



# VR 360° and its impact on the immersion of viewers of suspense AV content

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## Abstract

With the development of new technologies, audio-visual (AV) content creators are looking for more immersive experiences, so a greater involvement of the viewer with the action and the narrative occur. Based on this vision, virtual reality (VR) is increasingly considered a tempting option for the world of entertainment. VR 360° AV content is beginning to emerge, allowing greater immersion for the spectator. In the cinematic genre of suspense, VR 360° has high potential to provide a more impacting experience for the spectators. However, it is necessary to confirm whether this potential is true. In this sense, the study focused on the production of an AV content of suspense and its adaptation to three different formats (2D, 360° and VR 360°), with the objective of understanding the impact on the immersion of the spectators when they watch VR 360°, in comparison with the other formats. Three tests were performed in the laboratory, with sample of 36 participants in total. In order to understand the immersive differences, each test consisted of 12 participants, in which they all watched the same suspense content, an adaptation of *The Tell-Tale Heart* by Edgar Allen Poe, but in different formats. The results showed that the VR 360° format intensifies perceptual immersion but decreases narrative immersion, when compared to 2D and 360° formats. Also is shown that the fact that narrative immersion has decreased in this format is a consequence of the user being allowed a 360° stereoscopic view with the Head-Mounted Display (HMD).

**Keywords** Virtual Reality · 360° · Immersion · Audio-visual · Suspense · Audio-visual production

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## 1 Introduction

In recent years, the sharp development of virtual reality (VR) technologies has enabled filmmakers, artists and other media producers to begin creating VR experiences [7]. They actively seek ways to develop more attractive, impactful and engaging content, with the potential to increase the immersion of the user [22]. Perceptual immersion is characterized by the user's sense of being involved, interacting and being included in an environment that allows a continuous flow of stimuli and experiences [25]. In VR, the immersive qualities of these systems foster a sense of presence [3]. Frame rates, angle/area of vision, tracking latency, visual and sound quality are some of the characteristics of immersive technology that impact the sensation of presence of the user [23]. However, immersion is not an exclusive concept of the perceptual plane, narrative immersion also plays a very important role in the involvement of the spectator and can be evaluated through the scales of functions identification, credibility, curiosity and suspense [20].

Moreover, there are some empirical evidences [6] that these immersive systems can allow viewers to intensify their engagement with the narrative and experience more empathy compared to less immersive technologies. Nevertheless, filmmakers should consider navigation/interactivity as a dimension of high relevance in VR and that should be explored with the perspective of combining entertainment with the possibility of offering the viewer the freedom to have an active role and participate in the narrative [2]. However, the fact that the spectator become an active participant brings the challenge of creating techniques to focus his attention on the action of the story, due to his inability to simultaneously capture various stimuli from the narrative and virtual space.

It is the filmmaker's responsibility to capture the spectator's attention through the immersive narrative in order to avoid distraction. Thus, to better understand the potential of VR compared to other formats under study, the genre of suspense was chosen. Film genres such as thriller and suspense have enormous potential in VR as they seek to produce excitement, nervousness, tension, doubts and false assumptions in viewers. The intensity and complexity of the events narrated in this genre foster a deep involvement of the viewer in the plot [17]. In addition, excitement is a fundamental dimension in the emotional experience of suspense and is, at the same time, a reliable indicator and relatively easy to measure in an objective way [5].

In this context, following Work in Progress (WiP) "How VR 360° impacts de immersion of the viewer of suspense AV content" [15], this paper aims to understand how immersion, both narrative and perceptual, can be impacted by the format used by the viewer to watch an audio-visual (AV) suspense content. For that, it prepared the same AV content to be delivered in different formats (2D, 360° and VR 360°) and get the users perceptions of the narrative in each format. As a VR 360° proof of concept was created, the paper also presents relevant clues for the creation of VR content, from its pre-production to its post-production. After this introductory section, the paper is structured as follows: Section 2 presents the related work; the development of the short film *The Tell-Tale Heart* is dealt in Section 3; Section 4 presents the evaluation made for the study; and the conclusions are presented in Section 5.

## 2 Related work

Nowadays, viewers have the opportunity to experience content in a new way, through VR, allowed by recent technological advances in this area [8]. VR has the ability to immerse viewers by evoking intense sense of presence and empathy. The affective link between content, spectator/user and

technology are also factors that attract sectors such as entertainment, industry, art, communication and tourism [7] for the production of VR content. In addition, this technology has the power to emotionally engage viewers in ways never before explored [19].

VR is perceived as an “empathy machine” [16] with the potential to connect viewers to places, people and lived experiences. A study from Fonseca [6] shows that there is a connection between a sense of presence and emotional involvement, through experiences that boost the feeling of presence in the spectator and consequently contribute to the generation of empathic emotions. A possible and deeper explanation would be that emotions are influenced by immersion, in a basic dimension commonly related to emotional intensity, more precisely, to the dimension of excitement [4]. Emotions play a central role in decision making and automatic responses, since they influence how individuals understand, describe and react to the environment. It seems that regardless of the type of emotions felt by the spectator, the increase in excitement amplifies all the emotional responses of the spectator [9]. One study [10] compared the use of visualization systems (head-mounted display (HMD) vs. non-HMD) with content with distinct emotional stimuli (horror and empathy) and revealed that viewers felt more intense emotions and had a greater immersive experience when they wore an HMD to watch terror content. However, there were no significant differences in the content considered empathetic, regardless of whether participants used viewing systems or not. These results suggest a connection between immersion and emotional responses when viewers experience stimulating content. The authors of the study [6] conclude that a more immersive technology (VR) promotes greater empathy, compared to other visualization platforms.

The VR 360° contents have already demonstrated the potential of being a resource for studies about the induction of emotions, using this technology. A study [13] that sought to explore the relationship between the participants’ head movements and their emotions, using the self-assessment manikin scale (SAM) to measure the dimensions of valence and arousal, showed a significant relationship between the yaw movements and the dimension of valence, which suggests that the participants who performed this movement more frequently, had greater pleasure in viewing the content. Regarding the arousal dimension, the results showed a correlation between the pitch movements and the arousal dimension, which indicates that users who tend to tilt their head are more excited.

Well-structured narratives can result in strong emotional responses from viewers who engage with the content, even when viewed in low immersion devices [21]. More immersive technologies such as VR, allow a better engagement of the viewer with the narrative compared to less immersive technologies [24]. Authors of a study [18] revealed that more immersive technologies promote the viewers’ engagement with the narrative. Nevertheless, the participants revealed to be distracted from the narrative when they observe the 360° environment. This can be a problem for those who have never experienced this type of technology [14]. Users who first experience technologies such as 360° video or VR may even behave differently from those they have experienced before.

In contrast to what was previously mentioned, Bindman et al. [3] showed that in the visualization of VR content does not necessarily encourage a better understanding of the story, involvement with the narrative or empathy with the characters, when compared to less immersive technologies. In this way, filmmakers should choose cinematographic genres that enhance the public’s involvement with the narrative, such as the suspense genre. In this genre (suspense), the constant doubt of the spectators regarding the destiny of the characters provokes nervousness, anxiety and anguish in the spectators, key factors that make the plot so involving. However, the concept of suspense is quite broad, not only because of its popular

use, but also because of the inherent difficulty in defining a cinematographic “genre”. Therefore, the study adopts the definition developed by Nogueira [17] for its clarity and facility to instrumentalize the three main characteristics prevailing in the suspense genre:

- i. Intention to create intense excitement and nervousness in spectators. The decisive moments provoke urgency and disturbance in the spectators to know the course of action;
- ii. Constant establishment of doubts about the fate of the characters and the outcome of events. Doubt is a constant of suspense;
- iii. The suggestion of verisimilitude, which comes from false assumptions, but which creates expectations in the spectators. They feel a constant uncertainty, anguish, restlessness and anxiety;

Considering the aforementioned studies [3, 23, 10], similar methodologically approaches were used like in the Bindman et al. study [3] where the authors compared the participants’ narrative involvement and empathy when viewing the same content, but in different formats (VR 360° and 360°). In accordance with this method, in the Tse et al. study [23] they compared how immersion is affected by the use of headphones in different viewing formats (VR 360° and 360°). Another study [10] investigated the relationship between immersion and emotion by comparing two viewing conditions (HMD and non-HMD), using two types of emotional content (horror and empathy). However, while in the studies [3, 23] the same sample was used to make the comparison between formats, in Kim et al. study [10] the sample was divided by the two visualization conditions.

### 3 The development of the short film *The Tell-Tale Heart*

In order to achieve the proposed goals of the study, the short film *The Tell-Tale Heart*, an adaptation of Edgar Allan Poe’s short story, was developed. In the Fig. 1 it is possible to see a synthesis of the production process of the short film. The suspense AV content was created for the VR 360° format, and later adapted to 360° and 2D formats, with the objective of allowing an understanding of how immersion (perceptual and narrative) can be impacted by the VR 360° format in comparison with other visualization formats.

#### 3.1 The pre-production process

For the conceptualization of this project, the decision on the cinematographic genre was supported by literature review. The suspense was the chosen genre since it has vast possibilities to foster a deep engagement of the viewer with the story. To decide on the story to adapt, the following indicators of suspense (characteristics mentioned above) were considered: (i) the intention of creating intense excitement and nervousness in the spectator; (ii) the constant establishment of doubts about the fate of the characters and the outcome of events; (iii) the suggestion of verisimilitude, which comes from false assumptions, but which creates expectation in the spectators [17]. The decision relayed in a short story by Edgar Allan Poe, *The Tell-Tale Heart*. This story has an unknown character (narrator), which may foster some suspense, as described in the following storyline: “*The main character (the narrator) lives with an old man who has a blue eye. He becomes obsessed with the eye, so every night he spies the old*

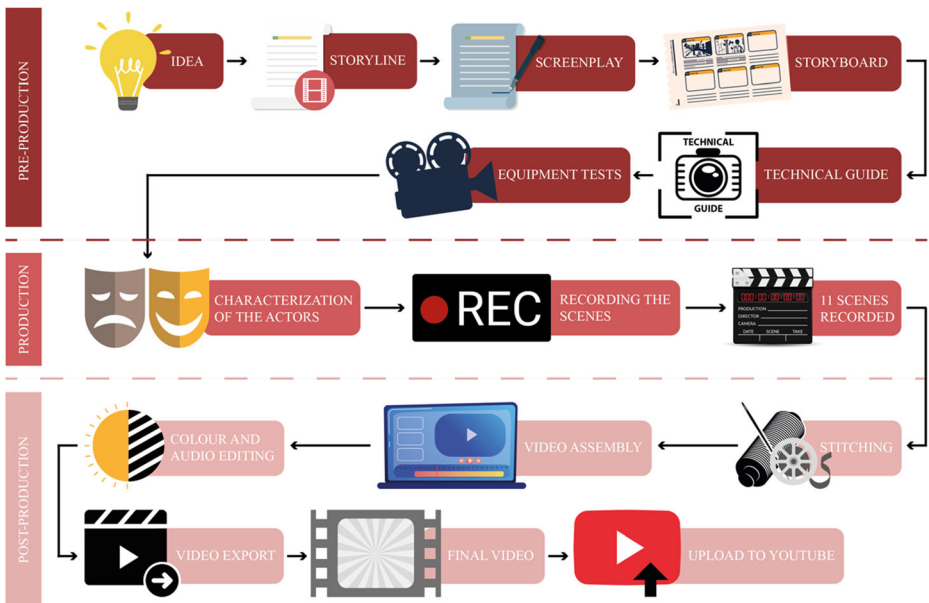


Fig. 1 Pipeline of the short film production process

man to sleep. One night, he sees that he has an open eye and decides to kill him. The police appear in reaction to a neighbours’ complaint. The main character starts to listen to the old man’s heart and confesses his crime.”

The development of the screenplay, storyboard and technical script has changed and was adapted to the needs raised by a VR 360° AV content. For the preparation of the screenplay a model developed by Filmatics’ producers, structuring the action by quadrants, was adopted. As seen in Figs. 2 and 3, the quadrants Q1, Q2, Q3, Q4, identified by colours that relate to the viewer’s 360° vision [1]. The colour corresponding to each moment of the action changes, depending on the quadrant in which the action is taking place or which may attract the spectator’s attention, such as the sound of the clock pendulum in scene 1.

9. INT - HOUSE (HALL/DOOR) - NIGHT

The narrator is at the beginning of the hall and moves to the door.

FADE IN

The narrator, opening the door, comes across two cops.

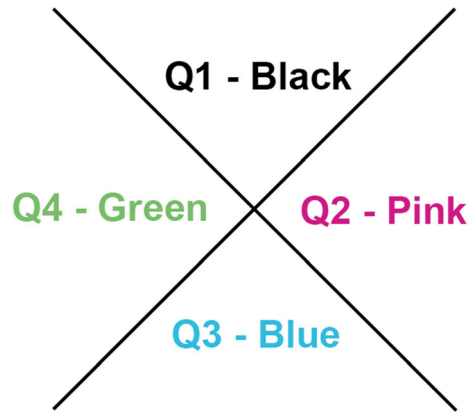
NARRATOR  
(surprised)

(More)

(CONTINUED)

Fig. 2 Extract from the VR 360° content script

**Fig. 3** Quadrants and their colour pallet

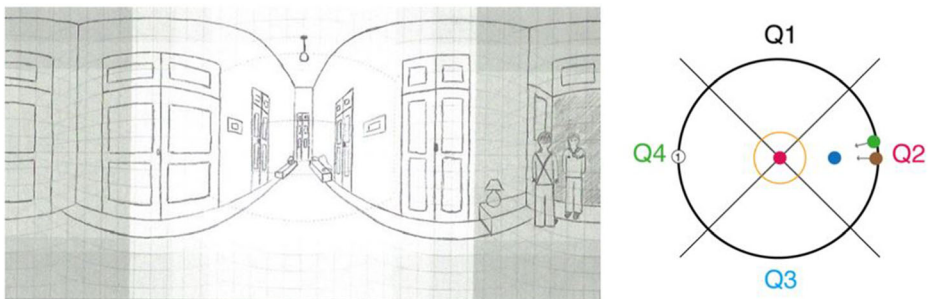


As previously mentioned, the storyboard and technical script were also adapted to the VR 360° format (see Fig. 4). For the storyboard a panoramic model developed by Kurbatov was used, which allows a wide angle view [12]. In the technical script a block diagram was used, which allows a visualization of the quadrant in which the scene is concentrated, the quadrant where the scene begins and the positioning and movements of the characters. This script was based on the model presented by Kraakman [11]. To support the production process, these two stages of the VR 360° pre-production (storyboard and technical script) were grouped together.

During the pre-production of the VR 360° project the equipment was also tested for 360° filming. In order to avoid editing problems (stitching), all the scenario props and actors were 0.5 m from the camera. The camera movements had to be thought in such a way that they did not trigger motion sickness in the spectators. The fluidity of the movements was maximized in order to be imperceptible by the users. The lighting was designed and tested to be integrated into the scene as a decorative element. Some adjustments were also made to the position of the camera in the different scenes.

### 3.2 Production VR 360°

The production process of the 360° AV content took place over four days. To shoot the scenes, VR 360° filming equipment (a Vuze camera, tripod with casters, memory cards,...), regular audio equipment (Zoom Hn4 recorder, microphone; memory cards,...) and props were used.



**Fig. 4** Storyboard and technical script of a given moment of action

Figures 5 and 6 show the most intense scenes (scenes 6 and 10) in the narrative, which had to be recorded several times in order to achieve the desired intensity at the climax of the narrative. Scene 6 shows the narrator killing the old man and scene 10 shows the moment when the narrator, listening to the old man's heart (hallucination), confesses his crime to the police.

Throughout the development of the short film *The Tell-Tale Heart*, perceptual stimuli were created (e.g. scene 1 - sound of the clock pendulum; scene 4 - the old man drops the cup on the floor, breaking it) that did not jeopardize the spectator's focus of attention in the narrative. Nevertheless, these stimuli allowed the spectators to explore the 360° environment at certain moments without losing the continuity of the narrative. The entire process inherent to the production of the short film was thought out with a view to minimizing the overlapping of these stimuli. In addition, in order to make it easier for spectators to follow the action of the narrative, some camera movements (dolly movements) were created in the scenes to guide them in the action. For example, in scene 1, at a certain moment, it was intended that the spectator would turn his head to the right. In order to do this, a camera movement was created in that direction. This movement brings the action back to the focus of the camera.

Although these movements helped the spectators to follow the action, they were used only on specific moments in order not to interfere with the freedom spectators had to explore the 360° environment.

### 3.3 Post-production

All editing processes were performed using the Human Eyes VR Studio software (included with the Vuze camera) and Adobe Premiere Pro CC. The Human Eyes VR Studio was used exclusively for the stitching process, firstly by applying the automatic stitching of the videos, and then by doing a manual frame by frame editing to solve stitching problems. For the editing and colour correction operations Premiere Pro CC was used. The original set audio was complemented with sound effects to enhance tension moments in the narrative. In line with this suspense genre, colour correction was made to enhance a darker shade to the shots. The final video was exported in H.264 format and High Quality 2160p 4 K, in VR 360° and stereoscopy. The short film, *The Tell-Tale Heart* is available in the following url: <https://www.youtube.com/watch?v=nWmWdghypOs&t=28> s.



Fig. 5 Footage from scene 6 of the VR 360° content



**Fig. 6** Footage from scene 10 of the VR 360° content

After being created the VR 360° AV content, the result became available in two formats, VR 360° and 360°. However, in order to be able to compare the three formats (VR 360°, 360° and 2D) at the evaluation stage, a 2D version of the short film was prepared. The non-panoramic version followed the most relevant camera angle action in each scene.

## 4 Evaluation

This study followed a research and development (R&D) methodological approach considering that the development of the VR 360° AV content had, as a main objective, to perceive the immersive effect prompted in the viewer from watching a VR 360° format when compared to viewing the same content in 360° and 2D formats. Following this main objective, the following secondary goals were defined: **(i)** to perceive the levels of valence and excitement aroused in the participants when watching a suspense AV content ; **(ii)** to verify if the indicators of suspense were perceived in the AV content; **(iii)** to compare the focus of attention of the participants in the narrative parts, their levels of valence, excitement and immersion in the three viewing formats; **(iv)** to perceive if there is a relationship between the rotational head movements of the viewers and their levels of valence and excitement; **(v)** to perceive the side effects felt by the participants when viewing the short film in VR 360° format.

### 4.1 Procedure

In order to achieve the proposed objectives, a set of laboratory tests based on viewing sessions was prepared and the data collected through questionnaires and non-participating observation. Three groups of sessions were prepared and carried out to three groups of participants. Each group involved 12 participants, totalling a sample of 36 participants, leading to 36 individual evaluation sessions. Each group was presented with the same video, *The Tell-Tale Heart*, but in different formats (VR 360°, 360° and 2D). To ensure the necessary conditions for the study, the sessions were conducted in a comfortable and controlled environment, both in terms of noise insulation and lighting control. Participants were able to watch the video in a laptop with a 2560 × 1600 resolution (2D and 360° versions) and in a VR 360 kit (including a portable HMD (Samsung Gear VR) with a smartphone (Samsung S7)) for the VR 360° version. The



participants were seated in a chair, with a desk in its front and wearing headphones in all sessions except in the VR 360° session. In the latter, participants viewed the short film standing up so that they could more easily explore the 360° environment.

Participants were briefed of the purpose of the study and of the procedures to ensure the anonymity and confidentiality of the data to be collected and granted their consent. The study procedure and the format in which they would watch the short film was also explained. After this introduction, a characterization questionnaire was handed out to the participants. It was structured in two sections: (i) sociodemographic data; (ii) AV content consumption habits.

Once the characterization questionnaires were filled, each participant individually watched the content in the corresponding format. Participants were also briefed on how to interact with the 360° format, due to some inexperience in watching this type of content. For the VR 360° viewing experience the researcher used a complementary software, to remotely control the smartphone embedded in the HMD and the corresponding film. The researcher, after explaining the mode of visualization in both formats (360° and VR 360°), did not interact with the participants while they were exploring the proof of concept, so as not to affect their visualization experience.

After the tests were conducted, a final questionnaire was handed out to the participants. The questionnaire included an adaptation of the Self-Assessment Manikin (SAM) scale for VR 360° videos targeting it to the evaluation of valence and excitation indicators [13]. The SAM is an evaluation procedure that consists of 3 sets of simple drawings to evaluate the valence and excitation related with the affective reactions of the user to a given stimulus (in this case, the short film *The Tell-Tale Heart*). In addition to the SAM scale, the questionnaire included questions to assist the researcher to have a better understanding of how perceptual and narrative immersion is impacted by the visualization format. For that, questions like: “Do you consider necessary to watch the movie a second time to understand the narrative?”; “When watching the short film did you feel that you were part of the story?” were included.

As a data collection technique, a non-participating observation was also carried out to register the rotational head movements of the participants who saw the short film in VR 360° format. This information was used to analyse the relationship between these movements and the emotions expressed by the participants when watching the VR 360° content. This procedure took in consideration that the pitch and yaw movements are directly related to the valence and excitement dimensions, respectively. The greater the number of yaw movements, the greater the viewer’s pleasure in viewing the immersive AV content [13]. Considering the pitch movements, users who tend to tilt their heads up are usually more excited [13]. Therefore, to track these relations, along with the head movements, the behaviours of the participants were also registered during the visualization of the short film.

## 4.2 Participants

For the selection of participants, a convenience sample of individuals who frequently watched AV content was used. The sample consisted of 36 participants, 14 men and 22 women, mostly aged between 18 and 23 years (20) and 24–30 years (12). It also included one participant under 18, another over 50 and 2 participants aged 31–40. Due to limitations of resources for attracting participants, and as referred a convenience sample was defined with a majority of university students (28) were selected from the areas of new communication technologies (undergraduate – 15 participants) and multimedia communication (master’s degree – 13 participants). The remaining participants were teachers or former students of these areas.

When analysing the AV consumption habits, it was found that the majority of participants (30) watches AV content several times a day, having diversified preferences for film genres, such as comedy (17 participants), action (18 participants) and science fiction (18 participants). Regarding the suspense genre, 10 participants referred it one of the preferred ones. However, the participants of the study did not reveal to have regular daily consumption habits of this AV genre (watching less than once a month (13) or several times a month (18)). Fear (37 %) and surprise (35 %) were the primary emotions referred by the participants when watching a suspense content. Approximately half of the participants (19) have had previous experiences with both VR 360° and 360° content. Only 8 participants referred not having any experience with these formats.

### 4.3 Results

The evaluation results detailed in this section are based on to the data gathered from the final questionnaire filled in by the participants after the tests and from the non-participant observation carried by the researcher during the tests.

#### 4.3.1 Immersive effect on the viewer

Firstly, to the question “(do you) consider necessary to watch the movie a second time to understand the narrative?“, a significant number of participants (27) expressed that they did not need to watch it again to understand the narrative (see Fig. 7). However, when analysing the data according to the visualization formats, it was found that with the increased perceptual immersion allowed by the format, the understanding of the narrative reduced. In 2D format, only one participant said he would need a second view of the short film. However in the 360° and VR 360° formats there were increases with 3 and 5 participants respectively.

To assess the level of immersion, participants were required to answer the question “When watching the short film did you feel that you were part of the story?“ using a 5 level Likert scale, where 1 - I totally disagree and 5 - I totally agree. As shown in Fig. 8, the perceived immersion changed according to the format in which the test was performed. Most of the participants (11 out of 12) who carried the tests in the VR 360° format agreed (6) or totally

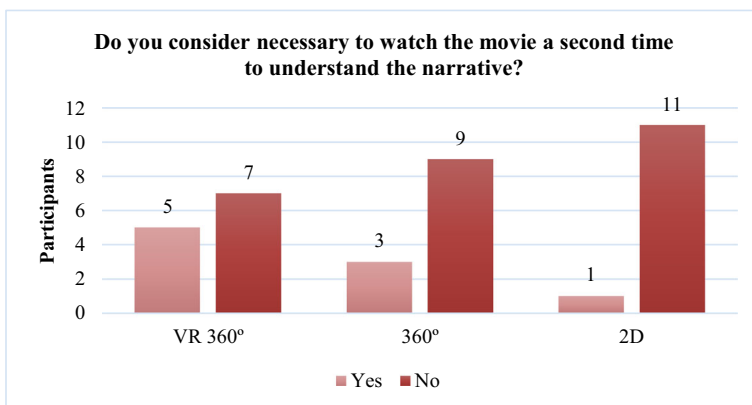


Fig. 7 Understanding the narrative of the short film

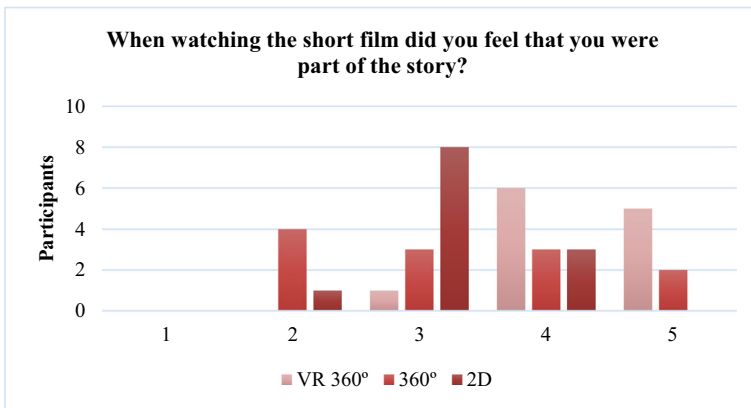


Fig. 8 Levels of perceived immersion of participants

agreed (5) to be part of the story when watching the short film. In the 360° format, the participants showed widely dispersed opinions: 5 participants felt part of the story (values between levels 4 and 5) and 4 participants did not feel it (level 2). Participants who watched in 2D format felt mostly neutral (8 participants).

Regarding the statistical analysis, due to the limitations of the sample (reduced number of participants), there were shortcomings in the statistical significance that did not allow us to assess differences between the formats, in terms of narrative immersion, valence and excitement. As can be seen below, significant differences were only found between the three formats (VR 360°, 360° and 2D) in terms of perceptual immersion.

When comparing the three formats, an analysis of the normality tests showed that the results, in general, deviate from a normal distribution, since  $p < 0,05$ . As the normal distribution was not proven, and given that three independent groups (VR 360°, 360° and 2D) were to be compared, a non-parametric test - Kruskal Wallis - was used. The following assumptions were made:

H0: The medians are the same in the different formats;

H1: At least one of the medians is different from the other medians of the distinct formats.

As it can be seen in the Fig. 9, there were statistically significant differences between the three formats in terms of perceptual immersion, since the null hypothesis was rejected by  $p < 0,05$ .

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of When watching the short film did you feel that you were part of the story? is the same across categories of Format.	Independent-Samples Kruskal-Wallis Test	,007	Reject the null hypothesis.

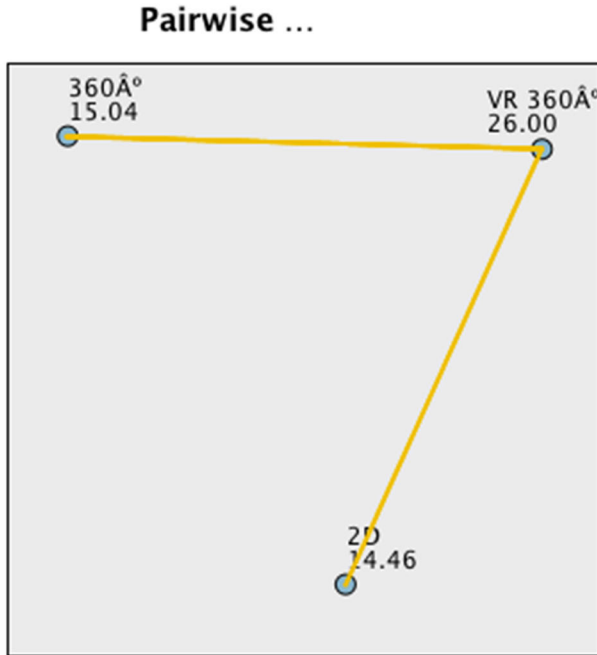
Asymptotic significances are displayed. The significance level is ,05.

Fig. 9 Kruskal Wallis test | Hypothesis test - comparison of perceptual immersion in the 3 formats

These differences, verified in the medians, were found between VR 360°-2D ( $0,016 < \alpha$ ) and VR 360°-360° ( $0.024 < \alpha$ ) formats (Fig. 10).

### 4.3.2 Indicators of suspense

Regarding the suspense indicators in the short film, the participants were asked to answer three questions, through a 5-level Likert scale, in which 1 - I totally disagree and 5 - I totally agree.



Each node shows the sample average rank of Format.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
2D-360°	.583	4.129	.141	.888	1.000
2D-VR 360°	11.542	4.129	2.795	.005	.016
360°-VR 360°	10.958	4.129	2.654	.008	.024

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Fig. 10 Kruskal Wallis test | Comparison of perceptual immersion in the 3 formats

The results shown in Table 1 reveal that, faced with the question “While watching the short film, did you feel urgency for knowing how the story unfolded?”, 22 participants felt urgency for knowing how the story unfolded, concentrating their values on levels 4 (16 participants) and 5 (6 participants). Nevertheless, 6 participants felt neutral. On the question “In the course of the action did you have feelings of doubt about the old man’s outcome?”, the participants (16) agreed with this question by classifying it at level 4. However, there were participants (7) who classified it in level 2, not having feelings of doubt about the unfolding of the story. In the last question, “In your opinion during the action did you think the narrator would accuse himself?”, the answers are concentrated on levels 1 (11 participants) and 2 (14 participants), revealing that the participants thought the narrator would not accuse himself.

### 4.3.3 Levels of valence and excitement perceived by the viewer

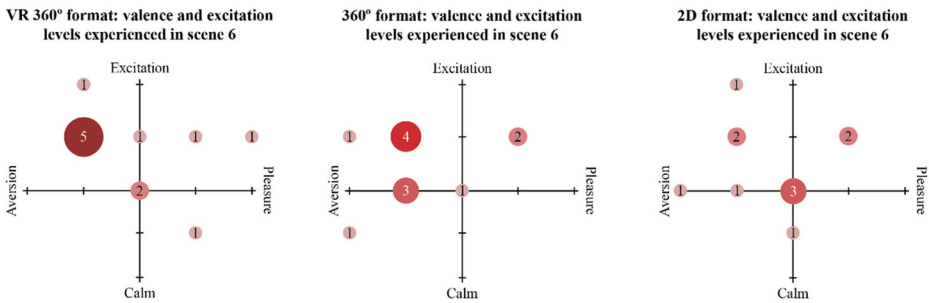
The participants’ emotional reactions to scenes 6 (Figs. 11) and 10 (Fig. 12) were assessed using the SAM scale. The scenes were chosen, considering the moments of greatest suspense of the short film *The Tell-Tale Heart*. Scene 6 shows the death of the old man and scene 10 shows the moment when the narrator surrenders to the police, confessing his crime. In the following figures, the x-axis corresponds to the valence level and the y-axis corresponds to the excitement level.

The levels of valence and excitement experienced in scene 6 are shown in Fig. 11. In the VR 360° format, 5 participants felt aversion and excitement and 1 participant felt aversion and excitement. The remaining answers were quite dispersed. In the 360° format, the focus is on participants who felt excitement and aversion (4 participants) and who felt only aversion (3 participants). The 2D format presented quite dispersed values, both in terms of valence and excitement. The most significant value of the results in this format (2D) correspond to 3 participants who felt neutral at the valence and excitement levels. These results suggest that the increasing of perceptual immersion tends to trigger a greater visceral response in the spectator.

Figure 12 shows the levels of valence and excitement experienced in scene 10. The results showed that in the VR 360° format, 5 participants felt aversion and excitement. However, there were three participants who felt neutral. In the 360° format, half of the participants (6) felt excitement, 2 participants felt aversion and another two felt pleasure. In 2D format, more than

**Table 1** Suspense indicators present in the short film

Suspense indicators	Format	Levels				
		1	2	3	4	5
While watching the short film, did you feel the urgency of knowing how the story unfolded?	VR 360°	0	3	3	3	3
	360°	1	0	3	7	1
	2D	2	2	0	6	2
In the course of the action did you have feelings of doubt about the old man’s outcome?	VR 360°	2	2	2	5	1
	360°	1	0	2	8	1
	2D	2	5	0	3	2
In your opinion during the action did you think the narrator would accuse himself?	VR 360°	3	6	2	0	1
	360°	4	5	0	3	0
	2D	4	3	3	1	1



**Fig. 11** Valence and excitement levels experienced in scene 6 in the different viewing formats

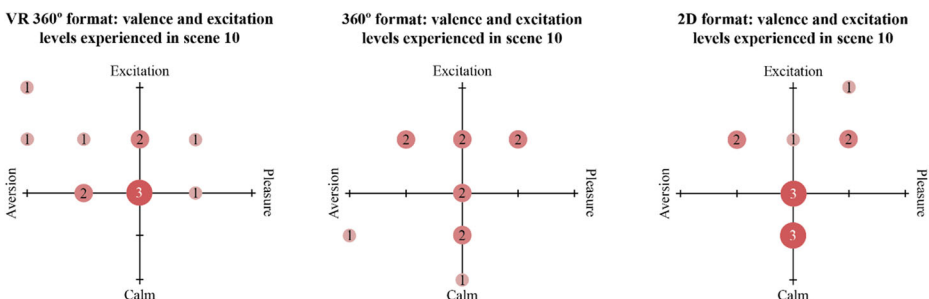
half of the participants (7) felt neutral at the valence level, and 6 participants felt excitement at seeing this scene. This results also shows that most of the values in VR format are concentrated on the first and second quadrant implying a more extreme response of excitement when compared to the other less perceptual immersive formats.

#### 4.3.4 Relationship between the rotational movements of the spectator's head and the levels of excitement and valence

The data collected by non-participant observation of the participants' head rotational movements have been translated into 5-level Likert scales that evaluate the valence and excitement dimensions. Figure 13 shows that in scene 6, the head movements revealed that more than half of the participants (8) felt pleasure and excitement and 2 participants felt pleasure and calm. More dispersed data indicates that 1 participant felt only pleasure, and another felt only excitement when viewing scene 6. In scene 10, the rotational head movements showed that half of the participants (6) felt pleasure and calm when viewing this scene. Also, in scene 10, 4 participants felt pleasure and excitement and 2 participants only felt pleasure.

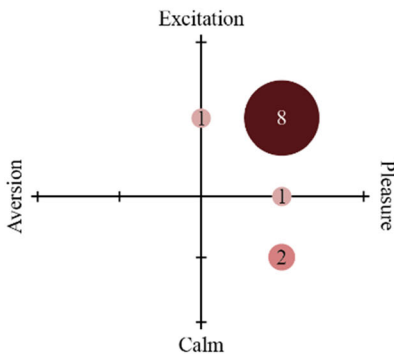
#### 4.3.5 Side effects felt by the participants when viewing the short film in VR 360° format

From the participants who viewed the short film in VR 360° format, 50 % (6 participants) mentioned having experienced various side effects, of which 4 participants referring feeling imbalanced, 2 participants physical discomfort, 2 participants stress and 2 participants headaches. Only 1 participant felt addiction and sickness when watching the short film in VR 360° format.

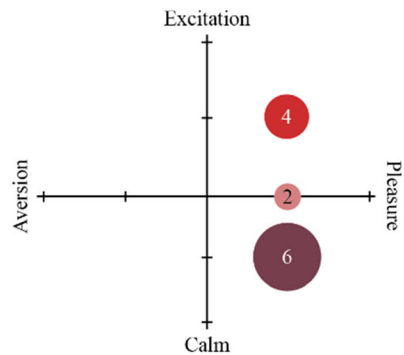


**Fig. 12** Valence and excitement levels experienced in scene 10 in the different viewing formats

### VR 360° format: valence and excitement levels experienced in scene 6



### VR 360° format: valence and excitement levels experienced in scene 10



**Fig. 13** VR format (non-participant observation): valence and excitement levels experienced in scenes 6 and 10

## 4.4 Discussion

Through the analysis of the **suspense indicators** available (Table 1) in the short film *The Tell-Tale Heart*, it was confirmed that the film complied with the predominant characteristics of suspense: intention to create intense excitement and nervousness in the spectator; constant instauration of doubts about the fate of the characters and the outcome of events; suggestion of likelihood, which comes from false assumptions [17]. Considering the answers about the need for a second viewing of the short film to understand of the narrative, it was verified (Fig. 7) that both interactivity and **perceptual immersion** are factors of distraction, which may cause a decrease of the spectator's attention to the narrative. It was also found that the greater the immersion made possible by the format, the smaller is the focus of attention to the narrative of participants. The VR 360° format provides greater distraction in relation to the other formats (360° and 2D), since it is more immersive at the perceptual level. Participants tend to be distracted by the surrounding environment, not being able to follow the fullness of the narrative. Therefore, the VR 360° format causes less **immersion at the narrative level** compared to the other formats. An analysis of the data collected (Fig. 8) also showed that participants who saw the short film in VR 360° format felt perceptually more immersed than participants who watched it in 360° and 2D formats. By statistically comparing the three formats (Figs. 9 and 10), the results showed significant differences between the VR 360° format and the others, which may prove that participants perceptually felt more immersed in the VR 360° format, compared to the 360° and 2D formats. There were also significant differences observed in the **valence dimension** of scenes 6 and 10, between the VR 360° and 2D formats (Figs. 11 and 12). The more immersive format (VR 360°) has a strong impact on the created valence intensity, which applies in this case to a more intense aversion level. The results suggest that the increasing of perceptual immersion tends to trigger a greater visceral response in the spectator. The results of the non-participant observation (Fig. 13) were not conclusive. It was found that the pitch, yaw and roll movements were probably performed due to the participants' need to follow the action and not exactly because of the suspense indicators. So, as reported in the study by Li et al. [13], important factors such as content and context should be considered when observing the **rotational movements of the head of spectators**, requiring a deeper analysis in order to identify the influence of each independent variable.

**Side effects** experienced by participants, such as imbalance, physical discomfort, stress, sickness and headaches, can be a consequence of participants often having to turn to follow the action of the narrative, since it has been created in a way that allows participants to explore 360° visualization to the fullest.

## 5 Conclusions

The visualization of VR 360° AV content using a visualization system (HMD), carries a very complex navigation/interactivity dimension (as expected in a VR game) that makes it difficult for spectators to simultaneously capture stimuli from the narrative and the virtual space.

Through the confirmation of the presence of the suspense indicators it was possible to validate the short film as belonging to the suspense genre. The screenings (tests) of the short film to different groups of users in VR 360°, 360° and 2D formats made it possible to measure the immersion levels (perceptive and narrative) of the participants, depending on the format in which they viewed it. Given the data collected, there was an intensification of perceptual immersion in the most immersive technology (VR 360°) compared to other formats and a decrease in narrative immersion, a possible consequence of panoramic viewing. Therefore, narrative immersion and perceptual immersion showed an opposite relationship. The results also showed that more immersive visualization strategies (VR) influence the level of valence felt by participants. In the case of this short film, it intensified the aversion felt by the participants. In addition, the data collected from participants' emotional responses when viewing scenes 6 and 10 shows that most of the values in VR format are concentrated on the first and second quadrant implying a more extreme response of excitation when compared to the other less perceptual immersive formats.

Despite the small dimension of the study and the need for more complete validations, it highlights relevant clues on how to adapt the pre-production process (script, storyboard and technical script), production (minimum distance to the camera and lighting) and post-production (stitching of the scenes) in the creation of VR 360° content. These tracks can be used to support the creative process of AV content creators who want to produce more immersive content, bearing in mind the necessary adjustments depending on the technologies used and the AV content idealized.

Due to a limited (small) sample, shortcomings occurred in the statistical significance of tests performed on narrative immersion, valence and excitement. Therefore, as future work, it is intended to expand the tests by using a larger and more diversified sample, in order to extract more significant data from a statistical analysis.

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