Affective Conditional Modifiers in Adaptive Video Game Music

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ABSTRACT

This paper presents an application of affective conditional modifiers (ACMs) in adaptive video game music – a technique whereby the emotional intent of background music is adapted, based on biofeedback, to enforce a target emotion state in the player, thus providing a more immersive experience. The proposed methods are explored in a bespoke horror game titled *"The Hidden"*, which uses ACMs to enforce states of calmness in stressed players, and states of stress in calm players, through the procedural adaptation of background music timbre and instrumentation. These two conditions, along with a control condition, are investigated through an experimental study. Due to the low number of participants, the results of the user study provide limited insight into the effectiveness of the proposed ACMs. Nevertheless, the experiment design and user feedback highlight a number of important considerations and potential directions for future work. Namely, the need for consideration of the individual affective profile of the player, the audio-visual and narrative cues that may reduce the impact of affective audio, the effects of game familiarity on affective responses, and the need for ACM thresholds that are well-suited to the context and narrative of the game.

CCS CONCEPTS

• **Software and its engineering → Interactive games**; • **Applied computing → Sound and music computing**; • **Human-centered computing** → *Interaction design*.

KEYWORDS

affective computing, biofeedback, video games, sound design, adaptive music, horror games

ACM Reference Format:

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1 INTRODUCTION

Since its emergence in the 70s, the use of non-diegetic audio in video games has become commonplace in the industry [11]. Over the years, we have seen various titles explore the uses of audio in gaming experiences, ranging from grandiose musical passages that strike the heart of an important narrative moment, to utilitarian sonic events that communicate vital information to the player [29]. In some cases, audio is integrated as a central component of the experience, provoking the player to investigate their environment through sound alone [9] – culminating with the concept of audio-only games [23]. In others, musical elements such as rhythm and tonality are used to cue expected player actions [20]. Despite such games residing in relatively niche corners of the industry, they share the common goal of using audio to cultivate immersive and emotional experiences [28], thereby generating interesting and memorable moments for the player. However, until recent years, the player's emotional responses to video game music have been little considered in how the game audio is designed. As such, music is typically composed to only convey or invoke emotions congruent with the game's scenes and narrative, without considering the player's real-time emotional response to the music. This one-sided dynamic provokes new fields of research centered around the integration of player emotion feedback into these experiences.

Affective gaming, being a sub-field of affective computing, is a topic of research that investigates and devises methods for integrating player emotions into video games [14]. This can take the form of narrative or audio-visual mechanics being linked to physiological signals collected during gameplay [10]. These affective markers can also be inferred from non-physiological sources, such as the pressure the player applies to the controller [24], their movements and behavioral patterns [14], their narrative choices [19], or through self-reports. Generally, in the affective gaming literature, the artistic components of video games (audio, visuals, and narrative) are combined as a single holistic concept [14] – the *design*. As a result, there are very few studies that attempt to isolate one sensory medium and explore how it could be exploited in affective feedback experiences. Affective audio, defined as the application of approaches from affective computing within the context of audio and audiovisual elements [27], is one such field that has been sparsely investigated with exclusive sensory interest [12].

In video games, it is common for the background music to shift in intensity to reflect the narrative of the scene. If the player is forced into a high-risk area, one may expect the music to become louder and more intense to reflect the increased threat. This technique, known as adaptive music, can be achieved by iteratively rendering a composition with increasing levels of instrumental intensity, and using software to blend between them based on some in-game parameter [7]. This dynamic blending of background music allows game designers to better leverage the affective qualities of music in their games to produce more meaningful experiences with a deeper capacity for immersion. In the context of affective gaming, adaptive music can be exploited to produce procedural background music that instead responds to (or enforces) the affects of the player.

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2 RELATED WORK

Affective gaming has received significant academic interest in recent years, with many studies investigating potential methods for measuring and integrating player affects [15]. Implementations range from using frustration to dynamically adjust difficulty [16], to controlling aspects such as player speed and visual aesthetics using heart rate and skin conductance [1]. In a review of affective gaming literature, Robinson found that the five most commonly used sensing modalities were: heart rate, facial expression, respiratory rate, skin conductance, and body temperature [22]. It was found that heart rate and skin conductance were most commonly mapped to game difficulty, facial expressions and breathing to game mechanics, and body temperature to the environment [22]. In all cases, player affects were represented using the valence (emotional pleasantness) and arousal (emotional intensity) dimensions of the circumplex model of affect [21, 22].

In 2001, Bersak presented one of the first practical demonstrations of biofeedback in video games. In their game, titled *Relax to Win*, players used their arousal, measured by EDA, to control the speed of a flying dragon in a player vs player competitive race [3]. This created an interesting juxtaposition between a task that required players to stay calm and a punishment (being overtaken) that made that requirement increasingly more difficult to maintain. Bersak argued that the game exampled a successful implementation of affective feedback, in that it used biofeedback to parameterize how stimuli are presented with the goal of invoking a desired affective state [3]. Though, it could be argued that this was just a developed case of bio-feedback; the game did not use speed or position to deliberately or purposefully influence the emotions of the player, and the emotional impact was rather just a passive effect of the mechanic.

The application of biofeedback in adaptive music was explored in *Lundheim* [18] using the Neural Scores [17] program to measure affects in electroencephalographic (EEG) data. The affective music of Lundheim comprised a dynamic multidimensional blending of musical timbre and orchestration mapped to the circumplex model of affect. States of high valence and arousal produced intense music with warm and organic timbres, whereas states of low valence and arousal produced calm music with cold and synthetic timbres [18]. In this case, biofeedback was only used to adapt the music to reflect the affects of the player. However, as the objective was only to demonstrate a possible application of affective audio, no empirical data was collected and evaluations were not conducted [18], making it difficult to evaluate the efficacy of the techniques and sonic material used. In their conclusion, the authors call for further research into these affective audio techniques [18].

3 METHOD

In the present work, we expand on the methods proposed in Lundheim by introducing affective conditional modifiers (ACMs) in adaptive music – A technique for adapting the instrumental intensity of video game music to induce some desired emotion state relative to the affective responses of the player. We implement our proposed methods in a bespoke horror game titled *The Hidden*, which uses ACMs to blend the background music between states of high and low instrumental intensity based on two conditions: a *help* condition which attempts to provoke calmness in stressed players, and a hinder condition which attempts to provoke stress in calm players. We examine the impact of these conditions during a number of experimental tasks through a user study, and we discuss the empirical observations and subjective accounts gathered during participant studies. Finally, we comment on the future of this technology and how our results may be applied to future work. Through this research, we contribute to the study of functional affective audio in video games and propose new methods for work in this area, thus contributing to discourses in the field.

3.1 Game Design

The player awakes in their house to an emergency TV broadcast and learns that a dangerous creature, which can only be seen in direct light, has been sighted in their area. The power is cut, and the player is left to navigate the game and escape the creature using only their flashlight, which they find nearby. The player also finds a discarded radio device, which emits a static sound in the presence of the creature, and is used to guide the player through the different sections of the game. The game begins with a short tutorial on how to interact with elements in the game world, such as opening doors and jumping over pits. The map is divided into three distinct areas: the town, the radio station, and the gas station. In each area, the player must complete two experiment tasks.

3.1.1 Chase Tasks. The chase tasks are short scripted scenes in which the creature suddenly appears behind the player and chases them down a narrow tunnel. In the tunnel, there are a number of hazardous objects that the player must avoid by either moving out of the way (fires) or pressing the jump button (spike pits). If the player collides with either of these, their health is reduced and a hit sound is played. The distance between the player and the creature grows and shrinks based on their arousal score. If the arousal score suddenly increases, the creature rushes up behind the player as though they are about to grab them. If the arousal score decreases, the creature falls back and gives the player more space. However, this is controlled, and the creature will never get close enough to touch the player giving only the illusion of danger. The areas leading up to the chase tasks, and the chase tasks themselves, are all visually and spatially identical, to maintain similarity between testing conditions. All chase scenes last exactly 24 seconds.

3.1.2 Search Tasks. The search tasks are longer unscripted scenes in which the player enters a large open area and searches for a number of key items they need in order to progress. Upon entering, a barrier slams closed behind them and the creature appears infront of them. The creature pursues the player using a dynamic path-finding algorithm as they search the map for the required items. The player can use their flashlight to locate the creature, which is otherwise invisible, and the radio emits static when the creature in nearby. In the town, the items to be found are batteries for the torch; in the radio station, they are computer terminals that boost the radio signal; and in the gas station, they are fuel canisters that are used to refill a car and make the final escape.

The map for each search task follows the same layout; a building in the top right, a maze in the top left, and a forest area with some

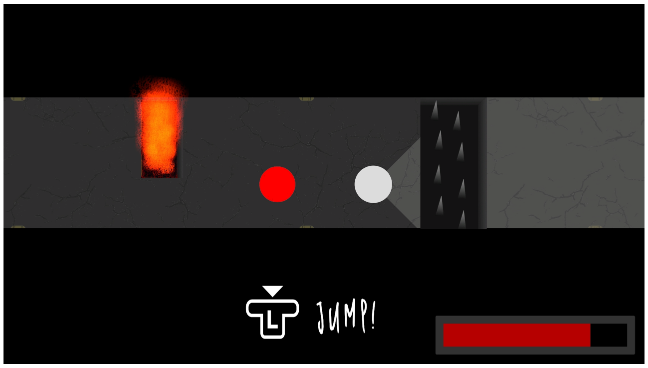

Figure 1: Example chase task frame

structures at the bottom. If the player collides with the creature during this scene, they lose health and a hit sound is played. However, the AI is configured to reduce its speed as it approaches the player and to stop just outside of the player's hit-box. This creates the same illusion of danger as in the chase scenes and means that collisions are only due to player mistakes. Once exactly 3 minutes have passed, regardless of how many items the player has found, the creature vanishes and the barrier opens to let them out.

Figure 2: Example search task frame

Given the experimental setting, it was important that the player was not required to restart any sections of the game as a result of their health reaching zero. Therefore, we based the health mechanic on a super-task [25]. Whenever the player takes damage, the game subtracts a fraction of their current health, proportionally reducing the amount of health lost each time without ever letting it reach zero. In practice, this gives the illusion of taking damage, but without any risk of the player dying. Additionally, to prevent visual components of the game from influencing the emotional responses of the player, the game was created almost entirely from simple 2-dimensional shapes; the player is a white circle and the creature is a red circle. Lastly, each task is preceded by a jumpscare, to normalise the entry arousal scores across participants.

3.2 ACMs & Adaptive Music

The music of The Hidden adapts its instrumental intensity based on the arousal of the player and a given target arousal state. We designed three conditional modifiers which are used to control the blending between three levels of instrumental intensity in each in-game task. In all cases, the conditional modifiers play a medium state when the arousal score is within the target range, and either a high or low state when the arousal score is outside of the target range. The first ACM aims to help the player stay calm, by reducing the intensity of the music from medium to low when the player becomes stressed. The second ACM attempts to hinder the ability of the player to stay calm, by increasing the intensity of the music from medium to high when the player becomes relaxed. The last is a control condition, which keeps the intensity at a medium state throughout. The ACMs were implemented using the Wwise game audio platform, and the progression through the music is achieved using blend-containers and RTPCs scaled by player arousal. The three areas in the game are each randomly assigned one of these ACM conditions when the game is loaded, without any repeated conditions.

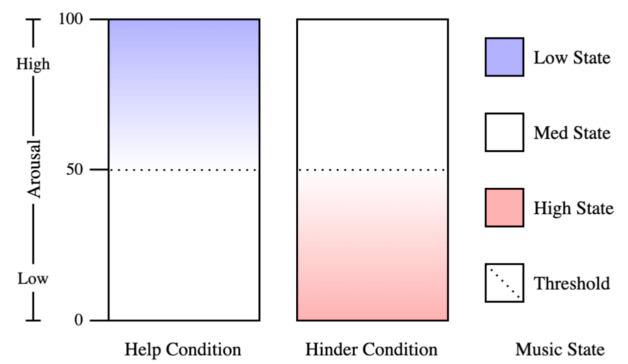

Figure 3: Visualisation of the blending profiles and trigger thresholds of the help and hinder adaptive music ACMs

3.2.1 *Chase Music.*

The chase task music was composed to feel intimidating and demanding, to match the narrative of the scene. The high state features prominent drums, screeching strings, buzzing drones, vocal hits, and roaring bass synths. As the music regresses into the medium state, most elements disappear, blending the drums into a more warmly-timbred profile with a lighter rhythm and accompanied by a more relaxed synth melody. Blending to the low state, the drums fade out and the synth melody is replaced with an ambient synth voice playing major chords enharmonic to the minor key of the medium and high states – inducing a sense of safety.

3.2.2 *Search Music.*

The search theme music was composed to feel more ambient and suspenseful, to help the player stay immersed during the longer tasks in the game without causing fatigue. The high state features multiple dark modulating synths with detuned glissando and tremolo strings. As the music regresses into the medium state, most elements fade out, and the synths morph into more airy and warm profiles while a rhythmic bass synth pattern fades in. Blending to the low state, all elements fade out as a single sustained airy synth voice fades in. As the arousal state decreases, a low-pass filter effect is gradually applied to reduce the piercing highs.

3.3 Player Arousal Measurement

To capture the arousal of the player, we measure their electrodermal activity (EDA). In short, EDA describes the skin conductance, or resistance, mediated by sweat gland activity in the dermis layer of the skin [22]. Skin conductance is known to reflect states of arousal [13] and stress (negative arousal) [8], and is generally used in affective computing to index arousal in the sympathetic branch of the autonomic nervous system [5]. The measurement is taken by attaching two electrodes to skin regions with sudoriparous glands and measuring the resistance between them [5]; the conductance is defined as the inverse of the resistance. Unlike other sensing modalities, the electrodes can feasibly be placed anywhere on the body, allowing for configurations with varying levels of intrusiveness [26]. However, electrodes are most commonly placed on the index and middle fingers as these locations contain dense collections of emotionally-sensitive eccrine sweat glands [22].

In this study, we used the BITalino revolution biomedical toolkit, which has been seen to produce results similar in accuracy and latency to reference systems – such as the BioPac MP35 Student Lab Pro [2]. The device was attached to the proximal regions of the index and middle fingers using gelled self-adhesive electrodes. The EDA reading was sampled at a rate of 100Hz, and transmitted to the host machine via Bluetooth where it was received in OpenSignals and rebroadcasted locally through Lab Streaming Layer (LSL) [4]. In the game, the EDA data x is received as an LSL stream, stored in a sliding window (approx. 2s), and processed to generate the arousal score, given by:

$$arousal = \frac{1}{1 + e^{-z}}, \quad z = \frac{x_n - \mu}{\sigma} \tag{1}$$

where x_n is the current EDA value, μ is the mean of the sliding window, and σ is the standard deviation. This computes a moving Z-Score from the sliding window, which is then normalized between 0 and 1 using a sigmoid function. What results is a standardized signal which is not reliant on some pre-calibrated baseline value, and which is not sensitive to the saturation and recovery patterns typical of tonic EDA. At the end of each Unity update, the arousal score is streamed back to LSL where it is synchronized with the raw signal. Additionally, a number of events were also streamed to LSL as markers: the randomly generated condition order, the start and end of each search and chase task, collisions with hazardous objects, and creature collisions. These data were recorded during each task using the LabRecorder module, which synchronizes and logs all incoming streams as a single XDF file.

3.4 Participants & Procedure

Ten participants (7 males and 3 females; mean age: 28) took part in the user study on a voluntary basis and were recruited in London. 4 Participants identified as being from the UK, 2 from the USA, 2 from India, 1 from Portugal, and 1 from Italy. All participants were postgraduate students, except for one participant who was a teaching assistant. The participants had mixed musical backgrounds and experience playing video games. There was a low participant turnout due to extreme weather and global health conditions.

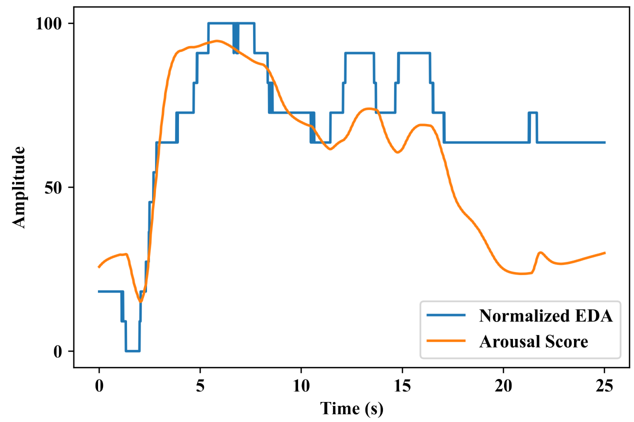

Figure 4: Computed arousal score plotted against post-hoc normalised EDA in a chase task

Before starting the experiment, participants were shown how to use the game controller – a Nintendo Switch JoyCon. The participants were then fitted with the electrodes, recording was started, and they completed a 2 minute guided breathing exercise. The game began after a short pause and took roughly 20 minutes to complete, though this varied between participants. Once the experiment was over, participants were asked to complete a 7-point Likert questionnaire about their experience, and a short semi-structured interview was conducted to collect a more detailed account of the conditions and the game overall. The questions for each are presented below:

3.4.1 7-Point Likert Questionnaire.

(1) I felt engaged while playing the game
(2) I enjoyed playing the game
(3) At some points, the sound and music changed according to my emotions
(4) The sound and music fit the game well
(5) I understood what I needed to do while playing the game
(6) I felt more stressed/anxious when the sound and music was more intense
(7) I felt more calm/relaxed when the sound and music was less intense
(8) Wearing the biosensing wristband did not affect my immersion while playing
(9) Wearing the biosensing wristband did not affect my mood while playing
(10) I play video games at least once every

3.4.2 Semi-Structured Interview.

(1) Was there any point in the experience that you felt the sound or music accurately reflected your level of stress or relaxation? If so, which area, and why?
(2) Did you find that the shifting intensity of the sound or music affected your level of stress or relaxation? If so, which area, and why?

(3) Was there any point at which you felt the sound or music made it noticeably harder for you to relax? If so, which area, and why?
(4) Was there any point at which you felt the sound or music made it noticeably easier for you to relax? If so, which area, and why?
(5) Were there any points at which you did not think the sound or music fit the scene?
(6) Did you feel comfortable using the controller while wearing the biosensor?
(7) What did you like in the game?
(8) What did you dislike like in the game?
(9) **[DEBRIEF]**
(10) How would you improve the emotion interaction in the game?
(11) Would you be interested in playing games that respond to your emotions, for example to drive audio visual or narrative elements?

4 RESULTS

The mean arousal scores were analysed for normality, by condition and condition order, using the Shapiro–Wilk test (α=.05). In search tasks, the arousal score means during the help, hinder, and control conditions were all normally distributed (p=.654; p=.321; p=.395). Additionally, the first, second, and third condition indexes were also all normally distributed (p=.602; p=.793; p=.346). In chase tasks, the hinder and control conditions were normally distributed (p=.479; p=.219), but the help condition was not (p=.016). The first and third condition indexes in the chase task were normally distributed (p=.108; p=.682), but the second condition index was not normally distributed (p=.045).

4.1 Music Conditions

The music conditions were analysed by means of one-way repeated measures ANOVAs, with the factor being music condition and the measure being mean arousal score (α=.05; small effect: η^2=0.01; medium effect: η^2=0.06; large effect: η^2=0.14) [6]. In search tasks, the effect of music condition was large but did not quite reach significance (F=2.978, p=.076, η^2=.249, 1-β=.507). The help condition had a large effect against the control, but did not reach significance (F=1.997, p=.191, η^2=.182, 1-β=.244). The hinder condition had a medium effect against the control, but did not reach significance (F=.880, p=.373, η^2=.089, 1-β=.134). In chase tasks, there was a medium effect of music condition, but it did not reach significance (F=.939, p=.409, η^2=.094, 1-β=.187). The help condition had a small effect against the control, but did not reach significance (F=.162, p=.696, η^2=.018, 1-β=.065). The hinder condition had a medium effect against the control, but did not reach significance (F=.839, p=.384, η^2=.085, 1-β=.130). In all cases, the statistical power (1-β) is too low to draw any formal conclusions about the results.

4.2 Condition Order

The effect of the randomised condition presentation order (help; hinder; control) was also analysed by means of one-way repeated measures ANOVAs, with the factor being condition index and the measure being mean arousal score. In the search task, the effect of order was large and reached significance (F=5.821, p=.011, η^2=.393, 1-β=.807). In the chase task, the effect of order was large, but did not reach significance (F=1.578, p=.234, η^2=.149, 1-β=.290). The statistical power of the search task effect is substantial (1-β>0.80), but the chase task effect is not.

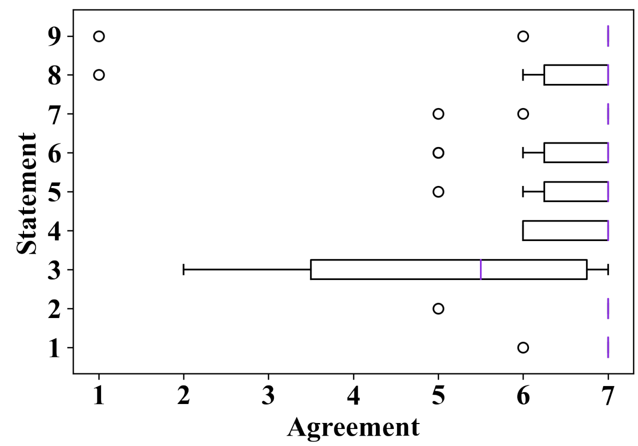

Figure 5: Responses to the post-completion questionnaire. Likert terms: Strongly Disagree (1), Disagree (2), Slightly Disagree (3), Neutral (4), Slightly Agree (5), Agree (6), Strongly Agree (7)

4.3 Questionnaire

Responses to the post-completion questionnaire (Figure 5) were generally very positive, with participants very strongly agreeing that the game was both immersive and enjoyable. The least agreed statement was that the music changed according to their emotions at times, but the response was still moderate. There was strong agreement that the music was fitting, that the participants understood what they had to do, and that they felt more stressed or anxious when the music was more intense. It was very strongly agreed that the participants felt more calm or relaxed when the music was less intense. Lastly, there was a strong agreement that the electrodes did not affect their immersion, and a very strong agreement that the electrodes did not influence their mood.

4.4 Semi-Structured Interviews

The participants generally did not notice a difference in the music between music conditions, and responses to questions about the tasks usually referred to all search or all chase tasks rather than individual cases. Almost all participants said they were able to predict when jumpscares and tasks would occur due to the visual similarity between areas. Responses to questions about comfort while wearing the electrodes agree with the questionnaire responses; the participants were not distracted by the electrodes and did not feel as though they influenced their mood, except for one. All participants had very positive responses to the game, except for one who had a neutral response. All participants stated that they would be interested in playing other affective games based on this experience, except for one who found the concept disturbing.

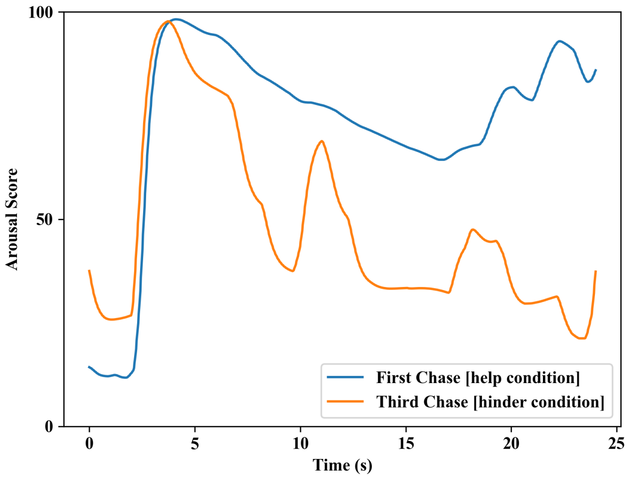

Figure 6: Comparison of the arousal scores over time from the same participant in the first and last chase tasks

5 DISCUSSION

While the analysis of the music conditions in the search tasks was not indicate any significant effect, the statistical power of the test was too low to form concrete conclusions. While this could likely be attributed to the low number of participants, it could also signal an interaction between the conditions and the presentation order. The most prominent effect observed was that of condition presentation order – participants were generally calmer during later stages of the game. The effect of this was evident in the arousal scores, which generally shared the same initial spike following the jumpscares, but recovered more quickly in the second and third areas of the game than the first – potentially as an effect of familiarity. The randomisation of condition order per participant combined with the low participant turnout also caused our condition order distribution to become skewed; the help condition was placed first far more often than hinder condition, resulting in the hinder condition generally being experienced with more familiarity than the others. These factors may provide some explanation for why we saw the hinder condition prove more relaxing than the help condition, as exampled in Figure 6.

The analysis of the music conditions in the chase tasks also did not indicate any significant effect. We suggest that this may primarily be an effect of the length of this task, which was likely too short to capture a meaningful arousal score sample. This is effect is amplified by the natural brain-body latency characteristic of EDA, which is observed to have an onset latency of around 1-4 seconds [13]. Additionally, in some cases, the arousal score of the participant did not cross the ACM trigger threshold (50%) before the end of the task. This caused some participants to not experience the active condition at all. This was more present in the hinder condition, as the initial jumpscare and ensuing chase task made a difficult environment to recover in. Given the nature of the game, this result is perhaps to be expected, but may also indicate that different thresholds are required for different game narratives and contexts, and that players may naturally have different resilience and response profiles to horror-themed content.

Nevertheless, the subjective feedback was favourable to both the design of the game and the integration of affective audio. The participants commonly said they enjoyed the game and felt immersed, and a few expressed their desire to continue playing. Further, there was strong agreement that the music fit the scene, despite most players not realising that the music was changing as they played. This may indicate that the changing intensity of the affective audio, despite occasionally being inversely mapped to their arousal, was not jarring or uncomfortable and did not break their immersion. This is an interesting result, considering that the music states were reported to induce their intended effects on the *felt* emotion of the participants; that is, without shifting their *perceived* emotion to the point of awareness.

6 CONCLUSION

This work presented a novel application of affective conditional modifiers in adaptive video game music. The proposed methods were explored in a user study using a bespoke video game, which attempted to enforce states of calmness in stressed players, and states of stress in calm players, through the procedural adaptation of background music timbre and instrumentation. These conditions, along with a control condition, were applied each to two in-game tasks per participant, and the emotional responses, among other data, were recorded. While the low participant count renders the statistical power of our analysis too low to draw formal conclusions, the experiment design and user feedback highlight a number of important considerations and potential directions for future work. The study also examples a successful implementation of affective feedback and affective audio in a horror game that provides both an enjoyable and immersive experience, without causing any jarring effects despite affective juxtaposition. This output may be used as a basis for future research, and the documented techniques, methods, and findings may be expanded for real-world applications.

Future work should take into account more extensive user trials with condition counterbalancing, to ensure an even condition order distribution and, therefore, a valid analysis of the conditions. Additionally, work should be done to mitigate the contextual and visual cues that allowed participants to predict the tasks and jumpscares. In a few cases, participants suggested extending the transition areas between tasks, and possibly adding additional and varied non-experiment tasks to break up the repetitiveness. Additions such as these may also provide some way to normalise the affective states of the participants between tasks. Further, the ACM conditions should be tested with various trigger thresholds and ranges, to ensure that all participants experience the full extent of the music conditions during gameplay. Lastly, future work should employ a pre-test calibration phase, to account for and offset the individual participant's emotional resilience to horror-themed content and affective response profile.

Further research is needed into affective conditional modifiers for adaptive video game music in other genres and contexts, to better understand their potential in affective audio applications and their suitability and value in the wider video game industry.

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