cybersickness and its subscales and perceived similarity, for the immersive environment;
7. The correlation between cybersickness and its subscales and expectancy, for the non-immersive environment;
8. The correlation between cybersickness and its subscales and expectancy, for the immersive environment.

As previously discussed, there was a need to develop a questionnaire to measure the underlying constructs (the similarity between the virtual and the real places, and the fulfillment of the users' expectations after visiting the virtual and the real places). The first construct ("similarity") consisted of six questions, and the second construct ("expectancy") consisted of four questions, as detailed before. A test to explore the internal consistency of the scale was applied.

IV. RESULTS

Regarding the questionnaire that measures the similarity and expectancy constructs, we performed a test to assess the internal consistency level of the scale. Results demonstrated a high internal consistency level, as determined by a Cronbach's alpha of 0.734 for the "similarity" construct and 0,705 for the "expectancy" construct. According to DeVellis [61] and Kline [62], all recommended values must be 0,7 or higher.

To assess the data's normal distribution, we performed a statistical analysis to verify Kurtosis and Skewness' values, which ranged, respectively, between -1.020 and $+1.964$, and -0.717 and 1.399, revealing a normal distribution.

Results will be presented distinguishing the non-immersive (Table 3) and the immersive (Table 4) VR experiences with the real physical visits. Subsequently, these results will be compared, considering the VR setup and the self-reported sense of presence and cybersickness. Regarding the non-immersive VR environment, Spearman's correlation analysis indicates statistically significant positive correlations between the global sense of presence score and both the users' perceived similarity ($r_s = 0.365$, $\rho < 0.05$) and expectancy ($r_s = 0.417$, $\rho < 0.01$). We also found a statistically significant positive correlation between the subscale of sense of presence "realism" and both the users' perceived similarity ($r_s = 0.447$, $\rho < 0.01$) and expectancy ($r_s = 0.429$, $\rho < 0, 01$). No statistically significant correlations were found between any cybersickness subscale and the perceived similarity or expectancy for the non-immersive environment.

Concerning the immersive environment, the Spearman's correlation analysis indicated a statistically significant positive correlation between the cybersickness global score and both the users' perceived similarity ($r_s = 0.343$, $\rho < 0, 05$) and expectancy ($r_s = 0.353$, $\rho < 0, 05$). Four statistically significant positive correlations were found between other variables: 1) between the cybersickness subscale "disorientation" and the perceived similarity ($r_s = 0.316$, $\rho < 0, 05$); 2) between the cybersickness subscale "oculomotor discomfort" and the users' perceived similarity ($r_s = 0.312$, $\rho < 0, 05$); 3) between the cybersickness subscale "oculomotor discomfort" and the users' expectancy ($r_s = 0.376$, $\rho < 0, 05$); 4) between the cybersickness subscale "nausea" and expectancy ($r_s = 0.337$, $\rho < 0, 05$). No statistically

TABLE 3. Summary of the results found for the non-immersive experience with spearman's correlation analysis (N = 43). Significant correlations are highlighted in bold.

		Users' global Similarity	Users' global Expectancy
Presence Subscales	**Realism**	**(r_s= 0.447, ρ=0.003)**	**(r_s= 0.429, ρ=0.004)**
	Spatial Presence	(r_s= 0.200, ρ=0.198)	(r_s= 0.275, ρ=0,074)
	Involvement	(r_s= 0.122, ρ=0.437)	(r_s= 0.101, ρ=0,521)
	Global Presence	**(r_s= 0.365, ρ=0.016)**	**(r_s= 0.417, ρ=0.005)**
Cybersickness Subscales	Nausea	(r_s= 0.059, ρ=0.706)	(r_s= 0.160, ρ=0.305)
	Oculomotor discomfort	(r_s= 0.194, ρ=0.212)	(r_s= 0.264, ρ=0.087)
	Disorientation	(r_s= 0.131, ρ=0.401)	(r_s= 0.211, ρ=0.174)
	Global Cybersickness	(r_s= 0.173, ρ=0.267)	(r_s= 0.251, ρ=0.105)

TABLE 4. Summary of the results found for the immersive experience with spearman's correlation analysis (N = 43). Significant correlations are highlighted in bold.

		Users' global Similarity	Users' global Expectancy
Presence Subscales	Realism	(r_s= 0.191, ρ=0.221)	(r_s= 0.071, ρ=0.652)
	Spatial Presence	(r_s= 0.029, ρ=0.855)	(r_s= -0.032, ρ=0,836)
	Involvement	(r_s= -0.106, ρ=0.499)	(r_s= 0.041, ρ=0,795)
	Global Presence	(r_s= 0.098, ρ=0.531)	(r_s= -0.006, ρ=0.969)
Cybersickness Subscales	**Nausea**	(r_s= 0.230, ρ=0.138)	**(r_s= 0.337, ρ=0.027)**
	Oculomotor discomfort	**(r_s= 0.312, ρ=0.042)**	**(r_s= 0.376, ρ=0.013)**
	Disorientation	**(r_s= 0.316, ρ=0.039)**	(r_s= 0.261, ρ=0.091)
	Global Cybersickness	**(r_s= 0.343, ρ=0.024)**	**(r_s= 0.353, ρ=0.020)**

significant correlations were found between any presence subscale and the perceived similarity or expectancy for the immersive environment.

V. DISCUSSION

Regarding the *RQ1*, findings from this investigation revealed no correlation between cybersickness and the users' perceived similarity for the non-immersive experience, as we hypothesized. For the immersive experience, our results showed a significant positive correlation between the global cybersickness scores and the perceived similarity, contrary to what we were expecting. This positive correlation is surprising, as we were anticipating that the discomfort associated with the high levels of immersion (cybersickness) would contribute to making the users focus less on the virtual environment and on the task of thinking about the similarity between the two sites. We believe that such results can be explained by the eventual high levels of relaxation caused by the virtual tourism experience, making the users ignore the discomfort, as postulated by Hakkinen *et al.* [8].

Regarding the correlation between the sense of presence and the users' perceived similarity (*RQ2*), a significant positive correlation was found for the non-immersive VR experience, but none for the immersive VR experience, contrary to what we were expecting. Due to the low levels of immersion provided in the non-immersive VR setup, we were expecting no correlation between the variables. In turn, we were supposing that the higher levels of immersion provided in the immersive experience would increase the users' sense of presence, and consequently, positively interfere with the users' perceived similarity, which did not occur. Nevertheless, this conclusion is important to clarify that, even though the users are provided with low levels of immersion in a virtual tourism experience, the perceived sense of presence will be enough to make them understand a certain destination.

Considering the correlation between the users' expectations and cybersickness (*RQ3*), we found no correlation for the non-immersive experience, as expected. However, we found a significant positive correlation for the immersive experience, contrary to what we were anticipating. Moreover, for the immersive experience, we identified a statistically significant positive correlation between the users' perceived similarity and the cybersickness subscales, "oculomotor discomfort" and "disorientation", and also between the users' expectancy and the cybersickness subscales, "nausea" and "oculomotor discomfort". In other words, according to our findings, high levels of cybersickness can indicate greater perceived similarity scores and the greater fulfillment of the users' expectations. This conclusion emphasizes the postulation of Hakkinen *et al.* [8], as previously detailed.

Regarding the *RQ4*, we detected a significant positive correlation between the users' expectations and the perceived sense of presence for the non-immersive experience, and no correlation for the immersive experience, contrary to what we were expecting. Additionally, we detected a statistically significant positive correlation between the realism subscale of sense of presence and both similarity and expectancy variables for the non-immersive experience. This finding supports the importance of providing a realistic and relevant mental representation of the destination to the user, highlighting the concept of mental imagery for virtual tourism [11], [15]. This finding was obtained for the non-immersive VR setup. However, it makes us believe that, despite the associated low levels of immersion, non-immersive VR setups comply with the goal of providing high levels of realism.

TABLE 5. Summary of the results according to the formulated Research Questions (RQ) and Hypotheses' (H) confirmation or rejection.

Research Questions/Hypotheses	Results: Non-immersive VR experience	Results: Immersive VR experience
RQ1: Is the users' perceived similarity between virtual and the real corresponding environment correlated with the cybersickness symptoms?	No correlation found	Significant positive correlation found
H1	Confirmed	**Rejected** – we were expecting a negative correlation
RQ2: Is the users' perceived similarity between virtual and the real corresponding environment correlated with the perceived sense of presence?	Significant positive correlation found	No correlation found
H2	**Rejected** – we were expecting no correlation	**Rejected** – we were expecting a positive correlation
RQ3: Are the users' expectations, after the virtual and the real corresponding visits, correlated with the cybersickness symptoms?	No correlation found	Significant positive correlation found
H3	**Confirmed**	**Rejected** – we were expecting a negative correlation
RQ4: Are the users' expectations, after the virtual and the real corresponding visits, correlated with the perceived sense of presence?	Significant positive correlation found	No correlation found
H4	**Rejected** – we were expecting no correlation	**Rejected** – we were expecting a positive correlation

According to the research questions, Table 5 summarizes the above-described results and presents the formulated hypotheses' confirmation or rejection.

Regarding this paper's limitations, we highlight the non-validation of the developed questionnaire, although our results demonstrate a high internal consistency level. Nonetheless, this paper contributes to fill a gap in the literature, as the comparison between virtual and "real" experiences is rare [17]. We recommend further research to entrench our conclusions. Moreover, we suggest that future investigation in this field must involve a bigger sample size and the concern for the individual characteristics, such as age, gender, ethnicity, education level, and personality, considering their influence on the VR experiences, and taking into account that they are significantly less explored [32], [63].

VI. CONCLUSION

This research aimed to understand the impact of sense of presence and cybersickness on the users' perceived similarity between the virtual and the corresponding real environment and the users' expectations after the virtual visit, considering two different VR setups. On the one hand, our results show four statistically significant correlations for the non-immersive VR experiment, all of them related to the presence variables and none related to the cybersickness variables. On the other hand, six statistically significant correlations were found for the immersive environment, all related to the cybersickness variable and none to the sense of presence. Firstly, these results reinforce the correlation between immersion and cybersickness [2], [6], [40]. Secondly, we underline the power of non-immersive experiences to promote tourism. Although more obsolete, we believe, based on the positive correlations found between realism and the perception of similarity and between realism and the users' expectations, that non-immersive VR setups have been doing positive work for the success of virtual tourism.

REFERENCES

[1] J. Steuer, "Defining virtual reality: Dimensions determining telepresence," *J. Commun.*, vol. 42, no. 4, pp. 73–93, Dec. 1992. [Online]. Available: https://www.cybertherapy.info/pages/telepresence.pdf

[2] S. Weech, S. Kenny, and M. Barnett-Cowan, "Presence and cybersickness in virtual reality are negatively related: A review," *Frontiers Psychol.*, vol. 10, pp. 1–19, Feb. 2019, doi: 10.3389/fpsyg.2019.00158.

[3] D. Monteiro, H.-N. Liang, J. Wang, H. Chen, and N. Baghaei, "An in-depth exploration of the effect of 2D/3D views and controller types on first person shooter games in virtual reality," in *Proc. IEEE Int. Symp. Mixed Augmented Reality (ISMAR)*, Nov. 2020, pp. 713–724.

[4] S. M. C. Loureiro, J. Guerreiro, and F. Ali, "20 years of research on virtual reality and augmented reality in tourism context: A text-mining approach," *Tourism Manage.*, vol. 77, Apr. 2020, Art. no. 104028, doi: 10.1016/j.tourman.2019.104028.

[5] M. A. A. Gutiérrez, F. Vexo, and D. Thalmann, *Stepping Into Virtual Reality*. London, U.K.: Springer, 2008.

[6] B. G. Witmer and M. J. Singer, "Measuring presence in virtual environments: A presence questionnaire," *Presence, Teleoperators Virtual Environ.*, vol. 7, no. 3, pp. 225–240, Jun. 1998, doi: 10.1162/105474698565686.

[7] M. Slater and S. Wilbur, "A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments," *Presence, Teleoperators Virtual Environ.*, vol. 6, no. 6, pp. 603–616, Dec. 1997, doi: 10.1162/pres.1997.6.6.603.

[8] J. Hakkinen, T. Vuori, and M. Paakka, "Postural stability and sickness symptoms after HMD use," in *Proc. IEEE Int. Conf. Syst., Man Cybern.*, Oct. 2005, pp. 267–268, doi: 10.1109/ICSMC.2002.1167964.

[9] K. M. Stanney, R. S. Kennedy, and J. M. Drexler, "Cybersickness is not simulator sickness," in *Proc. Hum. Factors Ergonom. Soc. Annu. Meeting*, vol. 41, no. 2. Los Angeles, CA, USA: Sage, 1997, pp. 1138–1142, doi: 10.1177/107118139704100292.

[10] L. Rebenitsch and C. Owen, "Review on cybersickness in applications and visual displays," *Virtual Reality*, vol. 20, no. 2, pp. 101–125, Jun. 2016, doi: 10.1007/s10055-016-0285-9.

[11] S. Baloglu and K. W. McCleary, "A model of destination image formation," *Ann. Tourism Res.*, vol. 26, no. 4, pp. 868–897, 1999, doi: 10.1016/S0160-7383(99)00030-4.

[12] I. A. R. del Bosque and H. S. Martín, "Tourist satisfaction: A cognitive-affective model," *Ann. Tourism Res.*, vol. 35, no. 2, pp. 551–573, 2008, doi: 10.1016/j.annals.2008.02.006.

[13] A. Correia and C. Moço, "Na senda da satisfação dos turistas. O caso do turismo português," *Estudos II Faculdade de Economia da Universidade do Algarve*, vol. 2005, pp. 59–76, Aug. 2005.

[14] K. Chon, "The role of destination image in tourism: A review and discussion," *Tourist Rev.*, vol. 45, no. 2, pp. 2–9, Feb. 1990, doi: 10.1108/eb058040.

[15] T. Iachini, L. Maffei, M. Masullo, V. P. Senese, M. Rapuano, A. Pascale, F. Sorrentino, and G. Ruggiero, "The experience of virtual reality: Are individual differences in mental imagery associated with sense of presence?" *Cognit. Process.*, vol. 20, no. 3, pp. 291–298, 2019, doi: 10.1007/s10339-018-0897-y.

[16] D. A. Guttentag, "Virtual reality: Applications and implications for tourism," *Tourism Manage.*, vol. 31, no. 5, pp. 637–651, Oct. 2010, doi: 10.1016/j.tourman.2009.07.003.

[17] A. Wagler and M. D. Hanus, "Comparing virtual reality tourism to real-life experience: Effects of presence and engagement on attitude and enjoyment," *Commun. Res. Rep.*, vol. 35, no. 5, pp. 456–464, Oct. 2018, doi: 10.1080/08824096.2018.1525350.

[18] N. Losada, F. Jorge, M. S. Teixeira, M. Melo, and M. Bessa, "Could virtual reality substitute the 'real' experience? Evidence from a UNESCO world heritage site in Northern Portugal," in *Advances in Tourism, Technology and Systems*. Singapore: Springer, Oct. 2021, pp. 153–161, doi: 10.1007/978-981-33-4260-6_14.

[19] S. Sussmann and H. Vanhegan, "Virtual reality and the tourism product substitution. Substitute or complement?" in *Proc. ECIS*, no. 117, 2000, pp. 1–7.

[20] P. Williams and J. P. Hobson, "Virtual reality and tourism: Fact or fantasy?" *Tourism Manage.*, vol. 16, no. 6, pp. 423–427, Sep. 1995. [Online]. Available: https://www.sciencedirect.com/science/article/pii/026151779500050X

[21] X. Deng, H. R. Unnava, and H. Lee, "'Too true to be good?' when virtual reality decreases interest in actual reality," *J. Bus. Res.*, vol. 100, pp. 561–570, Jul. 2019, doi: 10.1016/j.jbusres.2018.11.008.

[22] M. Slater, M. Usoh, and A. Steed, "Depth of presence in virtual environments," *Presence, Teleoperators Virtual Environ.*, vol. 3, no. 2, pp. 130–144, Jan. 1994, doi: 10.1162/pres.1994.3.2.130.

[23] P. A. Howarth and P. J. Costello, "The occurrence of virtual simulation sickness symptoms when an HMD was used as a personal viewing system," *Displays*, vol. 18, no. 2, pp. 107–116, 1997, doi: 10.1016/S0141-9382(97)00011-5.

[24] K. M. Stanney and R. S. Kennedy, "Aftereffects from virtual environment exposure: How long do they last?" in *Proc. Hum. Factors Ergonom. Soc. Annu. Meeting*, vol. 42, no. 21. Los Angeles, CA, USA: Sage, 1998, pp. 1476–1480, doi: 10.1177/154193129804202103.

[25] S. V. G. Cobb, S. Nichols, A. Ramsey, and J. R. Wilson, "Virtual reality-induced symptoms and effects (VRISE)," *Presence, Teleoperators Virtual Environ.*, vol. 8, no. 2, pp. 169–186, Apr. 1999, doi: 10.1162/105474699566152.

[26] S. Nichols, "Physical ergonomics of virtual environment use," *Appl. Ergonom.*, vol. 30, no. 1, pp. 79–90, 1999, doi: 10.1016/S0003-6870(98)00045-3.

[27] S. Nichols, "Individual characteristics and experiences of virtual reality induced symptoms and effects (VRISE)," in *Proc. Hum. Factors Ergonom. Soc. Annu. Meeting*, vol. 44, no. 5. Los Angeles, CA, USA: Sage, 2000, pp. 538–541, doi: 10.1177/154193120004400514.

[28] J. Guna, G. Geršak, I. Humar, J. Song, J. Drnovšek, and M. Pogačnik, "Influence of video content type on users' virtual reality sickness perception and physiological response," *Future Gener. Comput. Syst.*, vol. 91, pp. 263–276, 2019, doi: 10.1016/j.future.2018.08.049.

[29] R. Vlad, O. Nahorna, P. Ladret, and A. Guerin, "The influence of the visualization task on the simulator sickness symptoms—A comparative SSQ study on 3DTV and 3D immersive glasses," in *Proc. 3DTV Vis. Beyond Depth (3DTV-CON)*, Aberdeen, U.K., Oct. 2013, pp. 1–4, doi: 10.1109/3DTV.2013.6676647.

[30] G. De Leo, K. S. Goodman, E. Radici, S. R. Secrhist, and T. W. Mastaglio, "Level of presence in team-building activities: Gaming component in virtual environments," *Int. J. Multimedia Appl.*, vol. 3, no. 2, pp. 1–10, May 2011, doi: 10.5121/ijma.2011.3201.

[31] R. M. Baños, C. Botella, M. Alcañiz, V. Liaño, B. Guerrero, and B. Rey, "Immersion and emotion: Their impact on the sense of presence," *CyberPsychol. Behav.*, vol. 7, no. 6, pp. 734–741, Dec. 2004, doi: 10.1089/cpb.2004.7.734.

[32] A. Sacau, J. Laarni, and T. Hartmann, "Influence of individual factors on presence," *Comput. Hum. Behav.*, vol. 24, no. 5, pp. 2255–2273, Sep. 2008, doi: 10.1016/j.chb.2007.11.001.

[33] C. Heeter, "Being there: The subjective experience of presence," *Presence, Teleoperators Virtual Environ.*, vol. 1, no. 2, pp. 262–271, Jan. 1992, doi: 10.1162/pres.1992.1.2.262.

[34] J. Lessiter, J. Freeman, E. Keogh, and J. Davidoff, "A cross-media presence questionnaire: The ITC-sense of presence inventory," (in English), *Presence, Teleoperators Virtual Reality*, vol. 10, no. 3, p. 282, Jun. 2001, doi: 10.1162/105474601300343612.

[35] C. C. Bracken and D. J. Atkin, "How screen size affects perception of television: A survey of presence-evoking technology in our living rooms," *Vis. Commun. Quart.*, vol. 11, nos. 1–2, pp. 23–27, Jan. 2004, doi: 10.1080/15551390409388283.

[36] J. Barrett, "Side effects of virtual environments: A review of the literature," DSTO Inf. Sci. Lab., Melbourne, VIC, Australia, Tech. Rep. DSTO-TR-1419, 2004. [Online]. Available: https://apps.dtic.mil/sti/pdfs/ADA426109.pdf
[37] W. Xu, H.-N. Liang, Z. Zhang, and N. Baghaei, "Studying the effect of display type and viewing perspective on user experience in virtual reality exergames," *Games Health J.*, vol. 9, no. 6, pp. 405–414, Dec. 2020, doi: 10.1089/g4h.2019.0102.
[38] S. Nichols, C. Haldane, and J. R. Wilson, "Measurement of presence and its consequences in virtual environments," *Int. J. Hum. Comput. Stud.*, vol. 52, no. 3, pp. 471–491, Mar. 2000, doi: 10.1006/ijhc.1999.0343.
[39] S. Sharples, S. Cobb, A. Moody, and J. R. Wilson, "Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems," *Displays*, vol. 29, no. 2, pp. 58–69, Mar. 2008, doi: 10.1016/j.displa.2007.09.005.
[40] B. G. Witmer, J. H. Bailey, B. W. Knerr, and K. C. Parsons, "Virtual spaces and real world places: Transfer of route knowledge," *Int. J. Hum. Comput. Stud.*, vol. 45, no. 4, pp. 413–428, Oct. 1996, doi: 10.1006/ijhc.1996.0060.
[41] N. Cooper, F. Milella, I. Cant, C. Pinto, M. White, and G. Meyer, "The effects of multisensory cues on the sense of presence and task performance in a virtual reality environment," presented at the EuroVR, Lecco, Italy, 2015, doi: 10.1371/journal.pone.0191846.
[42] W. B. Stone, "Psychometric evaluation of the simulator sickness questionnaire as a measure of cybersickness," M.S. thesis, Dept. Psychol., Iowa State Univ., Ames, IA, USA, 2017, doi: 10.31274/ETD-180810-5050.
[43] C.-L. Liu and S.-T. Uang, "Effects of presence on causing cybersickness in the elderly within a 3D virtual store," in *Proc. Int. Conf. Hum.-Comput. Interact.*, vol. 6764. Berlin, Germany: Springer, 2011, pp. 490–499, doi: 10.1007/978-3-642-21619-0_61.
[44] Y. Ling, H. T. Nefs, W.-P. Brinkman, C. Qu, and I. Heynderickx, "The relationship between individual characteristics and experienced presence," *Comput. Hum. Behav.*, vol. 29, no. 4, pp. 1519–1530, Jul. 2013, doi: 10.1016/j.chb.2012.12.010.
[45] J.-W. Lin, H. B.-L. Duh, D. E. Parker, H. Abi-Rached, and T. A. Furness, "Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment," in *Proc. IEEE Virtual Reality*, Mar. 2002, pp. 164–171, doi: 10.1109/VR.2002.996519.
[46] Y. Y. Kim, H. J. Kim, E. N. Kim, H. D. Ko, and H. T. Kim, "Characteristic changes in the physiological components of cybersickness," *Psychophysiology*, vol. 42, no. 5, pp. 616–625, Sep. 2005, doi: 10.1111/j.1469-8986.2005.00349.x.
[47] M. Lombard, T. B. Ditton, and L. Weinstein, "Measuring presence: The temple presence inventory," in *Proc. 12th Annu. Int. Workshop Presence*, 2009, pp. 1–15.
[48] J.-C. Servotte, M. Goosse, S. H. Campbell, N. Dardenne, B. Pilote, I. L. Simoneau, M. Guillaume, I. Bragard, and A. Ghuysen, "Virtual reality experience: Immersion, sense of presence, and cybersickness," *Clin. Simul. Nursing*, vol. 38, pp. 35–43, Jan. 2020, doi: 10.1016/j.ecns.2019.09.006.
[49] T. B. Sheridan, "Musings on telepresence and virtual presence," *Presence, Teleoperators Virtual Environ.*, vol. 1, no. 1, pp. 120–126, Jan. 1992, doi: 10.1162/pres.1992.1.1.120.
[50] R. S. Kennedy, N. E. Lane, K. S. Berbaum, and M. G. Lilienthal, "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness," *Int. J. Aviation Psychol.*, vol. 3, no. 3, pp. 203–220, Jul. 1993, doi: 10.1207/s15327108ijap0303_3.
[51] K. Kim, M. Z. Rosenthal, D. J. Zielinski, and R. Brady, "Effects of virtual environment platforms on emotional responses," (in English), *Comput Methods Programs Biomed*, vol. 113, no. 3, pp. 882–893, Mar. 2014, doi: 10.1016/j.cmpb.2013.12.024.
[52] J. Vasconcelos-Raposo, M. Bessa, M. Melo, L. Barbosa, R. Rodrigues, C. M. Teixeira, L. Cabral, and A. A. Sousa, "Adaptation and validation of the igroup presence questionnaire (IPQ) in a portuguese sample," *Presence, Teleoperators Virtual Environ.*, vol. 25, no. 3, pp. 191–203, Dec. 2016, doi: 10.1162/PRES_a_00261.
[53] T. Schubert, F. Friedmann, and H. Regenbrecht, "Decomposing the sense of presence: Factor analytic insights," in *Proc. 2nd Int. Workshop Presence*, vol. 1999, 2001, pp. 1–5.
[54] M. Bessa, M. Melo, D. Narciso, L. Barbosa, and J. Vasconcelos-Raposo, "Does 3D 360 video enhance user's VR experience?: An evaluation study," in *Proc. 17th Int. Conf. Hum. Comput. Interact.*, Sep. 2016, pp. 1–4, doi: 10.1145/2998626.2998669.
[55] T. Nemoto and D. Beglar. (2014). *Developing Likert-Scale Questionnaires*. [Online]. Available: https://jalt-publications.org/files/pdf-article/jalt2013_001.pdf
[56] M. Magalhaes, M. Melo, A. Coelho, and M. Bessa, "Age and level of education impact on expectancy and perceived similarity between virtual and real touristic environments," in *Proc. Int. Conf. Graph. Interact. (ICGI)*, Nov. 2019, pp. 1–7, doi: 10.1109/ICGI47575.2019.8955049.
[57] W. H. Lo and K. L. B. Cheng, "Does virtual reality attract visitors? The mediating effect of presence on consumer response in virtual reality tourism advertising," *Inf. Technol. Tourism*, vol. 22, no. 4, pp. 537–562, Dec. 2020, doi: 10.1007/s40558-020-00190-2.
[58] M. Melo, J. Vasconcelos-Raposo, and M. Bessa, "Presence and cybersickness in immersive content: Effects of content type, exposure time and gender," *Comput. Graph.*, vol. 71, pp. 159–165, Apr. 2018, doi: 10.1016/j.cag.2017.11.007.
[59] M. Melo, S. Sampaio, L. Barbosa, J. Vasconcelos-Raposo, and M. Bessa, "The impact of different exposure times to 360° video experience on the sense of presence," in *Proc. 23rd Portuguese Meeting Comput. Graph. Interact. (EPCGI)*, Nov. 2016, pp. 1–5, doi: 10.1109/EPCGI.2016.7851192.
[60] D. George and P. Mallery, *IBM SPSS Statistics 25 Step by Step: A Simple Guide and Reference*, 50th ed. New York, NY, USA: Routledge, 2019.
[61] R. F. DeVellis, *Scale Development: Theory and Applications*, 2nd ed. Thousand Oaks, CA, USA: Sage, 2003.
[62] R. B. Kline, *Principles and Practice of Structural Equation Modeling*, 2nd ed. New York, NY, USA: Guilford publications, 2005.
[63] C. Sas, G. M. P. O'Hare, and R. Reilly, "Presence and task performance: An approach in the light of cognitive style," *Cognition, Technol. Work*, vol. 6, no. 1, pp. 53–56, Feb. 2004, doi: 10.1007/s10111-003-0145-8.

MARIANA MAGALHÃES received the master's degree in multimedia from the Faculty of Engineering, University of Porto, in 2017, where she is currently pursuing the Ph.D. degree in digital media. Her research interests include immersive environments and multisensory virtual reality.

MIGUEL MELO is currently an Assistant Researcher with the INESC TEC, where he is specialized in computer graphics. He is also the Manager of the Multisensory Virtual Reality Laboratory. His research interests include computer graphics, HDR, and multisensory virtual reality. He is a member of the Executive Committee of Eurographics.

MAXIMINO BESSA is currently an Associate Professor with Habilitation at the Department of Engineering, University of Trás-os-Montes and Alto Douro, Portugal, where he has been a Senior Researcher with the INESC TEC, since 2009, and the Director of the Multisensory Virtual Reality Laboratory MASSIVE. Since 2003, he has also been a member of the Eurographics Association and the President of the Portuguese Computer Graphics Chapter for the period 2020–2022.

ANTÓNIO FERNANDO COELHO is currently an Associate Professor with Habilitation at the Department of Informatics Engineering, Faculty of Engineering (FEUP), University of Porto (UP), where he teaches in the areas of computer graphics, programming, and digital games. He is also the Director of the Doctoral Program in digital media at the University of Porto. He is a Senior Researcher with the Center for Information Systems and Computer Graphics (CSIG), INESC TEC, being the coordinator of the computer graphics and virtual environments area.