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REGULAR PAPER

Immersive multisensory virtual reality technologies for virtual tourism

A study of the user's sense of presence, satisfaction, emotions, and attitudes

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Abstract
Virtual reality (VR) technologies have been used successfully in tourism marketing. While most conventional VR applications are of an audiovisual nature, the constant evolution of these technologies allows providing enriched multisensory VR content that can further increase the potential of VR applied to the tourism field. To generate insights into the impact of such VR technologies, this manuscript investigates the impact of such multisensory VR setups and gender on the user's sense of presence, satisfaction, emotions, and attitudes. A user study with a gender-balanced sample ($N = 80$) was carried where two VR setups (audiovisual vs multisensory) were compared taking into account the user's gender. Results revealed that the female sample scored significantly higher spatial presence across VR setups and reported more involvement and overall presence in the audiovisual condition. In addition, correlations were found between the pairs Spatial Presence–Emotions, Spatial Presence–Enjoyment, Satisfaction–Involvement, Satisfaction–Enjoyment, and Satisfaction and Usefulness to perceive the destination. Results also suggest that multisensory stimulus can mitigate possible gender differences in passive VR scenarios. We concluded that the capability of the VR system to make users feel physically present in the virtual environment contributes significantly to the development of positive emotions and enjoyment, which can contribute positively to the user's consumer behaviour towards the touristic products and services.

Keywords Immersive technologies · Multisensory virtual reality · Virtual tourism

1 Introduction

Virtual reality (VR) allows transporting users to virtual environments, making them disconnect from the real world and engage in the virtual world as if they were there. The potential that VR has to make users feel present in a virtual environment (VE) has led to the successful adoption of VR technologies in a wide variety of application fields such as education [40, 55], medical [26, 37], military [2, 72], entertainment [15, 73], and virtual tourism [7, 24, 27, 47]. The effectiveness of a VR application, i.e. transporting users to the virtual space and making them develop a sense of "being there", is widely evaluated through the sense of presence [9, 59, 63, 64]. For evaluating the sense of presence, the literature widely adopts subjective metrics such as the Presence Questionnaire [70], the iGroup Presence Questionnaire [61], or the ITC-Sense of Presence Inventory Questionnaire [41], respectively. Nevertheless, the sense of presence can be evaluated using objective metrics by measuring physiological data such as cardiovascular measures and skin measures or task performance measures.

Different factors can impact the sense of presence, such as the hardware characteristics, the user characteristics or the virtual consent. In terms of VR hardware characteristics, previous studies have shown that the type of VR setup can affect the sense of presence. VR setups can be categorized as non-immersive (conventional desktop-based

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setups), semi-immersive (e.g. large displays, projection-based systems), or immersive setups (e.g. head-mounted displays, CAVE), with the more immersive the setup, the more presence being reported [10, 38, 39, 56].

As for the user characteristics that can affect the perceptual media quality, there are personality factors such as the capability of absorption, the cognitive style, the capacity for managing anxiety, or even the gender of the user [62]. Regarding the impact of gender on the development of the sense of presence, the known biological differences may contribute to different outcomes depending on the VR experience [13, 19]. For instance, it was already reported that men tend to report more presence than females in interactive environments, serious VEs or when required to perform complex tasks. However, female participants report higher levels of presence in virtual environments without interaction [18, 19, 51, 64] and to have more sensitivity to multisensory effects than men when evaluating the quality of experience [60].

Virtual content can be divided into two major categories: 360 video or synthesized content. These different natures can affect the sense of presence differently, as shown in Ref. [45]. In their study, the authors have compared an immersive 360 video experience versus an immersive virtual experience in a realistic synthesized VE. The variables considered were the spatial presence, involvement, and overall sense of presence. Users have reported more presence and involvement in the 360 video condition, while the synthesized VE's spatial presence scores were higher. More than the nature of the content, the environment can also affect the sense of presence. For instance, Banos et al. [4] have conducted a study that evaluated two VEs, one neutral and the other to induce sadness. Results have revealed that the emotional ambient elicited more presence as it was more engaging and natural to users than the neutral environment.

Another feature of the virtual content is the sensory stimuli delivered in the virtual experience. Although most of the VR systems are audiovisual, the addition of more stimuli captures the user's attention and can enhance the quality of experience [14, 71]. Moreover, multisensory stimulation impacts the sense of presence: adding stimulus such as smell, haptics (e.g. thermal sensation or force feedback) or even taste to the VR system can also affect the sense of presence. Previous studies have shown that multisensory VR has a positive impact on the sense of presence, making the experience more authentic or more enjoyable [23, 46, 57, 58]. However, simply adding multisensory stimulus does not guarantee an increase in the sense of presence. Namely, suppose the stimuli are incoherent with the depicted virtual scene. In that case, they can cause adverse effects such as cybersickness or even impose a cognitive overload that affects the sense of presence negatively [6, 17].

Focusing on the potential of VR applied to tourism, the potential of VR technologies has been seen as a game changer for the industry since long ago [49, 69]. Such predictions have been fulfilled, and it is now a fact that adopting such technologies can benefit both touristic agents and customers. For instance, for touristic agents, VR technologies allow a novel medium to develop, manage, and disseminate new tourism-related products and services [22, 54]. From the point of view of the customer, VR technologies open the possibility of searching and purchasing tourism products and services with the highest degree of personalization [7, 25, 47]. Due to the unique features, VR is a powerful tool for tourism marketing [33], as it can deliver a prime experience by transporting users to a virtual environment that depicts the touristic destination, which can be further enriched by the delivery of a multisensory stimulus to achieve credible experiences [44]. Such rich environments allow not only to captivate potential tourists, but also to make more informed decisions when purchasing tourism products and services, which may increase the satisfaction of the touristic experience itself as it allows more realistic expectations [69].

Previous work has already shown that an increased sense of presence can contribute to the intention of visiting the depicted touristic destination [65]. Most of the previous work, following the work of Kim and Biocca [39], explored from a presence perspective the impact of VR in tourism experience, perceived destination image of a destination and future behaviours. Hyun and O'Keefe [34], in the context of virtual destination image formation, found that telepresence influences positively virtual cognitive image and virtual conation. Tussyadiah et al. [65] suggested that "positive attitude change" in VR environments, where presence has a significant positive effect, leads to a higher level of visitation intention. Wagler and Hanus [67] found that the sense of presence perceived by individuals in 360 virtual experience was similar to that perceived by individuals physically at the location. Chung et al. [11] showed that the sense of presence positively affects the intention to revisit and recommend cultural heritage sites. Bogicevic et al. [8] revealed that VR hotel preview induces a stronger sense of presence compared with both 360 and images preview, thereby transforming into an enhanced brand experience. Wei et al. [68] found the positive impacts of the sense of VR presence on visitors' theme park intentions to revisit and recommend. Kang [36] found that a higher level of telepresence of HMD VR users compared with video users increases the impulsive desire for a destination. Finally, Adachi et al. [1] showed that the sense of presence provided by HMD VR leads to a more positive image of the destination, affective, cognitive, and overall.

However, there is also evidence that the sense of presence is not a trigger to change user attitudes. For instance, Hopf et al. [30] compared different VR setups (audiovisual vs. multisensory) and found no statistically significant differences regarding presence, but verified a significant increase in the users' intentions to recommend a given destination when using the multisensory setup. Thus, besides presence, user emotions and attitudes are a key concern when targeting tourism as an application field since they can shape the consumer behaviour [3, 31]. At the emotions level, it was already established that positive emotions such as amusement, contentment, interest and delight have a positive impact on the behavioural intention to visit the destination [32, 53]. Thus, by evaluating the user's emotions towards the tourism destinations, it is possible to predict and better understand their decision-making towards the consumption of tourism services and products [5, 52]. From the emotions in general, enjoyment has been revealed to be a pivotal factor to trigger engagement on users [65]. The construct of enjoyment is capital for understanding virtual experience in human and computer interaction [32]. Between the user attitudes that can affect an individual's behaviours, there is the perceived enjoyment and the intention to visit. Huang et al. [32] indicated that perceived enjoyment in virtual environments could be used as an antecedent of behavioural intentions. Previous works have revealed that a positive stimulation of these attitudes will result in a positive effect in the users towards the destination image as well as in the intention to visit it [29, 65].

Due to this complex equation regarding how different factors can affect the sense of presence and how the user's emotions and attitudes can affect the consumer behaviour intentions, it is of utmost importance to generate knowledge on how these variables interact so we can get the most of VR technology when applied to virtual tourism. Following such a line, this paper investigates the influence of immersive multisensory VR setups and gender on the sense of presence, satisfaction, user emotions, and user attitudes. Beyond that, this work analyses the relationship between the different VR-related dependent variables (presence, satisfaction, and usefulness for promoting the destination), emotion, user attitudes considered (emotions, enjoyment, and intention to visit). This work further includes a dependent variable labelled "usefulness for promoting the destination" to gain knowledge regarding the vision of potential consumers regarding the use of these novel technologies for tourism promotion). Such knowledge generates valuable insights for designing more effective VR tourism solutions.

2 Materials and methods

The experimental study is of a comparative cross-sectional nature with a between-group design. The following subsections detail the study.

Table 1 Sample distribution by experimental groups

	Gender		Total
	Male	Female	
VR setup			
IVR	20	20	40
MIVR	20	20	40
Total	40	40	80

2.1 Variables

This paper presents two studies with a factorial design: 2 (VR setup) × 2 (gender). The independent variable (IV) VR setup is composed of two levels: immersive VR (IVR) and multisensory immersive VR (MIVR), and the IV gender is composed of the two biological genders, male and female.

The dependent variables (DV) of both studies are presence (composed of the subscales spatial presence, involvement, experienced realism, and overall presence), satisfaction, user emotions, and the user attitudes perceived enjoyment, intention to use, and perceived usefulness.

2.2 Sample

The sampling technique used was the non-probabilistic convenience sampling procedure. The sample consisted of 80 participants (40 males and 40 females) aged between 17 and 27 years (M = 18.67, Std. Dev. = 1.55). The sample was distributed between the two experimental setups evenly while also balancing gender, as shown in Table 1. The sample size was determined following [43] recommendations, namely that comparative study groups should be between 8 and 25 participants per group. All participants reported normal or corrected-to-normal vision and no olfactory problems.

2.3 Instruments

The sociodemographic data (age and gender) were collected via a simple questionnaire with such items. Presence-related data were obtained by adopting the IPQp questionnaire [66], a Portuguese validated version of the presence questionnaire IPQ [61]. Such questionnaire allows assessing Overall Presence (sense of "being there") and the Spatial Presence (sense of being physically in the virtual environment), Involvement (attention devoted to the virtual world and the involvement experienced), and Experienced Realism (subjective experience of realism) dimensions. Satisfaction was assessed via the ASQ (after-scenario questionnaire), a validated questionnaire for assessing the user satisfaction regarding the experienced scenarios from a usability perspective [42]. This

Fig. 1 Screenshots of the virtual stimulus

questionnaire comprises three items that must be rated on a seven-point Likert scale.

The perceived usefulness of virtual reality for promoting the destination was measured based on Ref. [16] scale. The user attitude variables emotion, enjoyment, and intention to visit were measured using a questionnaire developed by the research team. Regarding the emotion variable, items used in the questionnaire, “interested”, “excited”, “enthusiastic”, “inspired”, “attentive”, “happy”, “in a good mood”, and “calm”, were based in the previous studies of Refs. [32, 53]. Enjoyment was assessed through four items, “fun”, “pleasant”, “exciting”, and “enjoyable” following previous research of Refs. [11, 32, 65]. Intention to visit was assessed through four items “After the Virtual Reality experience I am motivated to visit the site”, “After the Virtual Reality experience I find it not worth visiting the site”, “After the Virtual Reality experience I have no interest in visiting the site”, and “After experiencing Virtual Reality I want to visit the place”, based on Refs. [11, 65] previous studies. All assessments were rated on a seven-point Likert scale ranging from Strongly Disagree to Strongly Agree (strongly disagree = 1 to strongly agree = 7).

2.4 Materials and apparatus

The virtual environment depicts an actual touristic location: the São Leonardo da Galafura viewpoint, located at the Alto Douro Wine Region (north of Portugal), which UNESCO classifies as a World Heritage Site. To create a realistic experience, the research team adopted photogrammetry techniques to achieve a 3D replica of the real environment (Fig. 1). The Unity game engine was used to build the custom virtual experience. The navigation on the virtual world was possible using both real walking (which is limited to the 3.5 m × 3.5 m tracking area of the VR setup) or teleport by pressing the VR controller’s trackpad pointing the spot to teleport to. As the virtual environment is larger than the tracked area and for safety purposes, when the user reached the tracked area’s limits, it was presented a blue fence to indicate that he should turn around or use teleport to go further ahead.

The virtual environment was synced with the hardware responsible for delivering the wind and smell stimuli. The wind stimulus was delivered via a custom-made system based on compressed air with four air pressure hoses, each one placed on each side of the squared tracked area. The system is controlled by electrovalves that open to emit an airflow that simulates wind. Prior to the experiments, the system’s pressure was calibrated and modulated by the research team that was aware of the real location conditions so the system could deliver a smooth breeze that is typical of the real scenario. The duration of the wind delivery was between 10 and 20 s with an air pressure that ranged from 1.5 to 2.58 bar and a volumetric flow rate that ranged from 2 to 4.3 lpm. These values were calibrated using an M-series mass flow meter from Alicat Scientific, placed exactly 10 cm away from the air pressure hose.

The smell stimulus was delivered using the SensoryCo SmX-4D, which allows the personalized smell delivery based on three channels, each with a different smell cartridge. The smell cartridge consists of infused poly (high internal phase emulsion) cartridge that was selected from SensoryCo’s scent library[1]. The selected smell was the “Flower Shop/Garden” since it was the most representative of the real scenario depicted in the virtual experience. To avoid smell saturation but enable its perception throughout the experience, the smell was released in bursts of 0.5 s each 15 s during the whole experience. The smell dispenser was placed on a corner of the tracked area.

To deliver the VR experience, a desktop computer was used with an Intel i7-6700K and NVIDIA GeForce GTX 1080. The VR equipment used was the VIVE setup composed by the HMD to view the virtual environment and its controllers to interact with it. The HMD features one display for each eye with a viewing angle of 110° and a resolution of 1080 × 1200 pixels. The sound has a sample rate of 44100 Hz at 1311 kpbs, and it was delivered with Bose QuietComfort 25 headphones with active noise cancellation.

2.5 Procedure

The experimental study took place at MASSIVE Virtual Reality Laboratory[2], which provides all the conditions to

[1] Available at https://sensorycots.com/wp-content/uploads/2019/10/SCO-Aromas-191023.pdf.

[2] https://massive.inesctec.pt/.

perform research studies under a controlled environment. The first step was to welcome participants to the room where the study took place and briefly explain how they would participate without disclosing its goals to avoid bias. During this briefing, they were informed that they would be exposed to a virtual experience that depicts a touristic destination. They were encouraged to explore the VE as if they were in the physical site in a tourism context. Then, the participants were asked if they were willing to continue and participate in the study. An informed consent form was given to formally express their agreement in participating in the experiments, followed by a simple sociodemographic questionnaire. Participants were then forwarded to the middle of the experiment's room, which matched the centre of the tracked area by the VR system. They were instructed on how to interact with the system, namely, how to teleport. They were also informed that they could use the real walk to navigate. Then, they were equipped with the VR equipment with the help of the research team that ensured that it was fitted correctly. After this, the research team launched a habituation virtual environment where participants could try the interaction mechanisms to get familiar with the technology and clear any doubt that could have persisted. After this 1-min habituation period, the participant was asked if he was ready to start the actual touristic virtual experience. If the participant was not ready, another minute was given; otherwise, the virtual touristic experience was started. The virtual touristic experience was defined to last 5 min, finishing by fading out to a neutral grey screen with a message informing that the virtual experience was over. At the end of the virtual experience, the research team helped participants unequip the VR equipment. Then, an informal debriefing session aiming at gathering generic feedback from the participant's experience was held. The participant was then thanked and dismissed. The whole procedure had a length of approximately 20 min.

2.6 Statistical procedures

Descriptive and inferential statistics were computed using SPSS 23 software, with a confidence level of 95%. For determining if there were outliers, box plots of the residuals were created. Any data values which lie more than 3.0 times the interquartile range below the first quartile or above the third quartile of the box plots were considered an outlier [20]. The normal distribution of the data was assessed through Skewness and Kurtosis ($|\text{Skewness}| < 2$ and $|\text{Kurtosis}| < 2$) considering all combinations of groups of the two IVs [21]. The homogeneity of variances was ensured by having group sample sizes approximately equal, as recommended by Jaccard and Jaccard [35]. A two-way ANOVA analysis was considered to determine whether there was an interaction effect between two independent variables in each of the different dependent variables. All the assumptions for the two-way ANOVA were verified. Data are M ± Std.Dev., unless otherwise stated. Residual analysis (the differences between the predicted value and the actual, observed value for each cell of the two-way ANOVA design) was performed to test for the assumptions of the two-way ANOVA. The interaction effects were assessed. If there was no statistically significant interaction effect, main effects were analyzed. Otherwise, simple main effects were considered. If statistically significant differences were found, pairwise comparisons were run. All pairwise comparisons were run for each (simple) main effect with reported 95% confidence intervals and p values Bonferroni-adjusted within each (simple) main effect. Regarding the simple main effects, only statistically significant differences are reported. Mean scores are reported for the dependent variables where statistically significant differences are found.

The correlations between the different DVs was assessed using Pearson's correlation test. For determining the strength of the association, we considered that a coefficient value $0.10 < |r| < 0.30$ represented a small correlation, a coefficient value of $0.30 < |r| < 0.50$ represented a moderate correlation, and a coefficient value $|r| > 0.50$ represented strong correlation following [12] guidelines.

Table 2 Sample distribution by experimental groups after removing outliers

	Gender		Total
	Male	Female	
VR setup			
IVR	18	18	36
MIVR	20	18	38
Total	38	36	74

3 Results

The box plot analysis revealed six extreme data points that were considered outliers and removed from the sample before proceeding with the analysis. After removing the outliers, the sample was distributed as shown in Table 2.

The analysis of the Skewness and Kurtosis values allowed to verify the normal distribution of the data ($-1.357 < \text{Skewness} < 1.418$ and $-1.269 < \text{Kurtosis} < 1.520$).

3.1 Spatial presence

Regarding the main effect, there was no statistically significant differences concerning the type of VR setup on spatial presence, $F(1,70) = 1.743, p = 0.191, \eta_p^2 = 0.024, \text{O.P.} = 0.256$. As for gender, there were statistically significant differences $F(1,70) = 6.128, p = 0.016, \eta_p^2 = 0.080, \text{O.P.} = 0.685$.

Table 3 Mean scores across for spatial presence

	Gender		Average
	Male	Female	
VR setup			
IVR	4.76	5.15	4.96
MIVR	5.03	5.16	5.09
Average	4.89	5.15	

Table 4 Mean scores across for involvement

	Gender		Average
	Male	Female	
VR setup			
IVR	4.24	4.86	4.57
MIVR	4.58	4.47	4.53
Average	4.41	4.68	

Pairwise comparisons have revealed that female participants (5.15 ± 0.36) scored spatial presence higher than male participants (4.89 ± 0.54), representing a mean score difference of $0.261, 95\%$ CI $[0.051, 0.471], p = 0.16$. Mean scores for spatial presence are presented below (Table 3).

3.2 Involvement

There was a statistically significant interaction between type of VR setup and gender for involvement, $F(1, 70) = 4.935, p = 0.030, \eta_p^2 = 0.066$, O.P. $= 0.591$. The simple main effects presented statistically significant differences in the IVR condition, namely between males (4.24 ± 0.76) and females (4.86 ± 0.60), $F(1, 70) = 7.308, p = 0.009, \eta_p^2 = 0.095$, O.P. $= 0.760$. The mean difference between groups was $0.626, 95\%$ CI $[0.164, 1.089]$. Refer to Table 4 for the mean scores for involvement.

3.3 Experienced realism

There was no statistically significant interaction between type of VR setup and gender for experienced realism, $F(1, 70) = 2.671, p = 0.107, \eta_p^2 = 0.037$, O.P. $= 0.364$. Regarding simple main effect, there was no statistically significant differences concerning both type of VR setup and gender for experienced realism scores, $F(1, 70) = 1.007, p = 0.319, \eta_p^2 = 0.014$, O.P. $= 0.168$ and $F(1, 70) = 2.091, p = 0.153, \eta_p^2 = 0.029$, O.P. $= 0.297$, respectively.

Table 5 Mean scores across for overall presence

	Gender		Average
	Male	Female	
VR setup			
IVR	4.11	4.60	4.37
MIVR	4.44	4.44	4.44
Average	4.28	4.52	

3.4 Overall presence

A statistically significant interaction between type of VR setup and gender for overall presence was verified, $F(1, 70) = 7.727, p = 0.007, \eta_p^2 = 0.099$, O.P. $= 0.783$.

The simple main effects presented statistically significant differences in the IVR condition, $F(1, 70) = 15.682, p < 0.001, \eta_p^2 = 0.183$, O.P. $= 0.974$. This statistical significant difference reveals that male participants (4.11 ± 0.09) reported lower overall presence than female participants (4.60 ± 0.85) with a mean difference of $0.491, 95\%$ CI $[0.244, 0.739]$.

It was also verified a statistically significant difference between male participants between VR setups, $F(1, 70) = 6.953, p = 0.010, \eta_p^2 = 0.090$, O.P. $= 0.739$. Pairwise comparisons show that male participants scored the IVR setup (4.11 ± 0.36) lower than the MIVR setup (4.44 ± 0.41) with a mean difference of $0.336, 95\%$ CI $[0.082, 0.589]$. Table 5 reports all the mean scores for overall presence.

3.5 Satisfaction

There was no statistically significant interaction between type of VR setup and gender regarding satisfaction, $F(1, 70) = 0.049, p = 0.826, \eta_p^2 = 0.001$, O.P. $= 0.055$. Regarding the main effect, there was no statistically significant differences concerning both type of VR setup and gender, $F(1, 70) = 0.050, p = 0.823, \eta_p^2 = 0.001$, O.P. $= 0.056$ and $F(1, 70) = 1.421, p = 0.237, \eta_p^2 = 0.020$, O.P. $= 0.217$, respectively.

3.6 Emotions

There was no statistically significant interaction between type of VR setup and gender for emotion, $F(1, 70) = 0.076, p = 0.783, \eta_p^2 = 0.001$, O.P. $= 0.059$. Regarding main effect, there was no statistically significant differences concerning the type of VR setup or gender on emotion, $F(1, 70) = 2.098, p = 0.152, \eta_p^2 = 0.029$, O.P. $= 0.298$ and $F(1, 70) = 0.076, p = 0.798, \eta_p^2 = 0.001$, O.P. $= 0.059$, respectively.

Table 6 Pearson's correlation analysis results

	Emotion	Enjoyment	Intention to visit	Usefulness	Satisfaction
Spatial presence	0.34**	0.20*	−0.01	0.19	0.14
Involvement	−0.07	0.09	−0.12	0.11	0.24*
Experienced realism	0.06	0.08	−0.07	−0.05	−0.20
Overall presence	0.12	0.17	−0.10	0.11	0.19
Satisfaction	0.10	0.23*	0.01	0.43**	

*Moderate correlation, significant at $p < 0.05$ level (2-tailed)

***Strong correlation, significant at $p < 0.01$ level (2-tailed)

3.7 Enjoyment

There was no statistically significant interaction between type of VR setup and gender for enjoyment, $F(1, 70) = 1.311, p = 0.256, \eta_p^2 = 0.018, \text{O.P.} = 0.204$. Regarding main effect, there was no statistically significant differences concerning the type of VR setup nor gender on enjoyment, $F(1, 70) = 0.669, p = 0.416, \eta_p^2 = 0.009, \text{O.P.} = 0.127$ and $F(1, 70) = 2.500, p = 0.118, \eta_p^2 = 0.034, \text{O.P.} = 0.345$, respectively.

3.8 Intention to visit

There was no statistically significant interaction between type of VR setup and gender for intention to visit, $F(1, 70) = 2.456, p = 0.122, \eta_p^2 = 0.034, \text{O.P.} = 0.340$. Regarding main effect, there was no statistically significant differences concerning the type of VR setup nor gender on intention to visit, $F(1, 70) = 2.456, p = 0.122, \eta_p^2 = 0.034, \text{O.P.} = 0.340$ and $F(1, 70) = 1.486, p = 0.227, \eta_p^2 = 0.021, \text{O.P.} = 0.225$, respectively.

3.9 Usefulness for promoting the destination

There was no statistically significant interaction between type of VR setup and gender for usefulness for promoting the destination, $F(1, 70) = 1.500, p = 0.225, \eta_p^2 = 0.021, \text{O.P.} = 0.227$. Regarding main effect, there was no statistically significant differences concerning the type of VR setup nor gender on usefulness for promoting the destination, $F(1, 70) = 0.328, p = 0.569, \eta_p^2 = 0.005, \text{O.P.} = 0.087$ and $F(1, 70) = 3.375, p = 0.070, \eta_p^2 = 0.046, \text{O.P.} = 0.441$, respectively.

3.10 Correlations between the different dependent variables

The Pearson's correlation test has revealed statistically significant correlations between the dependent variables. Namely, strong correlations were found between the dependent variables Spatial Presence and Emotion ($r(72) = 0.34, p < 0.01$), and Satisfaction and Usefulness ($r(72) = 0.43, p < 0.01$). Statistically significant moderate correlations were also verified between the variables Spatial Presence and Enjoyment ($r(72) = 0.20, p < 0.05$), Involvement and Satisfaction ($r(72) = 0.24, p < 0.05$) as well as between Satisfaction and Enjoyment ($r(72) = 0.23, p < 0.05$). Please refer to Table 6 for a detailed analysis of the Pearson's correlation test for the different dependent variables.

4 Discussion

The goal of this paper is twofold: (1) to investigate the impact of a multisensory setup over conventional VR setup as well as the impact of gender on the sense of presence, satisfaction, user emotion, and user attitudes; and (2) to understand how the different technology-related variables (presence and satisfaction) interact with the virtual tourism and consumer behaviour-related variables (user emotions and attitudes). For this purpose, an experimental study of comparative nature was conducted with a sample of 74 valid participants balanced between the different experimental conditions. The study fulfilled [50] recommendations on the evaluation of multisensory experiences to ensure its validity.

Presence scores have revealed statistically significant differences for the subscales Spatial Presence, Involvement, and Overall Presence. Female participants scored the sense of spatial presence higher than male participants regarding Spatial Presence, Involvement, and Overall Presence (only in the IVR setup for the latter subscale). This result does not support the literature reports that men generally are typically associated with more significant development of the sense of presence since they are considered to have more familiarity with virtual scenarios and handling with hardware and software [28]. We attribute this outcome to the nature of the virtual experience, as the environment was of a passive nature, and previous work has already found evidence that a female audience is more prone to develop the reported sense of presence in such environments [19]. This suggests that more than biological differences, previous experience with the technology can be a key determinant in developing the sense of presence. Another aspect that arises is that when developing VR applications targeted at a particular gender, the extent of the interactivity shall be considered as applications that target mainly a male audience shall have an interactive nature. In contrast, applications for a primarily female audience shall be more passive. Another interesting finding is the statistically significant difference for the type of VR setup concerning male participants, who have scored the multisensory setup higher than the audiovisual setup (M = 4.96 vs. M = 5.09, respectively). In this scenario, we theorize that this higher scoring of the male participants compensated the gender differences for Overall Presence, thus, revealing no statistically significant differences across gender at this level. Considering the known fact that female participants outperform male participants in non-interactive tasks and that the multisensory setup was able to suppress such differences, we speculate that if adopting a multisensory setup, one can overcome gender differences that can arise when experiencing non-interactive VR content. This topic was already addressed in the literature from a QoE perspective [48], proving the existence of a very complex relationship between these factors. The results obtained point that such a relationship also exists at a level of sense of presence. However, we acknowledge that the current study was not initially designed to test such a research hypothesis, and, as such, this research question shall be addressed in future work.

Regarding satisfaction, no statistically significant differences were found. However, such an outcome was expected since the satisfaction measured was from a usability point of view. The two different VR scenarios are identical in the system usage, with the only difference between them being the stimuli delivered to the users.

No significant differences were found regarding user emotions and attitudes at any level. These results indicate that the sense of presence is more sensible to the variation of the variables gender and type of VR setup than to the user emotions and attitudes.

The correlation analysis revealed a statistically significant strong correlation for the pair Spatial Presence–Emotions and a statistically significant moderate correlation for Spatial Presence–Enjoyment, revealing that the capability of the VR experience to make the users feel physically in the VE contribute to positive emotions. This shows that it is essential to depict the touristic destinations as realistic as possible to trigger emotions that, by their turn, have the potential of stimulating the consumption of touristic products as shown in previous works [5, 52]. The strong correlations between Satisfaction and Usefulness for promoting the destination further reveal that the more the user is satisfied with the VR experience, the more susceptible he is to the content and the more the value he recognizes in the VR technology as a promotion tool the destination. Also, the moderate correlation between Satisfaction and both Involvement and Enjoyment suggests that the more the user is contented with the VR experience, the more attention he devotes to the VE and the more is the enjoyment felt.

5 Conclusions

The current work aimed at investigating the role of multisensory stimulus and gender on the user's sense of presence, satisfaction, emotion, and attitudes. A major conclusion is that passive VR experiences are more effective near a female audience as female participants scored higher Spatial Presence, Involvement, and Overall Presence (only on the IVR condition in the case of the latter two subscales). Other evidence found was that the multisensory stimulus mitigated the gender effect for the sense of overall presence, and no statistically significant differences were found between genders as verified in the IVR condition.

The effectiveness of the VR content to transport the users to the VE is also a factor to account for, as results revealed that Spatial Presence plays a role in the induction of positive emotions and enjoyment that, by their turn, promote the acquisition of touristic products. In addition, the usability of the VR experience is important as it enables users to devote their attention to the VE. The consequent sense of Involvement developed allows them to enjoy the experience and see value in VR as a tool to promote the touristic destination.

As research agenda, this work points to a research direction that can play a role in developing VR-based tools for tourism marketing: the role of multisensory stimulus to mitigate gender differences across passive VR scenarios.

The current study is not free of limitations. One of the limitations of this study is on the sample's age, representing a range across 10 years (from 17 to 27 years old). Although this age can represent the majority of VR users, tourism is also practised by older individuals, and as such, future work will expand the sample age towards those groups. Another limitation is associated with the attitude questionnaire used as it was a custom questionnaire in which the psychometric properties were not properly validated. This is mitigated by the fact that the questionnaire was based on other literature questionnaires, namely [11, 16, 32, 53, 65]. At last, as the literature and our results suggest, the level of interactivity with the virtual experience can be one of the factors that influenced the gender-related data obtained and, therefore, skewed the gender results. In future studies, the interaction with the environment will also be considered when comparing gender differences.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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