A novel method to enhance the touristic 360° promotional video experience

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***Abstract*—Promotional 360° videos are now widely used to promote touristic sites, giving consumers a more immersive glimpse of what they can expect from those places. However, these 360° videos often comprise so much information that it overloads the users, not allowing them to benefit from such a rich multimedia experience. To overcome this issue, we propose and evaluate a novel method that allows the experience of immersive 360° promotional videos to be more interactive and informative without overloading users.**

The evaluation study focuses on how the proposed interaction method performs versus the non-interactive method in terms of user satisfaction, presence, and cybersickness in both a low-immersive (computer monitor) setup and an immersive platform (head-mounted display (HMD)). Our sample (N=50) was randomly divided into four groups: 360° (computer monitor without interaction), 360°Interaction (computer monitor with interaction), IVR360° (HMD without interaction) and IVR360°Interaction (HMD with interaction).

The results show that the novel proposed method is preferred by users over the non-interactive approach regardless of the setup (low-immersive or immersive). For cybersickness, there were no differences across all the experimental scenarios. We conclude that our method has the potential to bring added value to touristic promotion when compared to conventional promotional approaches.

***Index Terms*—Virtual Reality, Tourism Promotion, User Satisfaction, Interaction, Presence, Cybersickness, 360° Video.**

I. Introduction

The potential of virtual reality (VR) has been considered since the early days of the technology. In 1994, Hobson and Williams [1] discussed the future potential of VR to revolutionise the promotion and sale of tourism experiences. The authors argued that operators and travel agents would be able to provide customers with simulated experiences of their future travel plans. They even speculated that "*through the increased use of digital communication links to homes and with the right equipment, customers will be able to view alternative travel and holiday destinations from their living rooms*". With the recent technological advances in virtual reality technologies, such a scenario is currently a possibility. The dissemination of low-cost VR equipment, such as Google Cardboard, which uses a smartphone to power up the VR experience, and high-end head-mounted displays (HMDs), such as HTC Vive or Oculus Rift, allows customers to explore touristic sites in the comfort of their homes at reasonable prices.

As tourism industry has explored technological advances [2], benefiting significantly from developments in information and communication technologies (ICT), namely, the Internet [3], many tourists have begun to use the Internet as a means to search for information about their travel destinations. This fact opens doors for business and organisations to establish themselves online to provide this information. These entities can then use immersive VR technology to deliver the necessary information and help customers in their decision-making process [4]–[6].

Guttentag [7] discusses the various applications of VR in tourism and divides it into five categories: planning and management, marketing, entertainment, education, accessibility and heritage preservation. Our work focuses on the marketing of tourism. Tourism services are typically characterised as experience goods because the consumer cannot conceptualise the tourism experience or its quality without experiencing the service itself [8]. As such, tourism has the particular aspect of production and consumption occurring at the same time and in the same place [9], and only when experiencing the tourism service can the tourist conceptualise the tourism experience or its quality.

VR can provide a rich and interactive environment in which consumers can explore touristic sites, allowing them to make informed decisions with more realistic expectations, resulting in more satisfactory holidays [1], [10], [11]. Wan et al. [12] showed that virtual experiences are better than a brochure when advertising themes and natural parks. Lee and Oh [13] studied whether VR functions in a hotel website can reduce anxiety in travel, as having more information is thought to be a factor in relieving anxiety in travel. Huang et al. [11] concluded in their studies that useful information in 3D tourism sites can enhance the consumer experience of enjoyment. The authors state that "*content elements such as pictures, graphics, local music, storytelling videos and integrating websites in the 3D virtual tourism destination convey the sense of place, contributing to planning for a future trip to the actual site*".

A. Presence and Immersion

A large part of the potential of VR is explained by the presence theory. Presence is defined as the feeling of "being there", the sense that a person has been transported to another place [14]. If a user's sense of presence is high, it means that

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the VR application is able to produce an environment that deludes users into thinking that what they are experiencing is real.

Tussyadiah et al. [15] conducted a study with 202 participants ranging from 18 to 24 years old to study how VR can influence travel decisions by investigating the sense of spatial presence and its impact on attitudes towards tourism destinations. They concluded that the more attention devoted to the VR experience, the higher the sense of spatial presence is. The results also indicated that higher spatial presence leads to stronger interest and liking towards destinations. The authors stated that it is essential to eliminate distractions that can divert the user's attention from the experience, giving examples such as hovering buttons and other unnatural elements that can be distracting. However, this suggestion was not tested by the authors.

Following the previous work, Tussyadiah et al. [16] continued to investigate how VR can impact tourism. Two studies were conducted, one in Hong Kong and the other in the United Kingdom, with a total of 926 participants. The participants wore HMDs powered by smartphones and experienced virtual walkthroughs based on 360° content. The results supported hypotheses: A sense of presence leads to higher enjoyment and attitude change; enjoyment leads to higher attitude change; and attitude change leads to visit intention. These results led the authors to conclude that "*a higher sense of presence during VR experiences leads to stronger interest and liking toward the destinations*".

Melo et al. [17] conducted an experiment with 128 participants about how varied content type (360° video or virtual environment), exposure time (1, 3, 5 or 7 min) and gender can influence the reported sense of presence. The results suggested that exposure time does not affect the sense of presence. Therefore, users can spend time ranging from a low amount to longer sessions in VR immersive touristic applications, for example, without affecting the level of their sense of presence. Users can thus quickly visit a VR touristic site for as much or as little time as they want and feel present regardless of the time spent there. However, this conclusion is valid only from a minimum of 1 min of exposure time to a maximum of 7 min, as tested in their work. Regarding the content type, in the same work, users reported a higher sense of presence for the 360° video and a lower sense of presence for the synthesised virtual environment.

The term immersion is sometimes confused with presence, as some authors interpret it in different ways. Witmer & Singer define immersion as "*a psychological state*" [18]], while & and Wilbur define it as "*the objective level of sensory fidelity a VR system provides*" [19]. In this work, we follow Slater's definition of immersion. Thus, immersion is measurable, allowing the comparison among different VR systems.

Mariana et al. [20] conducted an experiment in which participants visited a touristic location through a 360°video (HMD vs laptop screen) and *in situ*. The Igroup Presence Questionnaire questionnaire (IPQ)was used to compare the sense of presence between immersive (HMD) and low-immersive (laptop screen) experiences, and the results showed that the immersive experience scored higher than the low-immersive experience in the spatial presence, involvement, and experienced realism subscales. Regarding the participants' opinions, 88% of the participants preferred the immersive experience to the low-immersive experience. These results suggested that the use of immersive systems such as HMDs can bring more benefits to touristic applications than the use of less immersive setups.

B. Cybersickness

Although immersive VR systems bring benefits for the users' experience, there is a reported tendency for users to exhibit symptoms similar to those of motion sickness both during and after the VR experience [21]. These symptoms, if severe, can strongly impact the experience and keep away potential users. Among the symptoms are disorientation, nausea, headaches, eye strain, and sweating [22]. The underlying factors that can cause cybersickness can be divided into 3 categories: individual factors (age, gender, illness, posture); device factors (lag, flicker, calibration, ergonomics) and task factors (control, duration) [20], [22]–[25]. Such symptoms may arise due to the sensory conflict between the vestibular and visual systems. Although 360° videos are usually presented with a fixed point of view to avoid cybersickness, fast-paced promotional videos featuring different locations, together with the possibility of interaction, can create conditions in which such symptoms may arise. Therefore, we opted to keep track of cybersickness symptoms and test the applications frame rate in this work (as low frames per second (FPS) can contribute to cybersickness and possibly affecting other metrics).

Cybersickness can be measured both subjectively (through questionnaires such as the Simulator Sickness Questionnaire [26] or Pensacola Diagnostic Index [27]) and objectively(through physiologic data, namely, heart rate, blink rate and EEG [28], which can be more intrusive for the participants). In an experiment by Melo et al. [17], exposure time had no impact on the reported cybersickness.

C. Related Work

Coelho et al. proposed, developed and evaluated [29]–[31] an immersive authoring tool to create 360° multisensory VR experiences. The 360° experience could have multisensory elements, such as wind, scent and vibration. The authors compared the immersive version of the authoring tool (HMD with controllers) against a low-immersive version (desktop computer monitor, keyboard and mouse) using a sample of 32 participants [30]. They concluded that there was a significant difference in satisfaction scores, with the immersive version of the authoring tool scoring higher. Although user familiarity with VR can be lower than familiarity with the conventional use of a desktop computer, the usability scores were not significantly different.Thus, the results of Coelho et al. demonstrated significant potential. However, its focus is on a method to add multisensory stimuli to 360° videos. The output, although

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more immersive due to the extra stimuli, continues to be non-interactive in that the user can experience the content only passively and cannot interact with it.

The potential of VR is capturing the attention of companies such as Adobe. In the Adobe Creative Cloud [32] product, it is possible to create 360° videos with effects, texts, graphics, sounds and other types of media. However, as many other video editing software programs, the output is a linear video with a fixed length. Its contents (texts, graphics, etc.) are positioned in a fixed or predetermined location (e.g., moving animations) for a determined period of time. However, our method can use such output as a 360° promotional video and add an extra layer of information and interaction to enhance the experience.

AV360 [33] is a project composed of an editor and a visualisation tool. In the editor tool, we can add annotations that can be static over a specific object or dynamic, following an object or moving from area to area. The annotation types include text, images and hyperlinks. The visualisation tool, as the name indicates, allows users to visualise the output on a web page with or without a VR headset. In the visualisation tool, there is also a method to call attention to specific points of the video so that users do not miss the annotations. This visualisation tool was evaluated by Teresa et al. [34]. With a sample of 35 participants, using the HMD HTC Vive, the authors studied the different types of annotations. The participants were asked to perform four tasks consisting of finding markers and looking at areas of interest. In general, the results indicated that the guides helped the participants find the markers and areas of interest more efficiently and effectively than a system with no guides.

Table I lists the similarities and differences of each method to experience 360° videos. The 360° conventional method refers to a single non-edited 360°video. The 360°edited video includes editing such as joining multiple videos together, transition effects, embed annotations, etc. A description of the features follows:

- Multiple Locations: Refers to the possibility to visualize multiple videos depicting different locations.
- Fixed Annotations: Annotations (text, images, videos) that are built in the the rendered video and cannot be changed or interacted..
- Dynamic Annotations: Annotations that are included as an overlay and can be changed and interacted.
- Guides: Visual guides that orient users towards points of interest/annotations.
- Multisensory: The possibility to deliver multisensory stimuli (wind, temperature, scent, etc.).
- On-demand: The length of the experience is not fixed, and can adapt to the users need.

In this work we did not include multisensory stimulation, however, we support it in a future implementation. Although Coelho et al. does not include a multi-location video in its work, it is possible though video editing.

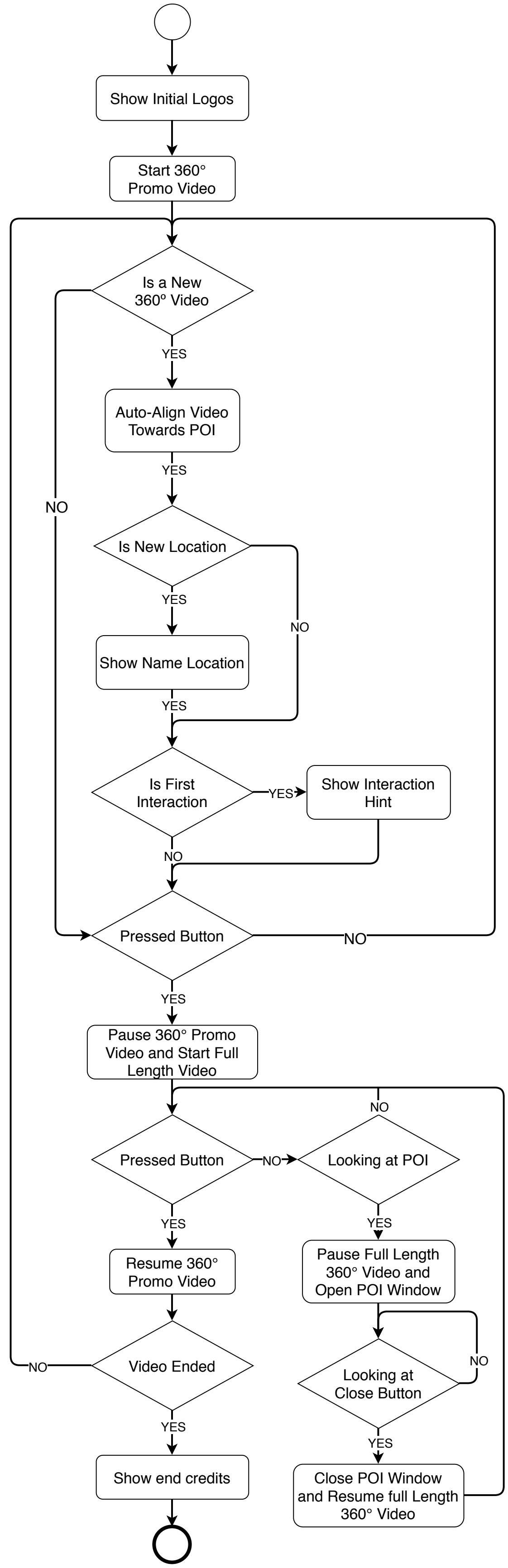

Fig. 1. 360° viewer flowchart

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D. *Contribution*

The main objective of this paper is the proposal and evaluation of a novel method that envisages filling the identified gaps to enhance the touristic 360° promotional videos experience.

To understand the effectiveness of the proposed interactive method, we evaluate it against the non-interactive version in terms of sense of presence, user satisfaction and cybersickness. As a secondary objective, we study how our interactive and non-interactive versions of the proposed method perform in both low-immersive and immersive setups.

II. Method Proposal

We have developed and evaluated a proof of concept of our interactive method, focusing on the user experience, tacking the issue of information overload caused by the lack of time to assimilate the 360° content. It was designed to be tested both in immersive (HMD) and low-immersive (computer monitor) setups. The application (360º viewer) was developed using the Unity Engine, with the purpose of allowing the research team to evaluate all the features of the new method through user studies.

Thus, because a 360° promotional video consists of different locations that change over time, the participants have time to obtain only a glimpse of each location. The proposed method automatically changes the orientation of the 360° video towards the most crucial POI without the user noticing. In this way, users do not waste time looking at the least relevant sections of the video and possibly miss the main POI.

The name of every location can be marked by a small text that follows the orientation of the user's head in the horizontal plane. Therefore, everywhere the participant looks in the 360° promotional video, he/she will see, on the horizon line, the name of his/her current location (Fig. 2.a). In the eventuality that the video follows previous one recorded in the same location but with a different perspective, the identification text does not appear, as it would be redundant.

The interaction schema of the user with the 360° viewer can be seen in Fig. 1. As shown in the figure, if the user is currently seeing a 360° location, a hint is shown to suggest interaction with the video (Fig. 2.a). If the user wishes, he/she can pause the 360° promotional video by pressing a button, and after a brief transition (Fig. 3), he/she begins experiencing the full-length video of that specific location (Fig. 4). Here, the user can explore the information available in the POIs. To better guide users, small arrows indicate where these POIs are so that users can quickly find them. POIs are represented by small coloured squares (Fig. 2.b). If the user looks at them for a short amount of time, the full-length 360° video will pause and turn to greyscale, and a pop-up with the POI information (text and images) will appear, similar to a "hyperlink" kind of interaction (Fig. 2.c). Just as the user can open the POI pop-up, it can close in the same way if the viewer looks at the close button. Once the pop-up has been closed, the full-length 360° video resumes without the greyscale filter.

The user can go back and continue playing the 360° promotional video at any time by a press of a button. This

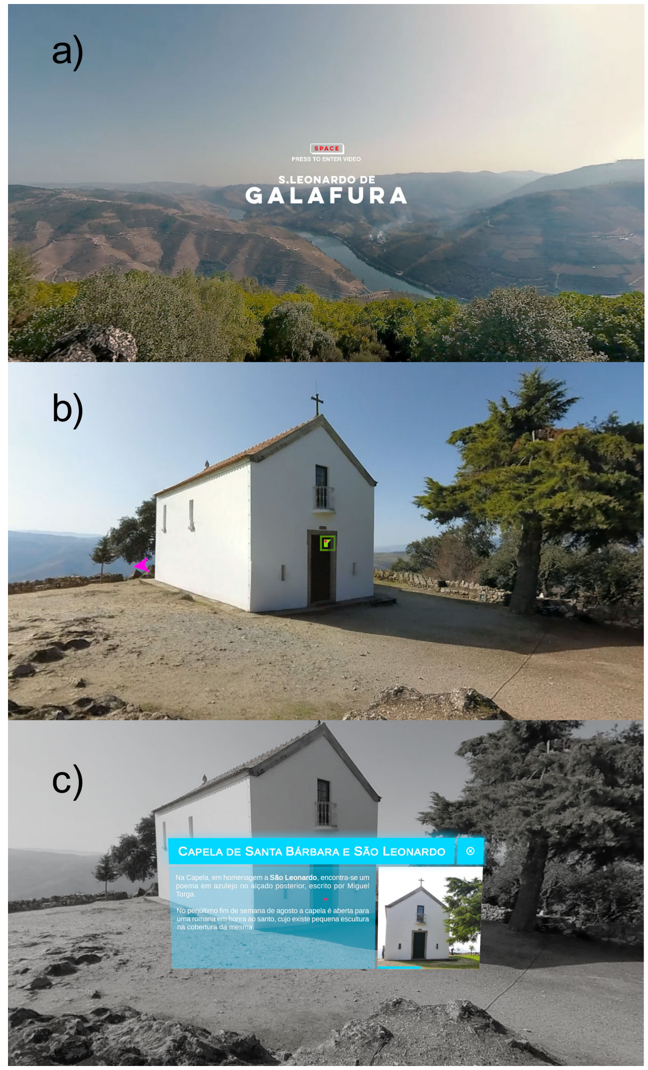

Fig. 2. a) Location name and interaction hint, b) POI being activated and an arrow indicating the position of another POI, c) Pop-up with information about the POI

experience can be repeated for each different location available in the 360° video until the video ends. The proposed method is not intrusive, so users can watch the 360° promotional video with no stops from beginning to end if they wish.

The non-interactive version of our method has only the following features:

- Auto-align videos towards the main POI, and
- Show the names of new locations

The interactive version of our method has the same features as the non-interactive one but also has the following features:

- Experience length adapted for each user;
- Descriptions of POIs through text and images; and
- Arrows orientating the user towards the POIs

For a better understanding, a video of how the interactive and non-interactive versions of the proposed method work can be found in the supplementary materials.

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TABLE I
FEATURES COMPARISON BETWEEN DIFFERENT METHODS TO PRESENT TOURISTIC 360º VIDEOS.

Features	Our method	AV360º	Coelho et al.	360º Conventional	360º Edited video
Multiple locations	X	X	X	-	X
Fixed Annotations	X	X	-	-	X
Dynamic Annotations	X	X	-	-	-
Guides	X	X	-	-	-
Multisensory	Supported	-	X	-	-
On-demand	X	-	-	-	-

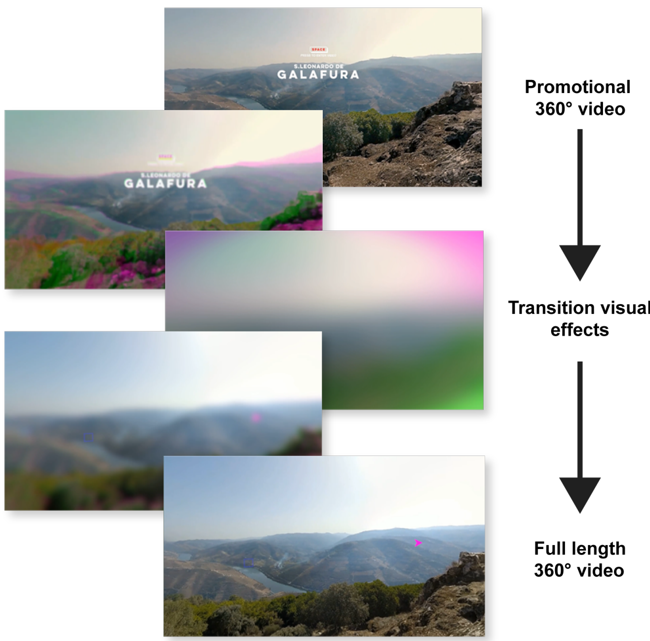

Fig. 3. Sequence of video frames depicting the transition between the 360° promotional video and full-length 360° video.

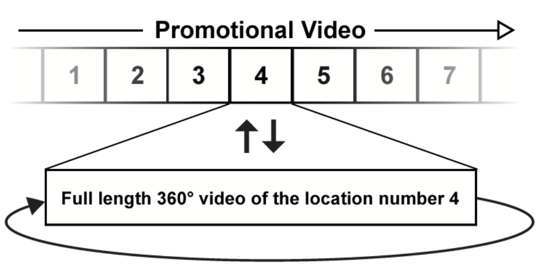

Fig. 4. If the user is currently seeing location number 4 in the promotional video (main timeline), and he/she presses the button, the main timeline will pause, and the user will start to experience the full-length 360° video corresponding to the same location.

III. STUDY METHODOLOGY

To evaluate and validate the hypothesis that our interactive method might have advantages over its non-interactive counterpart, we studied the variables user satisfaction, sense of presence, and cybersickness in both conventional (keyboard/mouse with a computer monitor) and immersive (HMD-based) setups (as our proposal is meant to support both). To achieve this aim, an experimental cross-sectional study, of a comparative character using a between-group design was conducted.

A. Sample

Our sample consisted of 50 participants (24 males and 26 females). The sampling method adopted was the non-probability convenience sampling technique, meaning that the sample was recruited spontaneously based on the random available population that was approached and invited to take part in the study. There was no interference or influence of the researchers in the participants' selection. The participants were mostly students, with ages ranging from 18 to 45 years and a mean age of 22.80. A description of the participants' experience with computers and familiarity with VR can be found in II.

The participants were randomly divided into 4 groups corresponding to 4 different experimental scenarios:

- 360°: Desktop monitor without any interaction (control group) (N=12);
- 360°Interaction: Desktop monitor with interaction, where users could navigate through the video via hyperlinks (N=14);
- IVR360°: HMD with no interaction (N=12); and
- IVR360°Interaction: HMD with interaction, where users could navigate through the video via hyperlinks (N=12).

In every group, users experienced the same 360° promotional video from beginning to end. However, the groups that included interaction could use the features of our proposed 360° promo viewer, dynamically entering the full-length 360° video and seeing the POIs.

Although this is a study of a proof of concept, performance metrics, such as frame rate were also recorded to ensure

TABLE II
DESCRIPTION OF THE SAMPLE REGARDING EXPERIENCE WITH COMPUTERS AND KNOWLEDGE ABOUT VR.

	Exp. with Computers	Knowledge about VR
None	0%	6.4%
Basic	6.4%	44.7%
Intermediate	17%	25.5%
Good	48.9%	21.3%
Excellent	27.7%	2.1%

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the performance would not impact the user experience and interfere with other metrics.

B. Materials

A 360° viewer application was created to test the interactive and non-interactive versions of our method. The research team captured 360° videos in several locations of the Douro region in Portugal, which is classified as a UNESCO World Heritage Site. The footage captured was then edited to create a 360° promotional video. The video is composed of 7 different locations with a mean of 7.5 seconds per location. The 360° promotional video is accompanied by music and, in the background, the ambient sounds of every location. For the full-length videos, we used the original footage captured.

An XML file was created for each 360° video featured in the 360° promotional video. The file contains the names of the locations and all the necessary data to create the POIs (Fig. 5): title, description, image paths and location within the 360° video (identified by horizontal and vertical degrees). An XML tag also identifies the main POI.

For the 360° condition, we used a full hd (1920x1080 @ 60hz) 24-inch monitor, a mouse (to look around the 360° video) and active noise-cancelling headphones (Fig. 6).

The 360°Interaction condition used the same materials as the condition described above plus a keyboard to interact with the video.

For the IVR360° condition, we used the Oculus Rift CV1 HMD (2160x1200 @ 90hz) and the same noise-cancelling headphones used in the previously described conditions.

The IVR360°Interaction condition used the same materials as the IVR360° condition, but we added the Oculus Remote for the interaction component (Fig. 6).

All the participants performed the experiment sitting in a swivel chair to facilitate mobility while looking around with the HMD because this is the most likely position in which users would watch and interact with contents in a computer.

Regarding the performance analysis, the videos used in the 360º viewer for the experiments were coded with h.264 codec, had a resolution of 4000 x 2000 pixels, 30 FPS, and a bitrate of 68000 kbps. The computer hardware used for both the experiments and performance analysis consisted in an AMD Ryzen 7 2700X Octa-Core 3.7GHz c/ Turbo 4.35GHz, NVIDIA RTX 2080, and 32GB of RAM.

```
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  <IsMain>true</IsMain>
  <Title>Point of Interest 1</Title>
  <Information>POI info</Information>
  <Image>
    <string>Image Path</string>
    ...
  </Image>
  <HorizontalDegree>334</HorizontalDegree>
  <VerticalDegree>2</VerticalDegree>
  </PoI>
  ...
</PoIList>
```

Fig. 5. XML excerpt regarding the POI information

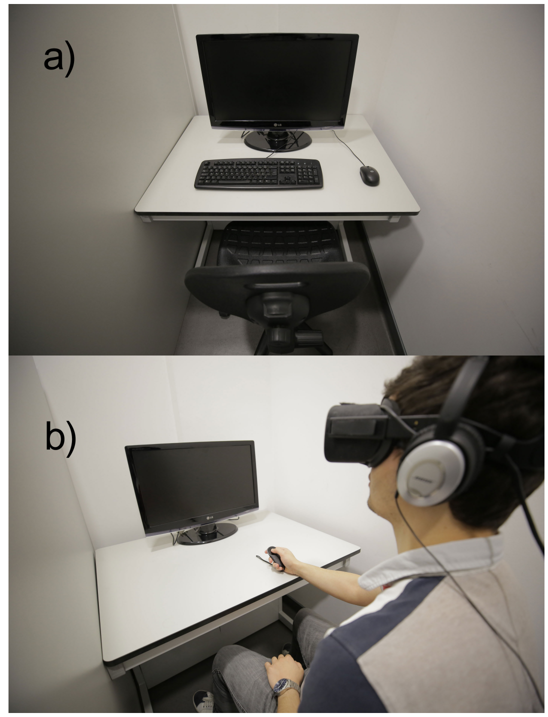

Fig. 6. a) Low-immersive setup, b) Immersive setup

C. Instruments

To assess the sense of presence we used the translated and validated Portuguese version of the IPQ [35], the IPQp [36]. This is a valid and reliable [37] questionnaire. It has 14 items on a five-point Likert scale with the following subscales: spatial presence (the feeling of being physically present in the virtual environment), experienced realism (the subjective experience of realism), involvement (the attention that is given to the environment and the level of involvement experienced) and presence (the global sense of presence). To evaluate cybersickness, we used the SSQ [26]. The questionnaire was translated into the Portuguese language and is composed of 16 items corresponding to a set of symptoms that can be classified as none, slight, moderate, and severe. The symptoms are presented in the following subscales : nausea (nausea, salivation, burping, stomach awareness), oculomotor discomfort (eye strain, difficulty focusing, blurred vision), disorientation (vertigo and dizziness) and cybersickness (global cybersickness). To evaluate satisfaction, we used the ASQ [38] translated into Portuguese.

D. Variables

In this work, we considered the following variables:

- Independent Variable (with 4 levels)

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  - IVR360°Interaction (HMD with our interaction method)
  - IVR360° (HMD without interaction)
  - 360°Interaction (computer monitor, keyboard and mouse with our interaction method)
  - 360° (computer monitor, keyboard and mouse without interaction)
- Dependent Variables
  - User Satisfaction
  - Presence (Spatial Presence, Experienced Realism, and Involvement)
  - Cybersickness (Nausea, Oculomotor Discomfort, and Disorientation)
  - Frame rate
  - Loading time of full-length video

E. *Procedure*

The experiences were conducted in a laboratory environment where the research team had full control over the ambient variables. The experimental room was soundproof, and the participants performed the experiments under the same ambient light, sound and temperature conditions. Before each experiment, the participants were briefed and asked to fill out a consent form and a socio-demographic questionnaire. In the featured interaction conditions, we explained how the participants could interact with the 360° promotional video. After the experiment, the participants completed the IPQp, SSQ and ASQ questionnaires.

The performance analysis consisted in running the interactive and non-interactive versions of the method in both immersive and low immersive setups. Each run we gathered the FPS at a rate of two samples per second as well as the time to load full-length videos. Because the conditions using the high immersive setup are capped at 90FPS (the refresh rate of the HMD), the same cap was also applied to the low immersive setups.

In the non-interactive versions, there were only camera movement simulating an usual exploration. The methodology in the interactive version consisted in triggering each full-length video, opening and closing every available POI, while also looking around.

F. *Statistical Procedures*

A preliminary analysis of the data was conducted to verify their normal distribution (Shapiro-Wilk's test (p >0.05)). From the analysis of the IPQp data, we verified that there were three outliers in the sample, as assessed by boxplot ($n = 50$). After their removal, the data were normally distributed, so we used parametric statistics, namely, one-way ANOVA. From the analysis of the SSQ data, we verified that the data were not normally distributed, as assessed by Shapiro-Wilk's test (p <0.05); thus, we used non-parametric statistics (Kruskal-Wallis H test). The analysis of the ASQ revealed that the data were not normally distributed, as assessed by Shapiro-Wilk's test (p <0.05), so non-parametric statistics, namely, the Kruskal-Wallis H test, were also used.

IV. RESULTS

The overall results are shown in Fig. 7. The results for every dependent variable are described in detail in the following subsections.

A. *Satisfaction between groups*

A Kruskal-Wallis H test was conducted to determine whether there were differences in satisfaction between groups that differed in their level of immersion and interaction: 360° ($n = 11$), 360°Interaction ($n = 14$), IVR360° ($n = 10$) and IVR360°Interaction ($n = 12$). Values are mean rankings. The distributions of the satisfaction scores were not similar for all groups, as assessed by a visual inspection of the boxplots. The mean rankings of the satisfaction scores were significantly different between groups, $x^2(3) = 8.982; p = 0.030$. Pairwise comparisons were performed using Dunn's [39] procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. This post hoc analysis revealed statistical significance for the 360° (mean ranking = 14.68) and IVR360°Interaction (mean ranking = 30.46) ($p = 0.029$) conditions. The satisfaction score increased from the 360° (14.680) to the 360°Interaction (23.070) to the IVR360° (27.800) to the IVR360°Interaction (30.460) group. The mean rankings can also be seen in Table III.

Summarizing the user satisfaction results, the IVR360°Interaction condition, which uses our interaction method and the immersive platform, outperformed the 360° condition, as the ASQ data shows. There were statistically significant differences between these two groups. By analysing the mean rankings, we can visualize that if we either increase the immersion level or add our interaction method, the mean rankings of satisfaction increase.

B. *Sense of presence between groups*

To compare the differences between conditions regarding the sense of presence, we conducted a one-way ANOVA. There was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.113$).

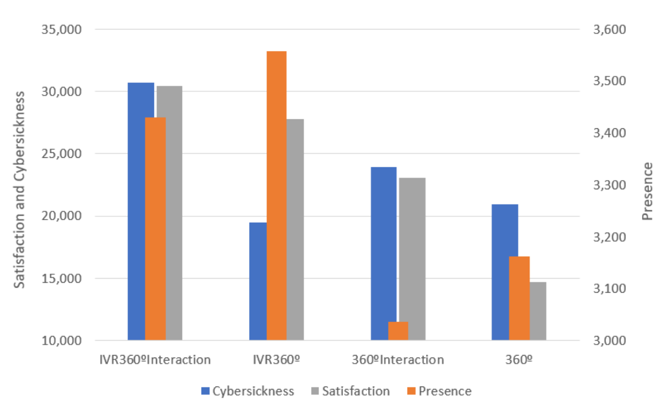

Fig. 7. Visual graphic of the main results between conditions regarding satisfaction, presence and cybersickness

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TABLE III
MEAN RANKING OF THE SATISFACTION SCALE FOR EACH CONDITION

Condition	Satisfaction
IVR360°Interaction	30.460
IVR360°	27.800
360°Interaction	23.070
360°	14.680

A one-way ANOVA was conducted for each presence subscale to determine the differences between groups with different interaction and immersion levels. The participants were classified into four groups: 360° (n = 12), 360°Interaction (n = 14), IVR360° (n = 12) and IVR360°Interaction (n = 12). There were a total of 3 outliers, as assessed by boxplot analysis. The means of all presence subscales in each condition can be found in Table IV. The data are presented as the mean ± standard deviation.

1) Presence: The presence score was significantly different between the different groups, $F(3, 43) = 3.581$; p = 0.021; $\eta_p^2 = 0.2; OP = 0.752$.

The presence score increased in the following order:

- 360°Interaction (3.036 ± 0.615)
- 360° (3.162 ± 0.344)
- IVR360°Interaction (3.429 ± 0.305)
- IVR360° (3.557 ± 0.328)

Tukey post hoc analysis revealed that the increase from 360°Interaction to IVR360° $(0.521; 95\%CI(0.042 \text{ to } 1.001))$ was statistically significant $(p = 0.029)$.

2) Spatial Presence: The spatial presence score was significantly different between the different groups, $F(3, 43) = 4.188; p = 0.011; \eta_p^2 = 0.226; OP = 0.822$.

The spatial presence score increased in the following order:

- 360°Interaction (3.179 ± 0.572)
- 360° (3.485 ± 0.540)
- IVR360° (3.717 ± 0.223)
- IVR360° Interaction (3.820 ± 0.524)

Tukey post hoc analysis revealed that the increase from the 360°Interaction to the IVR360°Interaction $(0.641; 95\%CI(0.118 \text{ to } 1.164))$ was statistically significant $(p = 0.011)$.

3) Experienced Realism: Experienced realism was not significantly different between the different groups, $F(3, 43) = 1.693; p = 0.183; \eta_p^2 = 0.106; OP = 0.411$.

The experienced realism score increased in the following order:

- 360°Interaction (3.036 ± 0.876)
- IVR360°Interaction (3.125 ± 0.794)
- 360° (3.363 ± 0.595)
- IVR360° (3.675 ± 0.566)

4) Involvement: The involvement score was not significantly different between the different groups, $F(3, 43) = 2.632; p = 0.062; \eta_p^2 = 0.155; OP = 0.604$.

The involvement score increased in the following order:

- 360° (2.478 ± 0.410)
- 360°Interaction (2.821 ± 0.410)
- IVR360° Interaction (3.146 ± 0.742)
- IVR360° (3.200 ± 0.610)

Although the univariate tests showed no significant differences $(p > 0.050)$, due to the large effect size $(\eta_p^2 > 0.140)$ and high observed power, we ran further tests. Tukey's post hoc analysis revealed that there were no differences between the groups.

We verified statistically significant results in overall presence and spatial presence. The data show that by raising the immersion level (from computer monitor to HMD), the spatial presence and overall presence scores also increased significantly.

C. Cybersickness between groups

A Kruskal-Wallis H test was conducted for each SSQ subscale to determine whether there were differences in cybersickness between groups that differed in their level of immersion and interaction: 360° $(n = 11)$, 360°Interaction $(n = 14)$, IVR360° $(n = 10)$ and IVR360°Interaction $(n = 12)$. Values are mean rankings. The distributions of the cybersickness, nausea, oculomotor discomfort and disorientation scores were not similar for all groups, as assessed by a visual inspection of the boxplots. A summary of the mean rankings of all presence subscales in each condition can be found in Table V.

1) Cybersickness: The cybersickness scores increased from the IVR360° (19.450) to the 360°(20.910) to the 360° Interaction (23.930) to the IVR360°Interaction (30.710) group, but the differences were not statistically significant, $x^2(3) = 5.941; p = 0.114$.

2) Nausea: The nausea scores increased from the IVR360°(21.150) to the 360°(23.270) to the 360° Interaction (24.360) to the IVR360°Interaction (26.630) group, but the differences were not statistically significant, $x^2(3) = 5.941; p = 0.617$.

3) Oculomotor discomfort: The oculomotor discomfort scores increased from the 360° (19.590) to the IVR360°(21.000) to the 360°Interaction (25.360) to the IVR360°Interaction (28.960) group, but the differences were not statistically significant, $x^2(3) = 5.106; p = 0.164$.

4) Disorientation: The disorientation scores increased from the IVR360° (19.609) to the 360°(21.450) to the 360°Interaction (23.930) to the IVR360°Interaction (30.080) group, but the differences were not statistically significant, $x^2(3) = 5.812; p = 0.121$.

Overall, results showed that symptoms occurred to some degree. However, they did not significantly differ between conditions.

D. System Performance

The system performance analysis was performed for the 360º viewer considering all the experimental conditions (except for the loading times of full-length video being possible only in the interaction conditions).

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TABLE IV
MEANS OF THE PRESENCE SUBSCALES FOR EACH CONDITION

Condition	Presence	Spatial Presence	Experienced Realism	Involvement
IVR360°Interaction	3.429	3.820	3.125	3.146
IVR360°	3.557	3.717	3.675	3.200
360°Interaction	3.036	3.179	3.036	2.821
360°	3.162	3.485	3.363	2.478

TABLE V
MEAN RANK OF THE CYBERSICKNESS SUBSCALES FOR EACH CONDITION

Condition	Cybersickness	Nausea	Oculomotor	Disorientation
IVR360°Interaction	30.710	26.630	28.960	30.080
IVR360°	19.450	21.150	21.000	19.600
360°Interaction	23.930	24.360	25.360	23.930
360°	20.910	23.270	19.590	21.450

In regards to FPS, the mean (M) and standard deviation (SD) were the following: 360°Interaction (M=89.109, SD=4.042) , IVR360°Interaction - (M=89.169, SD=3.483), 360º (M=89,985, SD=0.175), and IVR360° (M=89.718, SD=3.303). Figure 8 displays the FPS over time for all conditions. Note that frame rate was capped at 90FPS due to being the maximum FPS allowed in high immersive virtual reality environments.

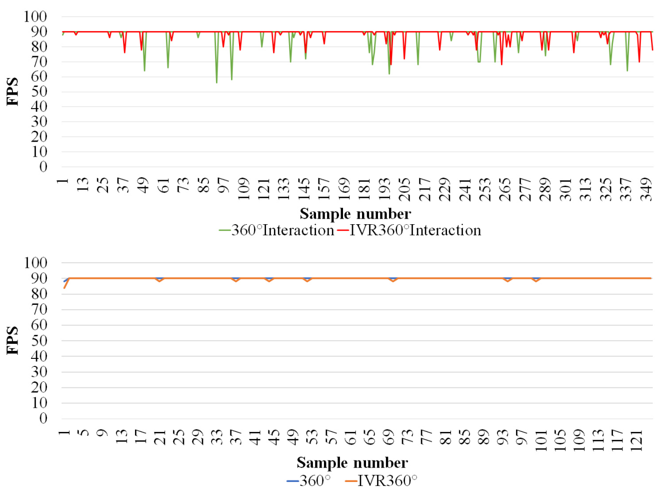

Fig. 8. Frames per second achieved in the conditions 360°Interaction, IVR360°Interaction, 360°, and IVR360°. Two samples were taken per second.

The overall loading time of the video in the conditions with interaction, when transitioning from the promotional video to the full-length video, was 0.941s.

V. DISCUSSION

Following the perspective in the literature that VR has potential in tourism marketing, this work aimed to propose and evaluate a novel interactive 360° video experience approach and compare it to the non-interactive version. Overall, the results revealed that the proposed interactive approach is preferred over the non-interactive approach and thus can be used to better engage with potential tourists because they can better conceptualise the touristic experience. Such results are significant as providing users with samples and demonstrations of the locations they want to visit enables them to make better-informed decisions and encourages them to visit those destinations in real life [1], [9]–[11], [40], [41].

Concerning user satisfaction, results suggests that the proposed interactive approach combined with an immersive setup delivers higher levels of satisfaction than the low-immersive and non-interactive 360° video experience. When referring only to the low-immersive setup (computer monitor with keyboard and mouse), the proposed interaction method still outperforms the non-interactive version in user satisfaction. We conclude that in terms of user satisfaction, our interactive solution outperforms the non-interactive version in both the low-immersive and immersive setups.

Presence can cause a positive attitude change towards a destination [16], so maintaining a high level of presence is crucial. The results for the sense of presence indicated no statistically significant differences across the scenarios except in the spatial presence subscale, which was found to be significantly different between the 360°Interaction and the IVR360°Interaction. However, this result was due to the use of the HMD, which provided higher immersion and resulted in a higher sense of spatial presence than a conventional setup. Analysis of the descriptive results shows that the proposed interaction method has lower scores on the overall presence and experienced realism scores. We attribute this finding to how the interaction was made occurred in the VR application; it allowed the user to pause the video wherever he/she wanted to pass more time to enjoy and explore. However, it also allowed him/her to open text and photos in a pop-up style, with information about the POIs of that location. Because this situation is not natural and does not exist in real life, it could disrupt the illusion of being there, and consequently lower the presence score in the IPQp questionnaire [15]. Even though this difference was not significant, further tests are needed to confirm the statement by Tussyadiah et al. [15] regarding the cause for the lower presence and to guarantee that a sense of presence is not compromised by our solution.

The use of immersive setups resulted in higher presence and

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spatial presence scores, which could lead to a stronger interest towards destinations [15], [16]. If we analyse the means, we can see that the condition that scored the highest in every presence subscale was always the one that involved the most immersive system (IVR360° or IVR360°Interaction). Additionally, the condition that scored the lowest in every presence sub scale was the one that involved the least immersive system (360° or 360°Interaction). These results corroborate those of previous studies, such as the [20] study, in which the most immersive condition (HMD) was also the one with the highest presence score. Note that although the conditions that involved interaction made the experience longer in time, they should not have affected presence, as previous work suggest [17].

Although our interaction method may not be the best for raising the level of presence, it was welcomed by the users as the condition that was most satisfying. Similar results can be found in [20], where the users reported preferring the most immersive system (HMD) over the laptop monitor.

Regarding cybersickness, there were slight symptoms which did not differ between conditions. We can assign these symptoms mainly to individual factors because both the equipment (computer monitor, keyboard, and mouse to HMD and remote controller) and the tasks (allowed to interact with the video) changed between the groups without affecting cybersickness. We can therefore assume that the symptoms that were reported across conditions were not due to device or task factors. This suggests that raising the level of immersion and our interaction method did not contribute significantly to the emergence of these symptoms.

Analysing the FPS over time, we can find spikes where FPS drops in the conditions featuring interaction. These drops are due to the transitions to the full-length videos. However, various factors compensate these drops, making them unnoticeable by users. One of them is the transition effects, which blurs the image making the transition softer. It takes on average 1 second to load the full-length video, which is masked by the transition effects (Fig. 3). Another factor is the motion smoothing techniques used in HMD setups which minimizes the impact of FPS fluctuations. When in need (the frame rate is lower than the required), the system synthesizes new frames to fill the gaps. This is particularly effective in rotational head movements, which is the type of movement users will use throughout the experience. Relative to the drops of FPS in the interactive low immersive setup (360°Interaction), when considering a standard 60hz monitor the drops should not be noticeable by users. Adding the fact that if we remove the cap, the FPS will be much higher, these frame rate spikes will not impact the end-user experience. All these factors allow users to experience a stable experience, not affecting other metrics studied in this work.

VI. Conclusion

As multiple works in the literature suggest, immersive VR is a desirable method of promoting tourism. This work aimed to contribute to the literature with a novel interactive, immersive and dynamic 360° video experience that provides users with supplementary information about the touristic site depicted without overloading them.

The interactive method proposed can adapt the experience time for each user while providing information about the touristic sites in which users are interested. Therefore, users are not overloaded by information due to a short experience time and also avoid the boredom that can result when the experience is too long.

We evaluated the proposed method for experiencing 360° touristic videos in terms of the interaction approach (interaction vs. non-interaction) in both low-immersive and immersive setups using user satisfaction, presence, and cybersickness as metrics as well as overall performance of the application through frame rate

The evaluation study led us to conclude that our interaction method outperforms the non-interactive method in terms of user satisfaction regardless of the immersive system. Additionally, neither version of the method significantly affected the feelings of presence or cybersickness. The increase in user satisfaction leads us to conclude that the interaction is easy and straightforward, which can help provide a more insightful preview of the touristic destination, leading users to be more prone to visit the depicted destinations. The performance was high enough to not cause any interference with the user experience and the metrics being studied.

Although focused on the promotion of tourism, our solution could easily be implemented in other fields.

For example, areas that already use 360° videos, such as marketing, advertising or education, could benefit from our solution by offering a more interactive way to experience 360° videos with all the advantages noted in this work. Thus, in future research, our solution could be adapted and evaluated in other fields, widening the target audience, and accumulating a set of validated features (including more metrics into the analysis, such as user performance) that can be turned on/off as needed. Application performance optimizations will also be done, lowering performance hits in less capable hardware. Multisensory stimulation is one of the features that was already approached by Coelho et al. [30], [31] and is planned to be implemented and evaluated in a followup study.

To allow creators to produce experiences taking advantage of our novel method, an authoring tool should be developed that enables the fast generation of such 360º experiences. Such authoring tool is planned to be developed down the line as the concepts presented and evaluated in this study and the following ones are validated through user studies.

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