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Optimizing Player and Viewer Amusement in Suspense Video Games

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ABSTRACT Broadcast video games need to provide amusement to both players and audience. To achieve this, one of the most consumed genres is suspense, due to the psychological effects it has on both roles. Suspense is typically achieved in video games by controlling the amount of delivered information about the location of the threat. However, previous research suggests that players need more frequent information to reach similar amusement than viewers, even at the cost of jeopardizing viewers' engagement. In order to obtain models that maximize amusement for both interactive and passive audiences, we conducted an experiment in which a group of subjects played a suspenseful video game while another group watched it remotely. The subjects were asked to report their perceived suspense and amusement, and the data were used to obtain regression models for two common strategies to evoke suspense in video games: by alerting when the threat is approaching and by random circumstantial indications about the location of the threat. The results suggest that the optimal level is reached through randomly providing the minimal amount of information that still allows players to counteract the threat. We reckon that these results can be applied to a broad narrative media, beyond interactive games.

INDEX TERMS Amusement, information management, interactive narrative, suspense, video game.

I. INTRODUCTION

Suspense is an influential strategy for evoking amusing emotions and story interest [1]. It has also been defined as a pleasant feeling experienced by humans before finding about the resolution of an interesting event [2], its intensity increasing along with the transcendence of the outcome [3]. Oliver (1993) supports that enjoyment is directly related to reactivity and suspense, and it has a clear influence on the audience's suspension of disbelief [4], [5]. These effects have been studied in different fields such as psychology [6], [7], narratology [8], [9], learning [10], and video games [11], among others.

Conceiving and managing suspense is a key question for storytelling, and it can be achieved by controlling the type and amount of information provided to the audience [12]. For instance, a well-known strategy to deliver suspense is providing the audience extra information that the characters do not know –"a bomb hidden under the table"–, which may be achieved through strategic camera shots, the use of flashbacks, or interspersing the main events with parallel stories [13]–[17]. Adapting the information flow is applicable not only to the classical narrative, but also to interactive storytelling or video games, where active participants are pushed to take decisions relying on their contextual knowledge. As with any linear story, interactive stories might take advantage of managing information to try to evoke different levels of suspense and amusement.

In the world of digital leisure, examples of suspenseful narratives are predominantly found in popular series of survival horror video games [18] –such as Resident Evil [19], Dead Space [20], Silent Hill [21], Fatal Frame [22],

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or Slender [23]–. Typically, they adopt the protagonist viewpoint during the whole plot, in either first or third person [24], which means that audience has the same visual and audible information as the main character. Similarly to horror/suspense movies[1], the experience involves exploration, traps, hiding, limited defense, persecution, escaping from labyrinthine, claustrophobic environments, and, ultimately, counteracting a deadly threat that can often be ''perceived before being seen'' [25]–[28]. Likewise, isolating and limiting the character's chance to escape are strategies used to increase the suspenseful feeling [29], [30]. All these factors evoke alienation and vulnerability experienced vicariously through the characters [31].

As previously mentioned, interactive scenarios in which the audience takes the role/viewpoint of the main character have a common particularity: the audience and the protagonist share the same information, so any information revealed to the player-controlled character is automatically revealed to the audience and vice-versa. It makes it impossible to provide additional, relevant information to the audience that is unknown to the protagonist, limiting the strategies to evoke suspense. In these cases, suspense must be centered on the user's experience and main characters' awareness of dangers, as well as the choices made by the user that can drive the events' development [32], such as deciding whether to face or escape from a threatening situation.

Indeed, suspenseful situations can simply arise from the proximity of a lethal danger [16], [33]. The tension emerges from the proximity between the character and the threat, being at its peak when it seems the encounter is inevitable [34]; conversely, if the threat is too far away, the emotion is hardly experienced [14]. In order to provide information that evokes the feeling of closeness, there are several possible channels such as visual images, text, music, speech and environmental effects [35]. According to Smith (1999) [36], fear makes us notice dark shadows, mysterious noises and sudden movements, and thus provides more potentially frightening cues that increase the emotional response without the need of changing the viewpoint. Overall, sound communicates players that a new situation is coming up even before they can see it; it reveals from which direction it will be coming, and whether that situation is dangerous, neutral, or pleasant [37].

In suspenseful video games, to emit or to change sounds, or –to a lesser extent– to visually modify the environment, are the strategies typically used to warn of the proximity of danger, implemented as following [38]–[40]. As a general rule, the approximation of a threat is what triggers the perceptible variations, which are maintained until the encounter is resolved [37], [41]–[43] –examples include Friday the 13th: the game [44], Silent Hill [21], Alan Wake [45], Amnesia series [46], or Alien: Isolation [47]–. On the other hand, a minor number of video games base their technique on random circumstantial warnings, which occasionally indicate the approximate location of the threat while helping the player understand the environment [48], [49] –as seen in Pacify [50], Dead by Daylight [51], Five Nights at Freddy's [52], or The Last of Us [53]–.

Regardless of the chosen strategy, finding *the right moment* –either distance, circumstance, or probability– to provide the information is essential to succeed in evoking the expected emotional response. This is particularly important when the potential audience members can be both players and viewers. Although in interactive systems the amount of uncertainty related to the outcome produces suspense in the same way as in the classic narrative, interactive and non-interactive suspenseful scenarios need to provide a different amount of information to evoke amusement [54], [55]. More specifically, in video games players feel bored when too much information makes the challenge too easy, but they also feel stressed when the lack of information makes it too hard [56]. By contrast, the amusement reported by passive audiences is higher when they feel a high level of suspense evoked by a lack of information, even though this lack of information can frustrate active players [55]. This might result in a challenge for story designers that target both groups simultaneously.

Examples of how passive audiences consume interactive narratives can be found in YouTube –and other streaming platforms– [57], where several of the most followed *youtubers* have reached their fame often by playing horror and suspense video games, a genre that has a constant acceptance due to psychological effects it has on both players and viewers [18], [58], [59]. In any case, the genre is not the only criterion: due to the vast amount of alternative choices, the game must be amusing enough to play. Similarly, the engagement achieved by the streaming platform professionals is related to the feedback from their audience. If the game is boring for the viewers, a low rating will be reported and the video game will be dropped by the streamer soon after [60].

There are other relevant scenarios on how passive audiences consume partially or totally interactive narratives, including interactive cinema [61]–[63], emerging serials [64] –as the Sweden SVT's thriller *The Truth about Marika* [65], UK Channel 4's *Dubplate Drama* [66], *Mosaic from Steven Soderbergh* [67], and, more recently, *Black Mirror: Bandersnatch* [68]–, also real performances in theatres such as the Swiss / English production *Late Shift* [69], or the Disneyland Paris *Stitch Live!* interactive attraction.

To sum up what has been introduced so far, the strategies for evoking suspense in video games with a narrative focalized on a main protagonist involve the use of cognitive signals to warn about the threat's location or imminent arrival. Relying on this mechanic, the signals are emitted either when the threat is about to appear –and, in the case of sounds, they are maintained until the resolution of the encounter– or based on occasional random circumstantial triggers. If this is *how* evoking suspense, *when* to effectively do it depends on the audience is whether active or passive. A strategic low amount

[1] Such as Alien (1979), Eden Lake (2008), House of Haunted Hill (1999), Saw (2004), The Birds (1963), The Mist (2007), or The Silent of the Lambs (1991), among many other films.

of warnings may increase amusement for a passive audience, but players will be frustrated as they won't have enough information to make a decision in time. On the other hand, the more warnings, the less suspense and, hence, the less passive audience-evoked amusement. Finally, if the signal is sent when the threat is still too far –leaving way too much time for the character to escape–, players might feel that the game is too easy to engage them.

This implies that, to achieve an optimized amusement level, disclosing the right amount of information is required, even at the cost of jeopardizing the balance of suspense delivery and potentially spoiling the audience's experience. The information amount must be enough to allow players to decide and behave in an informed –"non-blind"– manner, but not too much for the video game to become hardly a challenge for them, nor compromise the passive audience's amusement.

With the aim to analyze the best approach that optimizes amusement for both players and viewers in suspenseful video games, this paper presents a study of the effects of the two reported strategies –either randomly sending warnings, or sending warnings when the threat is within a specific distance–. Two experimental studies were conducted. In the first study, $N = 30$ participants experienced interactive or non-interactive versions of a suspenseful video game with a protagonist viewpoint. Using the obtained results, two computational models based on the two different implemented strategies to optimize amusement through suspense were obtained. After updating some environmental and design features, a second study involving $N = 28$ different participants was conducted in order to validate these models in new gameplay conditions.

II. STUDY 1

The first study was carried out in order to observe the effect of information management on amusement for interactive and non-interactive audiences when playing and viewing a suspenseful video game.

A. METHOD

1) PARTICIPANTS

The subject pool was composed by fifty-eight volunteer undergraduate students ($N = 58$), 36 males (62.07%) and 22 females (37.93%), from the University of Cádiz, with ages ranging from 17 to 34 years ($mean = 21.28$, $stdev = 4.34$). Thirty of them ($N_c = 30$) were chosen to participate in the first experiment. After computing a model from the data, the other twenty-eight ($N_t = 28$) were assigned to an experiment meant to test it –see Section IV–. The participants were distributed in groups with balanced age and gender –Table 1–. Two-tailed t-test power analysis ensured a power higher than.80 at the significance level of.05.

TABLE 1. Participants' distribution.

gender	N	percent	$mean_{age}$	SD_{age}
global (models and test)	58		21.27	4.34
male	36	62.07%	21.22	4.22
female	22	37.93%	22.52	5.36
computing model	30		21.93	4.94
male	18	60.00%	21.39	4.42
female	12	40.00%	22.75	5.75
testing	28		20.70	3.52
male	18	64.29%	20.35	3.20
female	10	35.71%	21.30	4.14

2) MATERIALS

An interactive computer video game displaying a 3D environment was used. In the story, the main character –the *victim*– must try to escape from a cave while chased by a *threat*. The *victim* has a lantern that illuminates the equivalent to three tiles around. The *threat* is visually represented as a shadow with human-like size and proportions. Likewise, the *victim*'s physical appearance is concealed from the player by using a first-person perspective, avoiding an affective, emphatic additional response from the audience [70]–[72].

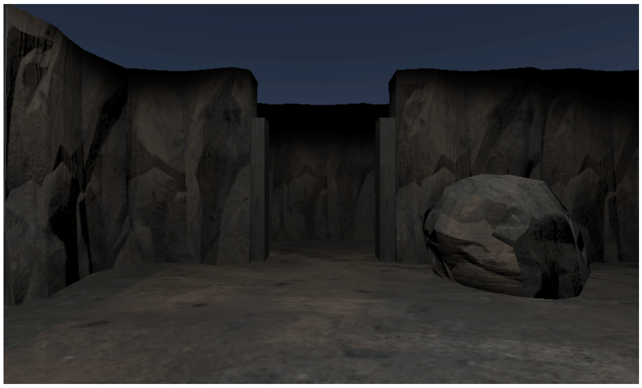

FIGURE 1. 3D virtual environment used in the experiment.

To escape the cave, the *victim* needs to find a key, then locate the exit door, and finally escape through it. The key is randomly hidden under one of the several stones placed throughout the scenery. No other decoration is included in the environment. The scenario is depicted in Figure 1.

The gameplay is turn based and the *victim* moves first. Initially, the *victim* is located in the center of the cave, and the *threat* is randomly placed in a location initially unknown to the players and viewers. Each turn, the *player* must move the character with the keyboard arrows. The left and right arrow keys are used to rotate –the character can face north, south, east and west–, while the up and down arrow keys are used to go forward and backwards, respectively. The space bar can be used next to a stone to search under it –potentially finding the key–. The *victim* moves four tiles on each turn, while the *threat* can move up to five. This advantage for the *threat* avoids endless or very long matches and forces the *victim* to try to avoid the *threat* –otherwise the character would not be able to escape–.

The *threat* is controlled by an AI. It systematically explores each one of the rooms of the cave following the random order in which they were generated, reaching the center of each one before switching to the next one. The AI uses the shortest path according to the path finding A* algorithm. The exploration goes on until the *victim* is within the sight range of the *threat* –less than four tiles away, with the *threat* facing the *victim*–, and with no walls between them.

If the *threat* detects the *victim*, it closes in the *victim* until it reaches it or until the *victim* gets out of its sight. If this happens, the *threat* switches back to room exploring until it finds the *victim* again. If the *threat* reaches the *victim*, the *victim* is killed, and the game is over.

Each time the *threat* moves, there is a chance of it emitting a footstep noise that reveals its position to the audience –set randomly at the beginning of each game–. The volume of the noise is proportional to the distance between the *threat* and the *victim*. The direction from which the sounds are coming from is represented by a directional arrow.

3) PROCEDURE

The experiment was run over the course of two sessions in the same laboratory.

In the first session, half of the participants ($N = 15$) were randomly assigned the *player* role while the other fifteen were assigned the *viewer* role. The screen of the *players* was shared through Adobe Connect so that the corresponding *viewers* could watch the game unfold in real time. The viewport, tile size and other rendering aspects were identical between the systems: all of them had the same specifications and configuration. After this first session, subjects exchanged heir roles – *players* and *viewers*– before repeating the same experimental procedure in the second session.

During each session, *players* played the *victim* role four times, for a total of 120 different complete matches –sixty per session–. For every game match, a different gameplay experience was procedurally generated by modifying two parameters: environment area size and distribution, and the probability for the *threat* to emit a footstep sound. In order to check the effect of the environment area size, the cave had three possible sizes; 16x16 units (256 u^2), 24x24 units (576u^2) and 32x32 units (1024 u^2). In gameplay terms, each unit u is a tile that can hold the *threat* or the *victim*. Bigger and smaller area sizes where discarded due to potential balance issues, making the escape impossible or at least much longer. Regarding the probability of the *threat* emitting a footstep sound, it ranged from 10% –statistically one move out of ten– to 100% –every turn–, with increments of 10%. This probability was randomly set at the beginning of each match. Considering both variables –chance of footstep sound and environment area–, all possible combinations were generated.

The environment was procedurally generated by using an implementation of the Jamis Buck's Dungeon Generator algorithm [73], [74], expanded to cover the inclusion of the rocks and the exit door. Figure 2 shows an automatically generated cave map of 256u^2.

In order for the participants to familiarize themselves with the user experience, every *player* and *viewer* could interact freely with a *sandbox* version of the environment for five

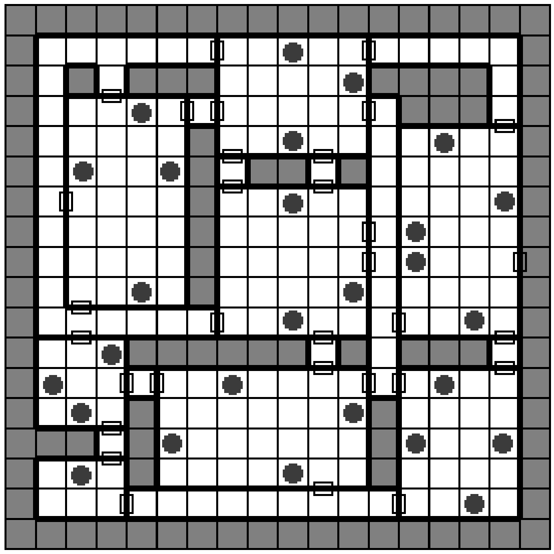

FIGURE 2. Example of an automatically generated map of the cave.

minutes, along with a description to the characters and controls. After that, each *player* and, indirectly, every *viewer* respectively played or watched four permutations of environment and footstep sound chance in random order. After each *threat* turn and before the *player* decided the *victim*'s next move, the participants had to fill a survey consisting of two questions:

- *How much suspense does the situation generate?*
- *How much amusement are you experiencing?*

The replies to both questions were recorded in a 4-Likert scale with the following values: *none*, *low*, *high* and *very high*, corresponding to values ranging from 1 to 4, respectively. This limits the cognitive bias of trying to adjust the perceived emotions to small ranges. Also, the perception of an implicit neutral option is avoided, forcing the respondent to commit to a position.

4) MEASURES

- **Suspense**: As mentioned above, participants were asked to rate how much suspense they were feeling in each turn, using a 4-point scale. Previous studies of suspense have proposed or used similar item measures [54], [75], [76].
- **Amusement**: The survey included an item that asked participants to indicate how amusing the game was, using a 4-point scale. Previous studies of behavior and motivation have studied amusement using similar item measures [77]–[79].

B. RESULTS

Results point towards a relation between *suspense* and *amusement*. Particularly, a strong uphill linear correlation for *viewers* ($r = 0.735$, $p < 0.000$) and a moderate quadratic correlation for *players* ($R^2 = 0.411$, $p < 0.000$) were observed. Moreover, t-test and F-test were used to analyze differences between groups. In this regard, no differences

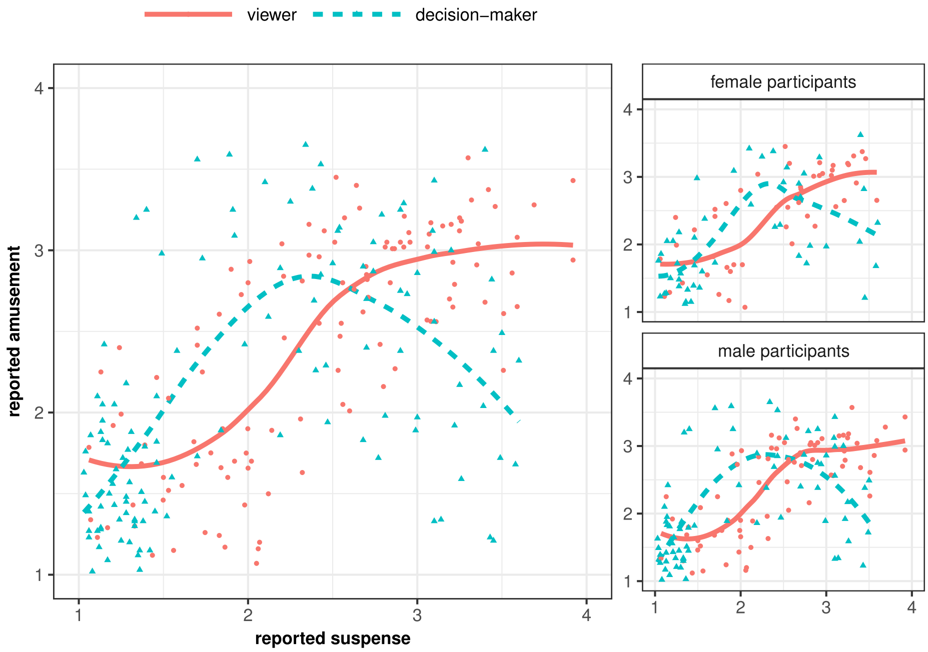

FIGURE 3. Comparison of *suspense* and *amusement*.

TABLE 2. Influencing variables (for every statistical).

influencer		viewer	decision-maker
	suspense		
information	$F_{9,120} =$	229.590 ***	437.604 ***
area size	$F_{2,120} =$	1.997	26.699 ***
(both)	$F_{26,120} =$	1.700	10.831 **
	amusement		
information	$F_{9,120} =$	253.112 ***	34.937 ***
area size	$F_{2,120} =$	3.232	6.682 *
(both)	$F_{26,120} =$	0.451	5.993 *

***: p-value < 0.001, **: p-value < 0.01, *: p-value < 0.05

TABLE 3. Correlations between audience reported values and difference of distance to the *threat*.

	viewer	decision-maker
suspense	0.456 ***	0.549 ***
amusement	0.404 **	0.344 *

***: p-value < 0.001, **: p-value < 0.01, *: p-value < 0.05

were found globally related to participant gender in *suspense* ($t = -0.315, p = 0.753, F - test = 0.940, p = 0.751$) nor *amusement* ($t = -0.094, p = 0.926, F - test = 0.953, p = 0.808$). Figure 3 illustrates these dependencies, which are consistent with the findings of the previous studies [55].

Two metrics were contrasted with the role types: a) probability of revealing threat positional *information* –through the footstep sound–; and b) environment overall *area size*. A multivariate analysis of variance (MANOVA) was conducted to determine whether there were any dependencies between each of these variables and *suspense* / *amusement*. The results show that both metrics –*information* and *area size*– seem to be correlated with both *suspense* and *amusement*, as seen in Table 2.

First, a high correlation between *information* and *suspense* was found for both roles ($r = -0.876, p < 0.000$ for *viewers*, and $r = -0.825, p < 0.000$ for *players*). Again, the higher the amount of disclosed information, the lower the reported *suspense*. Second, the reported *amusement* is also strongly correlated with the probability of sending information for *viewers* ($r = -0.829, p < 0.000$), not linearly for *players* ($R^2 = 0.743, p < 0.000$). Figure 4 illustrates this evolution of *suspense* and *amusement* regarding the probability of receiving information.

As seen in Table 2, with respect to the second influencing factor –environment *area size*–, MANOVA results point towards its effect on the *viewers* being minor and not significant; however, it affects *suspense* and *amusement* for *players*.

Figure 5 shows the effect of *information* and *area size* respectively in *viewers* and *players*.

Additionally and as shown in Table 3, when contrasting the distance variation between *victim* and *threat* –computed as the percentage mean of sums of the absolute values of distance difference with the mean of the distance between *threat* and *victim* during each game (100%)– with reported values, weak to moderate correlations are obtained for *suspense* and *amusement* for both roles. Figure 6 illustrates this tendency.

The results support a general inverse correlation between disclosed information and *suspense*, while reported *amusement* depends on the role of the audience and reveals differences between the impact of suspense in interactive and non-interactive gameplays.

III. COMPUTING TWO MODELS FOR OPTIMIZING AMUSEMENT

Based on the information gathered in the previous section, two regression models have been computed. According to

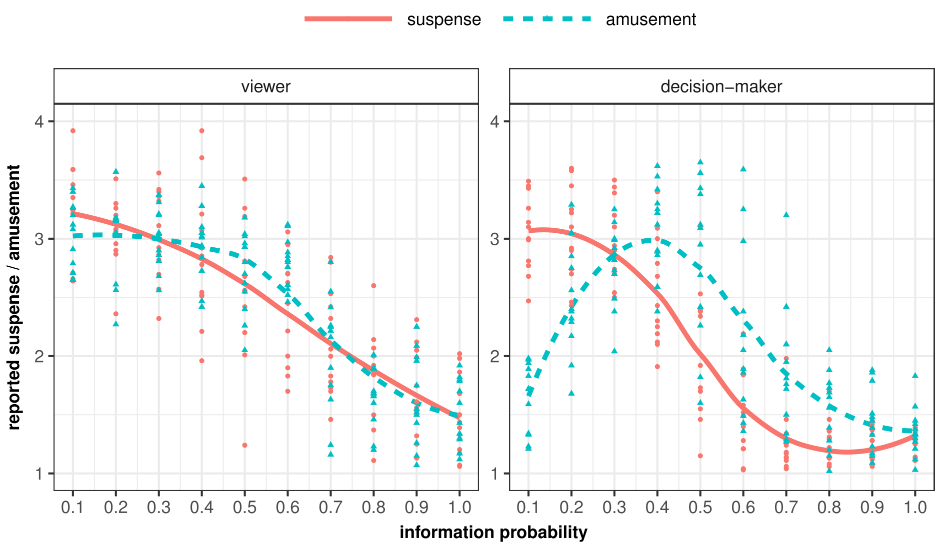

FIGURE 4. Evolution of *suspense* and *amusement* by information probability.

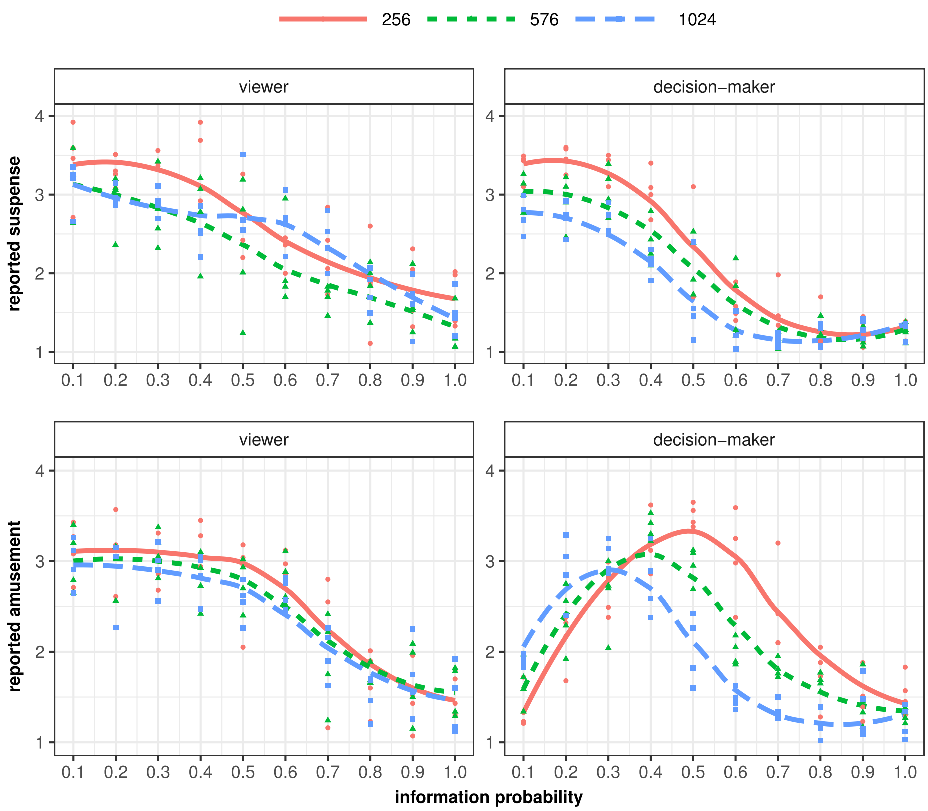

FIGURE 5. Evolution of *suspense* and *amusement* by information probability and environment size (up, in u^2).

the described strategies to evoke suspense, the first model is based on warning the audience by *threat*'s proximity –in terms of mean distance–, and the second model is based on the probability of revealing information about the *threat*'s location. For the two models, the variables have been estimated in order to optimize amusement for both active and passive audience.

To compute the models, the formulas of *players* and *viewers* were estimated independently. Otherwise, the models would not adjust adequately to an optimal *suspense* nor *amusement*, because the average of the reported data differs significantly for both roles. Once the equations were independently gathered, the values that maximizes the sum of both were obtained, as described below.

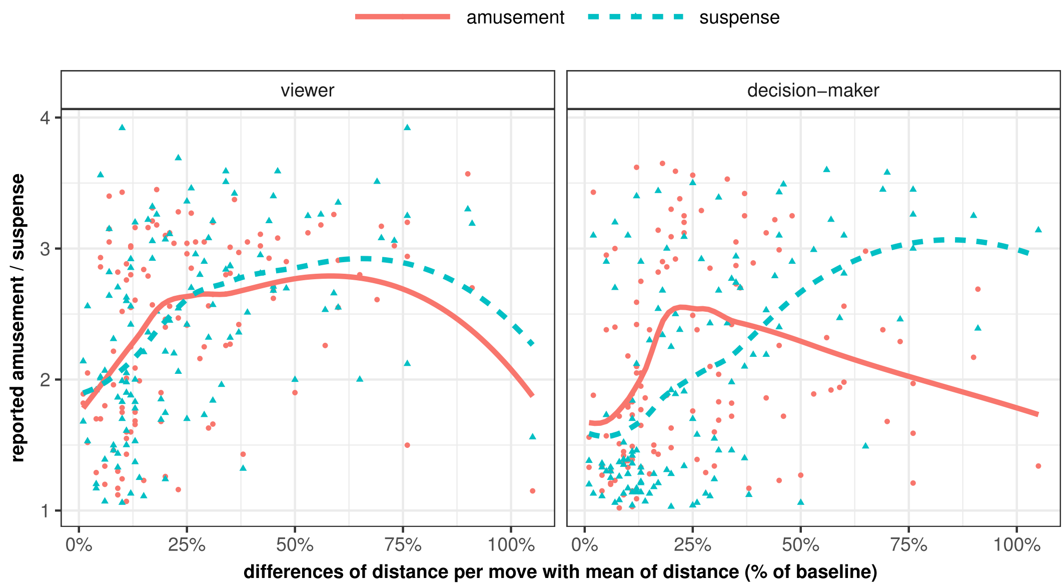

FIGURE 6. Relation between audience reported *amusement* and *suspense*, and difference of distance to the *threat*.

A. MODEL BASED ON PROBABILITY OF INFORMATION

A multiple regression analysis was conducted for *suspense* (s) and *amusement* (a) mean ratings as the dependent factors, while probability of communicating *information* (q) to the audience and the virtual environment *area size* (u^2) were used as independent factors. The resulting models s_p –*suspense* for *players*– and a_p –*amusement* for *players*– were compared to determine the best fit.

Equations 1 and 2, respectively show the *player* models obtained for *suspense* ($R = 0.933$, $F_{4,119} = 199.60$, $p < .000$, $RMSE = 0.301$) and *amusement* ($R = 0.820$, $F_{4,119} = 62.20$, $p < .000$, $RMSE = 0.430$).

$$s_p(q, u^2) = 11.010q^3 - 16.337q^2 + 3.863q - 0.027|\sqrt{u^2}| + 3.510 \quad (1)$$

$$a_p(q, u^2) = 17.758q^3 - 34.369q^2 + 17.855q - 0.024|\sqrt{u^2}| + 0.731 \quad (2)$$

The values of q that maximize and minimize the *amusement* are 0.360 and 0.930, respectively, which reach a maximum and minimum *amusement* of $3.530 - 0.024|\sqrt{u^2}|$, and $1.871 - 0.024|\sqrt{u^2}|$, respectively. It is achieved when *suspense* is $3.295 - 0.027|\sqrt{u^2}|$ and $1.828 - 0.027|\sqrt{u^2}|$, respectively. This suggests that the maximum *amusement* for *players* is achieved by revealing the *threat*'s position approximately every three moves (36.0%), while the minimum *amusement* value is achieved when the *threat*'s location is revealed nearly every move (93.0%).

Likewise, *viewers*' models for *suspense* ($r = -.813$, $F_{1,119} = 229.50$, $p < .000$, $RMSE = 0.427$) and *amusement* ($R = 0.862$, $F_{3,119} = 115.5$, $p < .000$, $RMSE = 0.350$) –s_v and a_v, respectively– are shown in Equation 3 and Equation 4.

$$s_v(q) = -2.057q + 3.555 \quad (3)$$

$$a_v(q) = 5.889q^3 - 11.526q^2 + 4.545q + 2.604 \quad (4)$$

Managing the disclosed *threat* information does not depend on the environment *area size*, therefore the optimal probability of *information* is the only one to be calculated in order to maximize *amusement* for both roles.

This time, the values of q that maximize and minimize the *amusement* are 0.242 and 1.062, respectively[2], which reach a maximum and minimum *amusement* of 3.112, and 1.484, respectively. It is achieved when *suspense* is 3.057 and 1.370, respectively.

Globally, the values of q that maximize and minimize the sum of a_p and a_v, and, hence, *amusement* for both *players* and *viewers*, are 0.326 and 0.970, respectively. These values are similar to the maximum and minimum values for *players*' *amusement*by itself.

By assigning q the maximizing value of 0.326 in the formulas a_p and a_v evokes *viewers* a constant *amusement* of $a_v = 3.065$, in the high range of our 4-Likert scale, and $a_p = 3.512 - 0.024|\sqrt{u^2}|$ for *players*.

Similarly, taking Equations 1 and 3 as reference, the optimal probability of *information* is expected to result in *players*' *suspense* level of $s_p = 3.415 - 0.027|\sqrt{u^2}|$, and a *viewers*' *suspense* level of $s_v = 2.884$.

B. MODEL BASED ON MEAN DISTANCE TO THE THREAT

Building upon the resulting experimental reported values –Figure 6–, the next model considers the distance between *victim* and *threat* as a measure of expected *suspense* and *amusement*, notifying the audience when the *threat* is within a certain distance. This way, any AI *threat* behavior may be enhanced with a simple "localization warnings" computed in real time and directed to the audience.

[2]The model residual standard error must be taken in consideration.

Equations 5 and 6 show the resulting model for the *player*:

$$s_p(\Phi) = -1.325\Phi^2 + 3.208\Phi + 1.322 \quad (5)$$
$$a_p(\Phi) = -3.936\Phi^2 + 3.694\Phi + 1.600 \quad (6)$$

where Φ is the distance percent based on the mean distance between *victim* and *threat* ($\bar{d}$). The real distance ($\triangle d$) may be obtained as seen in Equation 7.

$$\triangle d = \bar{d} \cdot \Phi \quad (7)$$

Equations 5 and 6 correlations with collected data are moderate to low (respectively, $R = 0.549$, $F_{2,119} = 26.71$, $p < .000$, $RMSE = 0.698$, and $R = 0.344$, $F_{1,119} = 7.72$, $p < .000$, $RMSE = 0.7122$).

According to the model, the value of Φ that maximizes *amusement* is 0.469, resulting in an *amusement* of 2.467. It is achieved when *suspense* is 2.53. This suggests that the maximum *amusement* for *players* is achieved by revealing the *threat*'s position when the *threat* approaches from a distance less than the half of the map length.

Regarding *viewers*, Equations 8 and 9 compute the relations.

$$s_v(\Phi) = -3.265\Phi^2 + 4.037\Phi + 1.735 \quad (8)$$
$$a_v(\Phi) = -3.568\Phi^2 + 3.869\Phi + 1.820 \quad (9)$$

In this case, the correlations may be considered equally moderate to low for *suspense* ($R = 0.471$, $F_{2,119} = 17.99$, $p < .000$, $RMSE = 0.644$) and *amusement* ($R = 0.413$, $F_{2,119} = 13.22$, $p < .000$, $RMSE = 0.628$). Additionally and as expected, the distance $\bar{d}$ is highly correlated to the environment *area size* ($r = 0.709$, $p < 0.000$).

This time, the value of Φ that maximizes *amusement* is 0.542, which results in an *amusement* of 2.869. It is achieved when *suspense* is 2.964.

The resulting model is represented in Equation 10. It allows to compute the expected mean distance between *victim* and *threat* in every environment.

$$\bar{d} = \delta(u^2) = 1.066|\sqrt{u^2}| - 5.879 \quad (10)$$

Globally, the distance Φ that maximizes *player* and *viewer amusement* sum functions is 0.501 –which is similar to the maximum value of the models separately computed by role–, being $\triangle d = 0.501 \cdot (-1.066|\sqrt{u^2}| - 5.879)$ –see Equations 7 and 10–. Likewise, a similar calculation to obtain maximum *suspense* results in $\Phi = 0.743$, where $\triangle d = 0.743 \cdot (-1.066|\sqrt{u^2}| - 5.879)$.

IV. STUDY 2

Once the previously described models were computed, a new experiment was conducted to test them in a modified version of the original environment. A third-person camera was used. Also, the *threat* proximity sound, the environment lighting, and the extension of area size were changed.

A. METHOD

1) PARTICIPANTS

Twenty-eight subjects from the University of Cádiz ($N_t = 28$), 18 males (64.29%) and 10 females (35.71%), with ages ranging from 17 to 30 years ($mean = 20.70$, $stdev = 3.52$), took part in the experiment. The conditions were identical to the ones already detailed in Section II. Each participant was randomly assigned to Group *M1*, meant for testing the first model –based on probability of *information*– or to Group *M2*, meant for testing the second model –based on distance to the *threat*–. Each one of the groups was composed of nine males and five females, with no significant age differences ($Z = 0.861$, $p = 0.353$).

2) MATERIALS

The experimental interactive environment followed the same rules than the one used in the previous experiment. However, the environment *area size* was not necessarily perfect square-shaped. The weight and height were randomly calculated, adding $40u$ to the previous range ($16u$, $24u$ and $32u$). This allowed to expand the range from three to sixteen possible area sizes ($\mathsf{a} \times \mathsf{b}, \mathsf{a} \in \mathsf{S}, \mathsf{b} \in \mathsf{S}, \mathsf{S} = [16u, 24u, 32u, 40u]$).

Also, while color management is a suitable method to elicit specific emotional responses [80], [81], the cave generator was modified to include two environmental color themes. Therefore, three possible environmental colors could be randomly generated in the experimental prototype: neutral/control –as before–, red (`#FF0000`) –high arousal, horror and excitement [80], [82]– and light blue (`#00FFFF`) –cold and calm [83].

Additionally, the new footstep sound selected was a 3.78 seconds long clip, the snarl used by the infected antagonists from the film *28 Days Later* [84], directly extracted from the movie –from 12'40'' to 12'43''–. The generated gameplay scenarios could use either the original footsteps or this new sound, but not both in the same gameplay session.

A third-person top-down view camera was used in this gameplay. To avoid the influence of the main character's physical features such as gender, the avatar model was designed to hide this information from the audience, showing only a head covered with a mining helmet, and neutral shoulders, arms and legs.

In order to test the two computed models, each group of participants –*M1* and *M2*– confronted a different *threat* AI implementing a specific strategy: the *threat* of Group *M1* emitted a warning sound –modulated with the *threat*'s distance and direction– depending on a specified probability, while the *threat* of Group *M2* emitted the sound when it surpassed a certain distance to the *victim*. These behaviors are detailed below.

3) PROCEDURE

The experiment was conducted over the course of two sessions in one single laboratory. In the first one, half of

TABLE 4. Comparison / correlations between measured and expected reports in first model.

	decision-makers		viewers	
factor	**suspense**	**amusement**	**suspense**	**amusement**
experimental group				
correlation	0.904 ***	0.806 ***		
t-test	-0.208	-1.767	-4.976 ***	-2.520 *
reported mean (stdev)	2.659 (0.170)	3.137 (0.582)	2.612 (0.309)	2.903 (0.333)
expected mean (stdev)	2.668 (0.165)	3.231 (0.103)	2.889 (0.000)	3.255 (0.000)
control group				
correlation	0.749 ***	0.704 ***	0.774 ***	0.805 ***
t-test	0.221	-2.191 *	-2.384 *	-0.676
reported mean (stdev)	1.824 (0.633)	2.040 (0.644)	1.921 (0.772)	2.253 (0.777)
expected mean (stdev)	1.785 (0.672)	2.416 (0.641)	2.351 (0.559)	2.377 (0.578)
(global)				
correlation	0.869 ***	0.821 ***	0.797 ***	0.807 ***
t-test	0.121	-1.835	-3.261**	-1.226
reported mean (stdev)	2.241 (0.623)	2.588 (0.741)	2.261 (0.676)	2.578 (0.687)
expected mean (stdev)	2.227 (0.658)	2.824 (0.609)	2.620 (0.476)	2.719 (0.533)

***: p-value < 0.001, **: p-value < 0.01, *: p-value < 0.05

the participants ($N = 14$) were randomly assigned the *player* role. The other fourteen were assigned the *viewer* role and were randomly paired with a *player* in their respective group. The screen of the *players* was shared through Adobe Connect so that the corresponding *viewer* could see the gameplay session in real time. The viewport, tile size and other rendering aspects were identical across both setups: all of them had the same specifications and the same configuration than in the previous experiment. After this first session, the roles of *players* and *viewers* were switched before the second –and last– session began.

During each session, the *players* played the role of *victim* four times, counting a total of 72 different complete games per group. The environment *area size* was randomly generated for each game session, the weight and height ranged independently from $16u$ to $40u$.

For each Group *M1* and *M2*, participants were randomly divided between experimental *e* and control *c* subgroups, each including the same participants. For Group *M1*, the probability of disclosing *information* for the experimental subgroup (*M1e*) was set to 0.326 in all the game matches –that is the value that maximizes *amusement* for both roles, as obtained in Section III.A–; on the other hand, the probability of disclosing *information* in the control subgroup (*M1c*) was randomly generated at the beginning of each game. The experimental subgroup for Group *M2* participants (*M2e*) heard the sound after the last step of the turn in which the *threat* achieved the optimal distance for *amusement* obtained in Section III.B, while distance from which the sound was emitted is obtained randomly at the beginning of each game for control subgroup (*M2c*).

Similarly to the previous experiment, the participants were allowed to get familiarized with the system for five minutes before the first experimental session. The experiment started after these five minutes. After each *threat* turn and before the *player* decided the *victim*'s next move, the participants had to answer the same questions than in the previous experiment –see Section II–.

4) MEASURES

- **Suspense**: Participants were asked to rate how much suspense they were feeling in each turn, using a 4-point scale [54], [75], [76].
- **Amusement**: The survey included an item that asked participants to indicate how amusing the game was, using a 4-point scale [77]–[79].

B. RESULTS OF MODEL BASED ON PROBABILITY OF INFORMATION

Results of the model based on probability of *information* show high correlations between reported and expected *suspense* and *amusement* for both *players* and *viewers*, as shown in Table 4, and also illustrated in the graphs in Figure 7.

Overall, the model is highly correlated with *suspense* ($r = 0.780$, $p < 0.000$) and *amusement* ($r = 0.812$, $p < 0.000$) for the interactive audience, specifically up to 90% for the experimental group regarding *suspense* for *players*, resulting in a better fit than for *viewers*. This better fit for *players* is observable in terms of contrast of means too, where the results for *viewers* evidence more significant differences between expected and reported values of *suspense* ($t = -4.976$, $p < 0.001$) and *amusement* ($t = -2.520$, $p < 0.05$) for the experimental group, and *suspense* for the control group ($t = -2.384, p < 0.05$). In comparison, results for *players* only show this divergence for *amusement* in the control group ($t = -2.191, p < 0.05$).

Regarding the involved variables, again, the probability of *information* reveals a high correlation with *suspense* ($r = -0.807$, $p < 0.000$) and *amusement* ($r = -0.701$, $p < 0.000$). MANOVA analysis does not present any significant difference on the effect of *information* due to the influence of the audience active/passive role in *suspense* ($F_{1,111} = 0.168$, $p = 0.682$) nor in *amusement* ($F_{1,111} = 0.499, p = 0.481$).

Nevertheless, while the impact of the role by itself neither is significantly correlated with *suspense* ($F_{1,111} = 0.067$, $p = 0.796$) nor *amusement* ($F_{1,111} = 0.015$, $p = 0.904$),

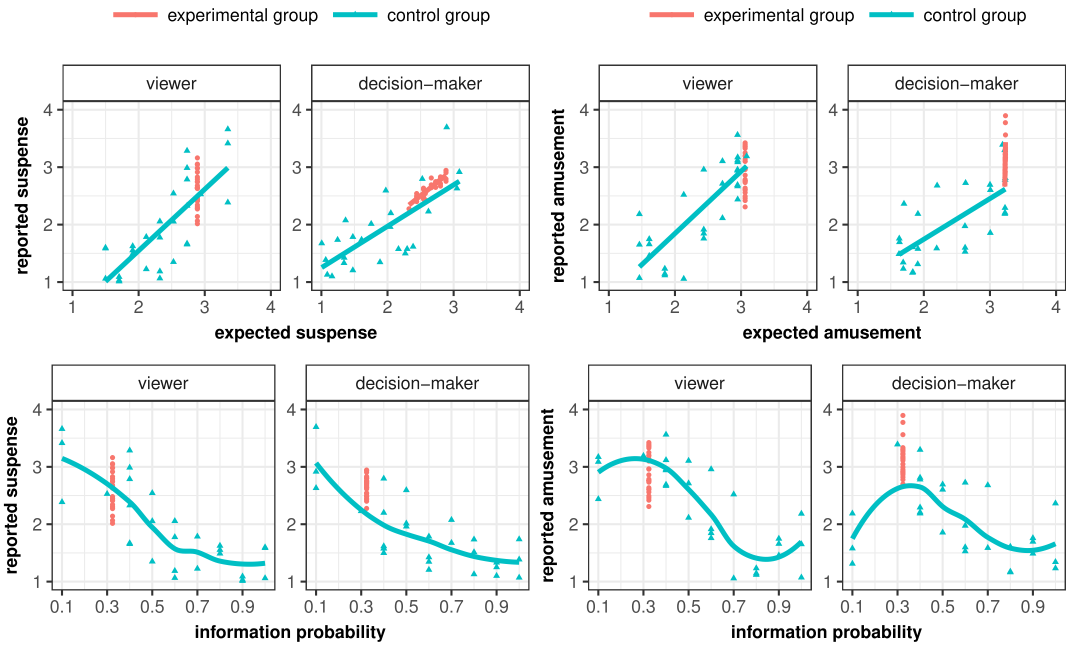

FIGURE 7. Comparison and evolution of reported / expected values in first model.

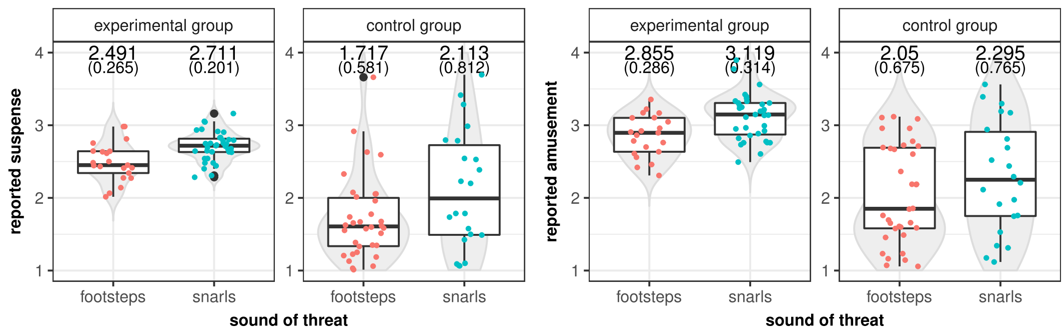

FIGURE 8. Effect of sound in suspense/amusement (on top, means and standard deviations) in first model.

in conjunction with the group it seems to influence *amusement* ($F_{3,111} = 13.53, p = 0.001$).

Regarding the environment *area size* for both groups, it behaves as predicted for *players*, impacting *suspense* ($F_{9,55} = 9.719, p < 0.000$) and *amusement* ($F_{9,55} = 10.677$, $p < 0.000$), but also influencing *viewers* reports when paired with the probability of *information* in *suspense* ($F_{17,55} = 3.741, p < 0.01$) and *amusement* ($F_{17,55} = 2.760, p < 0.05$).

Moreover, the study of environmental lighting does not reveal any significant impact. For *suspense*, results of ANOVA report a small influence in the limit but out of significance ($F_{2,109} = 2.858, p = 0.062$), while *amusement* is clearly not significant ($F_{2,109} = 0.465, p = 0.630$). Similar results are found when analyzing the effects on groups under similar conditions.

The effects of the emitted sounds data are illustrated in Figure 8. A significant global influence in *suspense* was found ($F_{1,111} = 16.63, p < 0.000$). However, for *amusement* this impact is significant only in the experimental group ($F_{1,55} = 9.891, p < 0.001$), not in the control group ($F_{1,55} = 1.590, p = 0.213$). A deeper scrutiny on this effect in the control group suggests an interesting observation: the sound of a nearby *threat* influences significantly the *amusement* when the overall reported *amusement* is also high. Specifically, the sound of the nearby *threat* reveals a significant impact when the reported *amusement* is higher than 2.6 ($F_{1,19} = 7.171, p < 0.0154$), rendering insignificant below this value ($F_{1,34} = 1.946, p < 0.172$). It is also backed by U-test results, as illustrated in Figure 9, and it will be discussed further.

Finally, demography seems to have no significant effect ($p > 0.05$ for participant gender and age).

C. RESULTS OF MODEL BASED ON MEAN DISTANCE TO THE THREAT

The second model also presents a better response from the experimental group in either reported *suspense* and

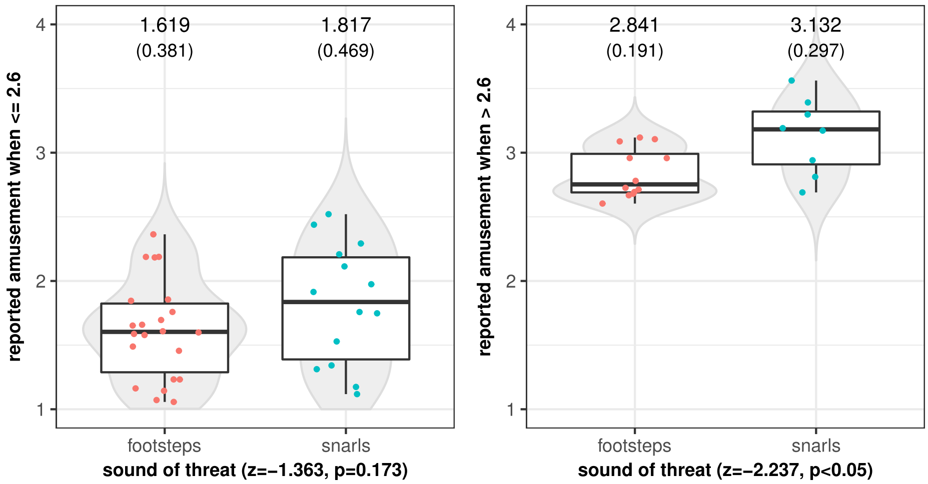

FIGURE 9. Effect of sound in amusement for control group (on top, means and standard deviations) in first model.

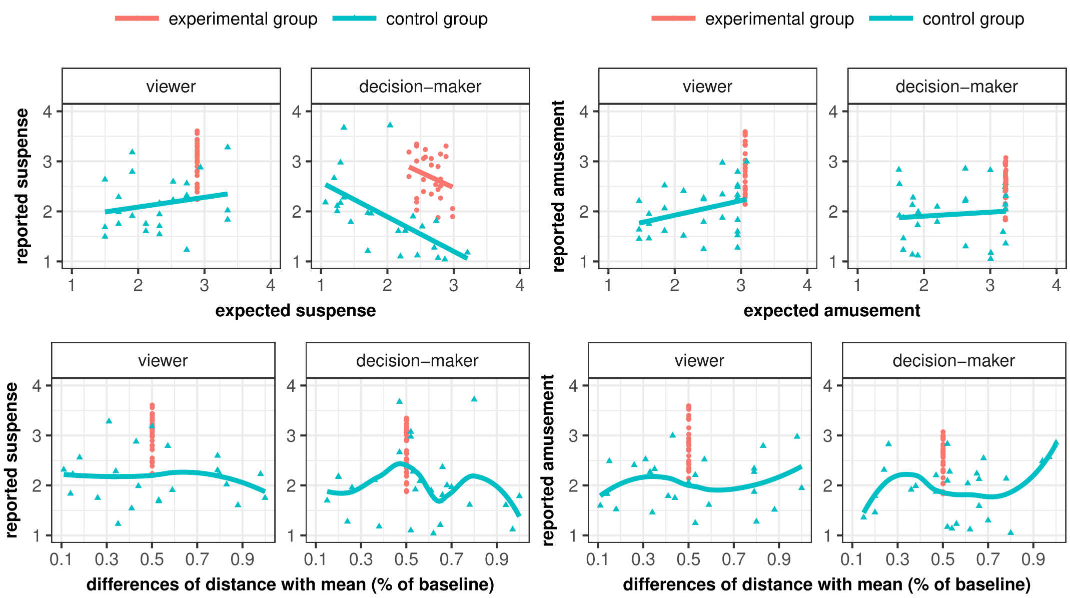

FIGURE 10. Comparison and evolution of reported/expected values in the second model.

amusement compared to the control group, as seen in the lower row of Figure 10 and Table 5.

However, the predictions of this model seem only reliable in terms of *suspense* for *players* ($r = -0.644$, $p < 0.001$) and, to a lower extent, in terms of *amusement* for *viewers* ($r = 0.352$, $p < 0.01$); predicted *amusement* for *players* and *suspense* for *viewers* do not present any significant correlation.

Regarding the implied variables, the impact of the subject's role by itself is in the borderline of significance for *suspense* ($F_{1,111} = 3.653$, $p = 0.059$) and *amusement* ($F_{1,111} = 4.053$, $p = 0.052$). This did not happen in the first model's analysis, where the role influence is far from being significant. On the other hand, the environment *area size* does not seem to affect the experience ($F_{9,111} = 1.124$, $p = 0.295$ for *suspense*, and $F_{9,111} = 0.798$, $p = 0.619$ for *amusement*). This effect has been analyzed for both subjects' roles, obtaining similar results.

Again, the study of environmental lighting does not reveal any significant impact, with $F_{2,111} = 0.821$, $p = 0.443$ for *suspense*, and $F_{2,111} = 1.062$, $p = 0.349$ for *amusement*.

Regarding the sound of the *threat*'s footsteps, this model presents a lower amount of emitted information warnings per game (59.55% less). In any case, results like the previous model for *suspense* were found ($F_{1,111} = 7.63$, $p < 0.01$), although the impact is lower here. However, its effect is not significant for *amusement* ($F_{1,111} = 0.057$, $p = 0.812$). Contrary to the other model, this impact does not seem to depend on the initial reported values.

TABLE 5. Comparison / correlations between measured and expected reports in second model.

factor	decision-makers suspense	decision-makers amusement	viewers suspense	viewers amusement
experimental group				
correlation	-0.753 ***	0.221		
t-test	0.525	-10.151 ***	1.573	-2.025
reported mean (stdev)	2.693 (0.356)	2.510 (0.884)	2.999 (0.342)	2.882 (0.466)
expected mean (stdev)	2.643 (0.213)	3.533 (0.325)	2.631 (0.000)	3.062 (1.014)
control group				
correlation	-0.594 ***	0.091	0.215	0.341 **
t-test	0.971	-2.976 **	-1.378	-0.676
reported mean (stdev)	1.984 (0.731)	1.938 (0.249)	2.154 (0.369)	2.033 (0.408)
expected mean (stdev)	1.797 (0.709)	2.217 (0.427)	2.461 (0.739)	1.925 (0.599)
(global)				
correlation	-0.644 ***	0.138	0.221	0.352 **
t-test	0.912	-5.454 ***	-3.261**	-2.343
reported mean (stdev)	2.339 (0.589)	2.224 (0.741)	2.576 (0.556)	2.458 (0.421)
expected mean (stdev)	2.101 (0.492)	2.889 (0.399)	2.511 (0.721)	2.592 (0.735)

***: p-value < 0.001, **: p-value < 0.01, *: p-value < 0.05

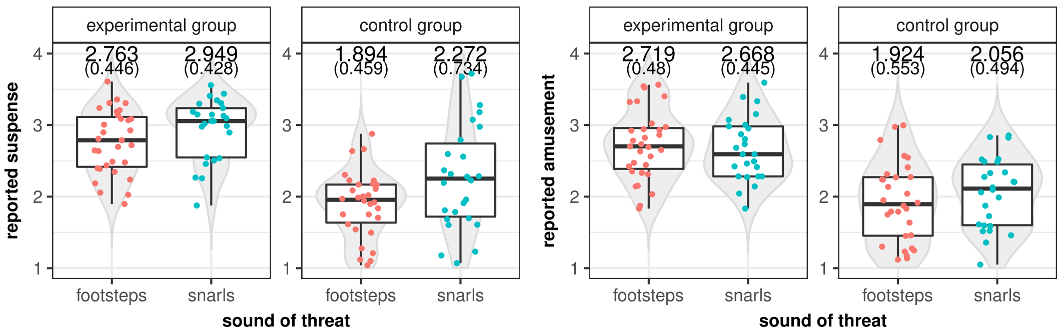

FIGURE 11. Effect of sound in suspense/amusement (on top, means and standard deviations) in second model.

Finally, demography seems to have no significant effect ($p > 0.05$ for participant gender and age).

V. DISCUSSION

As expected, the levels of *suspense* and *amusement* reported by the experimental group in both models were significantly higher than in the control group, presenting high correlations, and fitting the model based on probability of providing information better than the model based on mean distance to the threat. Additionally, the results seem to support that the variations of the virtual environment did not have a significant influence in the model predictions, substantially increasing the baseline operative conditions in which it would predict successfully the target measurements. Regardless, the model for predicting *amusement* can be improved by fine tuning some characteristics –such as the *threat*-emitted sound– which might impact the audience's perceived suspense and engagement.

Furthermore, Equations 3 and 4 propose a specific model for *suspense* and *amusement* that does not cover the potential impact of the environment *area size* on the *viewers*, although the *area size* has been revealed as potentially influencing in conjunction with the probability of disclosing *information*, even if this influence is minor in comparison with the effect of managing suspense through the management of the given information amount. This might be caused by a lack of *area size* variability in the formulas: the three values of *area size* used in the first experiment potentially affected *players* reports, but their influence was not significant for *viewers*. A broad variability and expansion of the settings would require specific experiments focused on distinct types of environments, scenery elements, and the suspense they convey. On the other hand, it is reasonable to assume that reducing the area size more than $16u$ would decrease the chances for the *victim* to escape because running into the *threat* in such a compact dimension would be very likely. Indeed, several experiments support that players' *amusement* is minimized when they face an inevitable defeat [85]–[87].

Likewise, the sound of the *threat* has a general significant impact on *suspense* and *amusement* with an exception: its influence on *amusement* was not significant when the reported *amusement* was observed under 2.6 –medium level of *amusement*–. This suggests that this kind of environmental effects helps to increase *amusement* if the experience is engaging enough; for values under a certain threshold of enjoyment, the environmental effects might have a decreased impact. In any case, this impact on *amusement* was not even found in the model based on distance, where the amount of different warnings is lower. In other words: environmental effects affect the discourse, but might fail at making up for a boring plot, a tedious interactive mechanic or similar elements.

Conversely, Figures 7 and 10 show data which barely fits in the predicted curves, exceeding them in a number of cases. This may support that the model does not consider other influencing elements such as audience's memory, predictability or empathy, all potentially involved in the process of evoking suspense and engagement [5], [35], [88]–[90].

The experimental analysis evidences that not only *amusement* can be modulated by the amount of disclosed information, but also that this information also conditions the actions of *players*, who, ultimately, try to counteract the threat. In fact, the results lead to suggest that providing the minimum information necessary to counter a threat involved in a suspenseful situation produces the optimal degree of amusement in both players and viewers.

Limitations:

Despite the results, the influence of some methodological aspects must be taken into consideration. Specifically, the virtual environment was intentionally modelled as an *easy-to-play* video game for the participants, resulting in a gentle learning curve. It is a simple fixed-rule scenario with little variations, without surprises for the audience. Also, the plot introduces a single ''mousetrap'' suspenseful scene in which the main character must escape or be killed, which is a common trope and setup typically used to evoke suspense [76], [91]–[93], but not the only one [14].

All these experimental design decisions allow the analysis of the emotional responses while reducing potential side-effects, but they also limiting the audience's experience if compared to most modern video games, interactive cinema, or real theater performances [94]. Therefore, even though the results evidence differences between audiences for the proposed experimental setup, testing our hypothesis in a more realistic and variable context would require a more in-depth experimentation. In that case and considering the variability of a more complex environment, the set of potential variables would be hard of control.

Indeed, even though the models have been presented and tested, it is unlikely that the formulas can be translated literally to other scenarios, as the models are highly dependent on the type of information they manage. Therefore, the type of information and the specifics of each layout would require *ad-hoc* analysis for each case.

Additionally, it is worth noting that no definition of ''suspense'' was provided in any of the experiments. On one hand, there is not a single unified definition of suspense that has an agreement [29]. On the other hand, the intention was for the subjects not to adhere to specific semantic bias that could potentially interfere with their emotional responses [95]. As already mentioned, previous studies of suspense have proposed or implement a similar methodology for studying suspense [54], [75]–[77] and amusement [78], [79], assuming the risk that participants report all the negative emotional spectrum felt during the process [96]. Regardless, our analyses suggest there is a significant agreement in the participants' own understanding of suspense and amusement.

Finally, the relatively small number of participants may reduce the statistical power necessary to detect significant differences between experimental and control groups. However, the two-tailed t-test power analysis reaches a factor for false negative finding of $\Pi = 0.96$ in the case of players, and $\Pi = 0.87$ for viewers –α for significant level set to .05–, resulting in values higher than 0.80, which may be considered adequate enough to accept potential Type II errors [97].

VI. CONCLUSIONS

This research has studied the effect of two strategies used to evoke suspense in video games that use a protagonist viewpoint to tell a story: warning the audience randomly, and warning the audience depending on the distance between victim and threat. In order to do it, a first experimental study was conducted in which players and viewers experienced, and rated suspense and amusement for different versions of a suspenseful protagonist-viewpoint video game.

Relying on the experimental results, two models were computed –respectively, one for each strategy– for optimizing amusement. Both models were based on managing suspense through providing information on the localization of the threat, and were tested in a second experiment. Contrary to the most commonly used strategy, the model based on probability of providing information fitted and performed better than the model based on mean distance to the threat, and explained more than 75% of the reported suspense and amusement for active and passive audiences. In any case, both models have been instrumental to obtain evidence in favor of: a) despite of the interactive spectator needs more information to engage, it is possible to optimize the reported suspense and amusement for active and passive audiences by controlling the amount of disclosed information; b) the information necessary for this optimization apparently tends to be the minimum required for players to counteract the threat; and c) this information approximately matches the information to optimally engage the interactive audience. Moreover, these effects seem to be reproducible even when a number of external environmental features vary.

All this evidence suggests that design of interactive experiences may take advantage of regression models obtained with similar processes, although a quantitative formulation that covers the elements involved in complex contexts, with multiple discursive variations –a film for instance–, might be challenging to compute. Any further attempt should consider scenes independently and prioritize the management of disclosed information before other features that may help in obtaining acceptable predictions, additionally taking into account that strategies to evoke suspense in complex discourses are not limited to those studied in this research.

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