The Power of Fear: Exploring the Neural Responses to Horror Scenes in Different Audiovisual Modes

Xiangning Liang
University of Nottingham
Aleksandra Landowska
University of Nottingham
Richard Ramchurn
University of Nottingham
Callum Berger
University of Nottingham
Max L. Wilson
University of Nottingham
Horia A. Maior
University of Nottingham
Jubilee Campus, Wollaton Road, Nottingham NG8 1BB, UK
{zy21702, aleksandra.landowska, richard.ramchurn, callum.berger, max.wilson, horia.maior}@nottingham.ac.uk

ABSTRACT
Neurocinematics is an emerging interdisciplinary field at the intersection between Human-Computer Interaction, Brain-Computer Interfaces (BCI), and cinematics, that explores the use of brain and physiological data (such as functional Near Infrared Spectroscopy (fNIRS)), to evaluate a variety of media content. While many studies focused on comparing features of physiological activity between genres, this study aims to examine the cinematic content in the same genre but in different modes. Specifically, we are interested in the brain responses to audio and visual content, which have a similar emotional impact, in horror movies. Using non-invasive brain monitoring devices (fNIRS) targeting participants' prefrontal cortex, we collected and analysed their brain activity responses in comparison to subjective experience while watching a series of horror video clips. The results show changes in cognitive and emotional responses during the A, audio only modes, V, visual only modes, and M, audio and visual together modes for the horror stimulus, across fNIRS and subjective data. Our results are in line previous findings and bring novel insights into how brain activity can help researchers evaluate audio-visual content and promise an exciting future for adaptive horror experiences.

Author Keywords
Neurocinematics; horror movie; cinematic experience; fNIRS; emotion; input modality.

ACM Classification Keywords
H.5.0. Information interfaces and presentation (e.g., HCI): General.

DOI: 10.37789/rochi.2023.1.1.12

INTRODUCTION
Advances in brain computer interfaces (BCIs) made it possible for researchers to study people in more naturalistic environments and settings. Due to their increasingly non-invasive nature, relatively low cost, and increased portability, the application area of BCIs has expanded from diagnosis to neuroscience research [9], human computer interaction [34], human factors [14], artistic practice [27] and others. In essence, the BCIs allow us to view, analyse and apply brain activity data for various purposes, creating more possibilities in our human society.

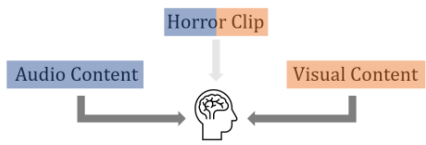

Figure 1. Illustration of research idea: test the contribution of audio and visual content to brain activity in horror experience.

There are a variety of BCI techniques such as fNIRS - that makes use of near infrared light to measure brain activity, fMRI - which relies on strong magnetic fields, and EEG - which measures the electrical charge of our brain using electrodes placed on the scalp. fNIRS has been used to evaluate various tasks ranging from remotely operating vehicles [14], mental arithmetic [41] and other complex cognition tasks such as work activities [34], video games [23], virtual reality [41], or movie watching [28]. Compared with other techniques previously mentioned, fNIRS is more portable than fMRI and more resilient to motion artefacts than EEG, making this technique particularly useful to study users in naturalistic settings. In this study, we will use a forehead fNIRS device (see Figure 3).

Neurocinematics. Neurocinematics is a multidisciplinary field in the intersection between Human-Computer Interaction, BCI, Neuroscience, Computer Science, and cinematics, which explores the use of brain and physiological data to investigate the neural responses of audiences during movie-watching. The findings of these studies provide a deep understanding of viewers' experiences and functions of cerebral regions and help evaluate the impact of various scenes and genres on participants' brain activity [28], or, if used in real time, these techniques can have the ability to contribute to interactive and adaptable experiences that were not possible before [43]. In addition, the results could guide filmmakers in producing better cinematic products (which are of great value in entertainment). The Neurocinematics terminology was first proposed by Hasson et al. [20]. This field has rapidly gained recognition and many studies investigated the different application of BCIs in the study of and creation of cinematics experiences [28, 48].

Existing work in neurocinematics indicates that there are different patterns of neural arousal between structured and unstructured clips [21], between different genres [28], between normal and tuned music [1], and between neutral and negative movies [48].

Audio and Visual Content in Horror Movies. Horror is a genre with a large population of fans all around the world. It applies artificial fear and terror with the help of audio and visual devices, eliciting audiences' inner scare without putting them into a real situation. Although horror has been studied in the scope of art [35], culture [38] and psychology [37], there is a limited amount of research focused on studying the possibilities of horror and neurocinematics.

The development of horror movies has led to the use of various audio and visual techniques, both of which play significant roles. These techniques serve for multiple purposes, such as creating atmosphere, generating suspense, inducing startle responses, portraying creepiness, and evoking uncomfortable and nervous feelings. In the most intense movie scenes, audio and visual elements work together to have a powerful physiological and psychological impact on audiences. Examples include jump scares accompanied by sudden loud sounds, increasing sound intensity as ghosts' approach, characters appearing flustered amidst intense music, chase scenes with dramatic music, and long static shots of old houses with mysterious sounds.

Audiences are simultaneously exposed to stimuli from both audio and visual channels, making it challenging to determine which channel contributes more to the horror experience. However, conducting separate experiments focusing on each aspect is feasible in research. Understanding the impact of audio, video, and audio-video in different horror scenes can help movie creators tune different levels of intended fear and scare to the audiences.

Horror and other Genres. Why is horror a good genre to explore and how is this different compared to other genres? In the book "A Dictionary of Film Studies" [25], horror genre is defined as a group of movies that seek to elicit fear, terror, suspense, and shock from audiences. Compared to other genres like romance, fantasy, science fiction, and drama that emphasise the narrative, the horror movie is emotionally directional. Although other genres could cause emotional surges after viewing, a horror film seeks instantaneous stimulation in audiences. Comedy seems to have similar features to horror by making people laugh right away, but it relies on language and visuals, while music and sound design is not a large contributing factor to the effect. While other genres usually have complex structures and mixtures of narratives and important events, horror movies are often structured with multiple narrative-horror pairs (Figure 2). Intense sound design and scary scenes can be found during the horror stage in the genre family, which are the ideal materials to increase horror, and ideal scenarios to experiment in this study.

The last point of interest is evaluation of different movie scenes; when we want to explore the contribution of audio and visual content of a completed scene, it is important to know if it is objectively and subjectively evaluable. BCIs are a good option for real-time or off-line objective measurement of different user/viewer states, and as horror movies are emotionally specific, this provides a shared metric. In summary, horror is the optimal genre for exploring the power of audio and visual content in the modern cinematic industry.

Figure 2. Classic horror movie Psycho (1960). Scenes move from left (narrative) to right (horror). The movie is structured with multiple narrative-horror pairs. Narrative parts push the story forward. Horror parts are to scare audiences with special audio and visual devices.

Objectives. In this study, we are interested in: (1) The patterns of our brains responding to different modes of horror content as measured with fNIRS and with subjective methods. (2) The contribution of audio and visual content in horror creation, plus their neuronal correlations and differences (Figure 1 also illustrates the objectives in our study). The three horror modes are: **A-Audio** (soundtrack of the original horror videoclips), **V-Visual** (silent version of the original videoclips), and **M-Mixed** (Audiovisual - the original videos with pictures and soundtrack).

RELATED WORK

Neurocinematics

Neurocinematics is a subject that embraces neuroscience, psychology, HCI and film to explain the reception and processing of movies [18]. This subject looks at the patterns of viewers' brain activity during the movie, where both intersubject and intrasubject scenarios are focused on. Recent advances in the field pushed the boundaries of adaptive experiences with the concept of a brain-controlled movies that showed great value to the viewers [39, 43, 44].

In 2004, Bartels and Zeki [8] found that each specialised area of the cerebral cortex is strongly responsible for feature-specific perception. Observers in the experiment were asked to rate the intensity of movie clips from the James Bond movie "Tomorrow Never Dies" in one of four attributes: colour, faces, language and the human body, using fMRI to capture brain activity. Functional segregation in the cortex can be confirmed as activated regions of the observers' cortex in each attribute are very different. Although these stimuli are all audiovisual, our brain perceives the content separately. Another finding is that the activity of specialised areas correlates linearly with the perceived intensity of features, which means that the brain patterns match our subjective perception.

Similarity between brains during a movie is another important topic. Hasson et al. [21] tested inter-subject synchronisation of cortical activity during the movie "The Good, the Bad and the Ugly" and demonstrated that individuals' brains tend to act collectively when exposed to the same stimulus. It includes the brain's visual and auditory areas arousing similarly in a time course among subjects. To understand the corresponding stimuli from the movie content, they extract frames according to the highest activation time of the brain regions. The result is surprising as the peak of certain regions correlate with the frames that have similar features. This shows that there are deep connections between the regions of the brain and the contents of media. In 2008, Hasson et al. [20] pushed their research forward and proposed the concept Inter-Subject Correlation (ISC) which has since become a popular topic in the field of neurocinematics. ISC measures similarity in brain activity across viewers by comparing the response time course in each brain region from one viewer with the response time courses obtained in the same brain region from other viewers during movie watching [20].

In 2014, two replicated fMRI experiments illustrated the same result and more relevant cerebral regions were marked [26]. With the development of portable brain scanners, ISC has been verified through more affordable devices than fMRI. Maior et al. [28] used fNIRS to attest to ISC during three genres: horror (Shining 1980 by Stanley Kubrick), comedy (The Adventurer 1917 by Charlie Chaplin) and violence (Children of Men by Alfonso Cuarón). The intensity of ISC varied from genre to genre; violent movie had the strongest intensity and horror movie was second. The relationship between movie stimuli and brains can be viewed as control and being controlled. The existence of ISC reveals the fact that movies can provide reliable and predictable neural arousal. A high ISC indicates that a movie has strong control over viewers, while a low one may mean that the movie has less control [20], which is a brand-new criterion for quality evaluation.

In addition to ISC, researchers focus on depicting detailed patterns of cerebral activity with video or movie situations, for example, scanning deep areas in the brain [16, 24], finding the connection between regions [29], and testing and comparing differences between viewers' brain responses and their subjective experience. In recent years, the brain-controlled films emerged, which enables the audience to engage with the content they are viewing [39, 40, 43], and the resulting movie no longer has a single directional feeding. With advances in generative artificial intelligence, there are further possibilities in the field of neurocinematics; Bai et al. used brain activity data to generate real time new image content [5].

Horror Movie Theory - Audio and Visual

The use of horror content in research is not new [11, 24, 28, 37]. A possible reason is that horror content provides reliable arousal and fear which is a biological universal feature of human beings. Why do people watch horror? A classic theory is we enjoy a positive aftermath thereby the previous negative feelings are worth enduring [3, 30]. From the perspective of psychology, the protective nature of fear creates "enjoyable fear" through the constant neural reminder of safety [37]. McAndrew et al. [32] claimed that a space with unpleasant feelings of fear and dread is important to make the vibe of creepiness. They summarised that isolated places, older places and places associated with death are naturally creepy to us. Directors may be inspired by these psychological facts, but cinematic language already exists to describe how they use various devices to manipulate the audience's emotions in a movie.

Jump-scare is one of the most effective devices in horror genre. An fMRI study proves that ISC is particularly strong during such episodes in the movies "The Conjuring 2" and "Insidious" [22]. Isolated jump-scares, however, do not have the same effect; timing and preparation are equally critical. Nummenmaa [37] stated that high-quality build-up can maximise scariness. Audiences are expected to have a certain level of awareness of upcoming scares, but the predictability should not be too high, otherwise, it may cause failure. After viewing forty horror film trailers, Dreyer [13] believes that using a close shot is an effective technique as it constrains the viewer's vision and evokes fear via their lack of visual information. Close shot increases the tension by concentrating our focus and excluding us from the wider environment. Another technique is cutting to black, which is often used during climax [36]. Winter [49] described two primary horror metaphors "evil is dark" and "evil is down", which means fear is usually aroused in dark scenes and in shots looking down at something. Lighting is another factor usually mentioned in papers on horror movies, which includes a series of tools such as flickering, luminance, warm/cool colour, saturation, contrast, etc. [2, 15]. Of course, visual techniques in creating horror includes more than those mentioned, such as monster figures and chase scenes.

Horror movies wouldn't be complete without a well-designed soundtrack [7]. A soundtrack has multiple functionalities within a horror movie, with the most effective use being to render a certain atmosphere [50]. Gong et al. [17] stated that sound in horror movies cooperates with visual effects to achieve immersion in the movie. Sound is a commonality in human perception. When the viewer is derailed from the visual track, the soundtrack can still establish a sense of fear. Bellano [10] used "I fear what I hear” to describe it. Auditory horror creation is very similar to jump-scares in visuals. They both particularly emphasise the contrast between the build-up stage and shock points. Grøn [19] described it in three steps: set-up (silence with low volume), pay-off (startle with high sound level, usually with jump-scare in visual), and fade-out (audiovisual inertia with static shot and low volume). Aragon [4] summarised in his paper on horror film soundtrack history, that unexpected quiet and high pitch are commonly used together in many successful films. The same argument has been pointed out by other researchers [46]. These are not the only uses of audio techniques for horror creation, the industry contains its own jargon for other techniques, for example, ghost sound effects, non-liner sound, or Foley sounds.

STUDY DESIGN

Compared to other previous work in fNIRS and Neurocinematics, this study followed a more controlled neuroscientific design.

Horror Stimuli

21 clips with of 1-minute duration were used in the experiment. These are from a wide range of cinematic products, which include 11 different horror movies and 2 short horror films. Horror movies are selected according to their high IMDb scores and their positive reviews from multiple platforms (Rotten Tomatoes and YouTube comments). Movies have been watched at first then the scary scenes were selected and cut into the final clips. To ensure the quality of stimuli and remove potential influences from other factors which are irrelevant to the research topic, the following criteria was considered: equality between audio and visual content, dialogue-free and clips, and familiarity (we did not select clips from recent movies). The clips were extracted from the following titles: Psycho; The Evil Dead; Evil Dead II; The Texas Chain Saw Massacre; Ringu; Deep Red; A Nightmare on Elm Street; Child’s Play; The Woman in Black; Halloween; Ju-On: The Grudge. Two clips are from YouTube: The Lake and Cicada.

Participants

Fifteen participants were recruited in this study (11 male and 4 female) with an average age of 24.47 (SD = 1.88). All experimental procedures were approved by the University of Nottingham’s Ethics committee. The experiment was held in a simulated mini cinema. Videos were played on a big screen in front of the participants. Participants listened to the soundtrack with high-quality stereo headphones.

Measurements

The fNIRS device used in this study is the Artinis Medical Systems’ Octamon headset, targeting the prefrontal cortex (PFC) (sensor layout information can be seen in Figure 3). It has 8 channels based on 8 near-infrared light emitters and 2 nearby receivers measuring oxygenated (HbO) and deoxygenated haemoglobin (HbR) concentration changes in the brain. fNIRS emitters used 760 nm and 850 nm wavelengths and the fNIRS data was acquired at 10 Hz. The data was recorded using the Oxysoft software (provided by Artinis Medical Systems).

The emotional assessment in this study uses PAD emotional state model [33], which includes three dimensions: valence, arousal, and dominance. We used 1-to-9 Self-Assessment Manikin (SAM) [42] to collect feedback from participants. We also used an extra question to quantify the performance of the horror stimuli (fear level): How fearful do you feel after experiencing the content (from 1 (low) to 9 (high))?

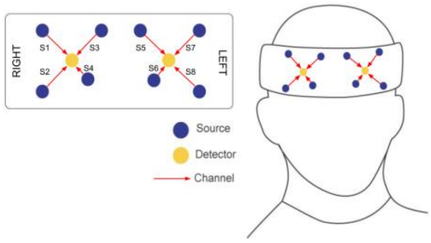

Figure 3. Sensor layout for fNIRS device.

Experiment Procedure

After entering the experiment room, participants provided informed consent, were then fitted with the fNIRS headset, and then the experiment began. Participants were asked to watch 21 horror clips (7 of each mode) in the three modalities while their brain activity was recorded. After each clip participants were asked to describe their emotions using SAM and rate the level of horror experienced on a scale from 1 to 9 as presented above. There was a 30 second rest before each stimulus where participants were asked to stay still and relax. The order of clips as well as the mode of the clips was randomised to ensure participants cannot predict what mode of clip will be coming next. Figure 4 describes the experiment procedure visually.

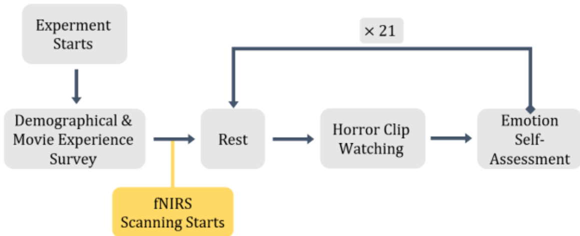

Figure 4. Experiment procedure.

Data Analysis

The fNIRS data was analysed using NIRS-Toolbox [45]. The significance level was set at $p < 0.05$. Contrast analysis was used to assess differences between conditions (similar to [41]). Significance analysis on emotional and subjective data was also conducted based on ANOVA with Tukey post hoc tests.

Hypotheses

A study of Baumgartnera et al. [9] shows that music could enhance the feeling of affective static pictures by strengthening the emotional valence. The result also shows that music evoking the same emotion as picture increases activation in more brain areas. Therefore, it can be speculated that horror with both pictures and sound could provide the best experience following the similar cognitive patterns as the previous study. Meanwhile, audio may play a special role in such mechanism. This research focuses on a specific emotion but expands the investigated objects to motion picture and sound separately. The following hypotheses are formulated:

- **H1a (subjective)**: Audio horror plays a different role in emotional feelings compared to visual horror.
- **H1b (subjective)**: Audiovisual is the best modality in horror creation compared to audio and visual-only.
- **H2a (fNIRS - objective)**: Evidence from brain activity analysis supporting **H1a** will be found.
- **H2b (fNIRS - objective)**: Evidence from brain activity analysis supporting **H1b** will be found.

RESULTS

Emotional Effects of Different Modes of Horror

Table 1 and Table 2 show the means and p values (pairwise comparisons) for the subjective measurements in this experiment. In terms of emotional arousal, there is a significant difference between condition A and V, as well as condition V and M. The result indicates that sound and audiovisual performed better than visual only stimuli in bringing audiences to a high energy state. Using sound caused stronger emotional activation in audiences, while silent horror clips kept audiences in a more soporific state.

A significant difference between modes was found in fear level measurement. There is a significant difference between condition A and M, and conditions V and M. As expected, Audiovisual is the most powerful mode for horror creation, while visual-only and audio-only had a lower impact on perceived fear. For valence and dominance, no significant difference was found. Yet the mean valence of audiovisual stimuli is lower than audio and visual.

The results support hypotheses **H1a** and **H1b**. Audio horror acts differently by providing more emotional arousal compared to visual horror, indicating the specialty of this mode in emotional feelings. The audiovisual horror is indeed the most effective mode in creating horror experiences, participants' fear level surpasses the other two conditions, and it has a similar effect in arousal as audio. The result confirms the impact of audio which enhances the emotional perception of visual content.

	Valence	Arousal	Dominance	Fear Level
A	4.1048	4.9238	6.6857	2.8952
V	4.0381	4.0762	6.7143	2.9333
M	3.6571	5.1048	6.0762	3.6476

Table 1. Mean values of the subjective measurements including Valence, Arousal, Dominance and Fear Level

	Valence	Arousal	Dominance	Fear Level
A-V	0.9638	**0.0121**	0.9955	0.9900
A-M	0.1936	0.8130	0.1293	**0.0218**
V-M	0.3033	**0.0016**	0.1066	**0.0316**

Table 2. P values of the ANOVA test ($p < 0.05$).

fNIRS - Activation of Horror Modalities from Rest State

fNIRS can monitor changes in oxygenated (HbO) and deoxygenated (HbR) haemoglobin that can be correlated with changes in brain activity. A significant change in brain activity in a particular region is considered when a negative correlation between HbO and HbR is detected [12]. In the analysis we have run statistical tests to compare the brain activity of participants experiencing the three modalities of horror as compared to a state of rest. Brain activity during the rest is considered as a baseline as no sound and no motion picture is being played. At first, the data was down sampled to 4 Hz. Next, the raw signals were converted to optical density changes and then to HbO and HbR estimates using the modified Beer-Lambert law, with a partial path length correction of 0.1 for both wavelengths [47].

It is common practice to use 60s or shorter task blocks when analysing fNIRS data; however, because our rest conditions was only 30 seconds long (study design limitation), we decided to discard the final 30 seconds of the stimulus for all study conditions.

As shown in Figure 5, we found no significant increase or decrease in activation during audio and visual-only stimuli. In line with the subjective results, we were able to see a significant decrease in HbR in regions S2 and S8 during the audio-video mixed condition - M (Continuous blue line in Figure 5). The corresponding HbO increase was not significant, but the trend was there (dotted red line). The result partially supports the hypothesis **H2b**. Audiovisual horror content causes the highest activation in audiences' brains from the basis of resting. Because only the first 30s of the stimuli were presented in the figures, the results should not be explained in a way of summarising the complete stimuli. Instead, it can be explained as a hook effect. Audiovisual horror is the strongest hook to get audiences' cognitive engagement and cause significant arousal in the brain in a short time, but sound and video fail to do so solely.

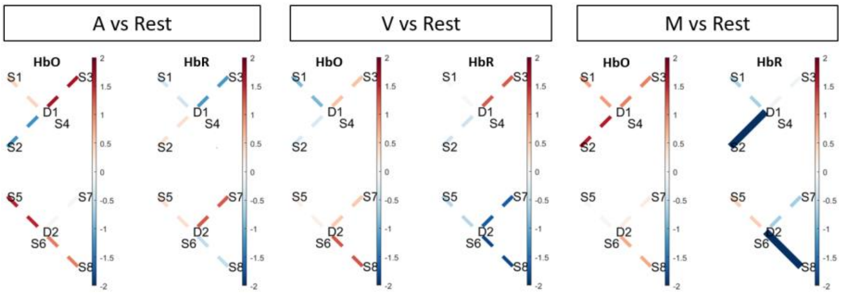

Figure 5. Comparing the effect of horror modalities and rest state with fNIRS data in the three study conditions. The layout of the S1-S8 channels is similar to Figure 3. HbR differences were found (solid color line) in the M vs Rest condition (S2 and S8).

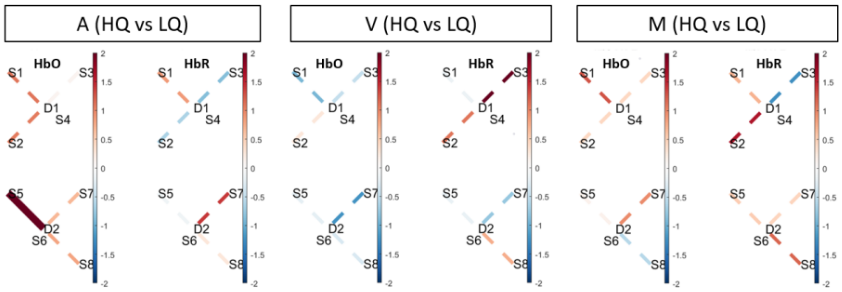

Figure 6. Comparing brain activity of HQ and LQ fear groups. S5 showed a significant activation in the HbO data for condition A.

fNIRS - Brain Activity during High- and Low-Level Fear

In the study, we have asked participants to rate the level of fear they have experienced on a scale from 1-9. Participants' ratings varied across the whole scale. We have then divided our data into Low Quality Fear (1-4 ratings) - LQ and High Quality Fear (6-9) - HQ fear content and we have conducted some further analysis of the fNIRS data. As shown in Figure 6, the HQ group of the audio condition caused strong activation in regions S5. It indicates that brain activity has significantly increased only when audio horror has reached distinct fear levels. The result shows the impact of audio modality in horror. However, there was no significant differences measured for visual and audiovisual horror. This partially supports hypothesis **H2a** by indicating that fNIRS can show differences in participants brain activity during different horror and fear conditions, and audio content is having a significant impact in this genre. There are various possible explanations why video and audiovisual did not show an effect in this comparison. It is likely that due to the relatively small sample size, as well as the limitations of the forehead fNIRS band used (not being able to measure other brain regions - e.g. visual cortex), that higher processes in the brain are taking place when we experience fear while processing visual content.

DISCUSSION AND CONCLUSIONS

Summary of Findings

This study investigated the use of audio, video and audiovideo content in the horror genre using both subjective questionnaires as well as objective brain data (fNIRS). The following findings were presented: (1) The enhancement of affective sound to motion picture is confirmed in horror movie clips. Audiovisual modality has the better performance in emotional assessment (subjective) and fNIRS brain activation compared to pure audio and visual horror. Adding sound onto the horror motion picture increases the activation level of prefrontal area (this was confirmed with both subjective and objective techniques). This highly corroborates and expands the findings from the work of Baumgartnera et al. [9]. (2) Modern horror movie is undoubtedly an art of both audio and visual. The combination of two modalities achieves the best horror experience. Without any one of them, a horror movie is not complete. (3) Although audio and visual horror has the same affective nature, sound has different features. Horror sound evoke more emotional arousal as compared with visual and the brain activity has the potential to evaluate this. (4) Horror movie watching is a multi-modal form of entertainment, where audio content seems to play a crucial role in eliciting emotional responses from viewers. (5) Furthermore, visual content is believed to be essential in the audio-video mix, potentially leading to significant activation of the prefrontal cortex.

Study Limitations and Future Work

There were several limitations in the study. Firstly, the study explores different modes of horror and builds a rough model for the horror movie watching experience based on visual and audio separation of the clips. In fact, audiences accept both sound and pictures at the same time during the movie. To understand the role of audio and visual content, our experiment adopts a work-around design to test them individually. The model we built is on the assumption that there was no correlation between audio and visual content. Although this design purifies the stimuli and ensures robust brain activity in each mode of horror, the simple combination of them may not reflect the real mechanism of an audiovisual/normal horror scene. A typical opinion about the function of a movie soundtrack/score is that the audio part is for creating mood and heightens the scene [31]. In other words, the soundtrack is not made individually but made for the visual content. Hence, the real cognitive process of viewing a horror clip could be more complicated. Future research should focus on identifying audio and video content that can independently evoke fear, without relying on each other. This will help address the current limitation in our experiment design and model, where the relationship between the two components is not reflected.

Secondly, while the subjective and fNIRS data are analysed using statistical methods, it wipes out the potentially significant differences between the participants. We observed that certain participants consistently reported low fear ratings, while others consistently expressed high levels of fear and even positive emotional valence. It is clear that different types of audiences exist. Some participants joined the study with the intention of challenging themselves, regardless of whether they had extensive or limited exposure to horror movies. Fear is a very natural feeling, yet modern humans may have already developed different routes when consuming it in a safe environment [3, 6]. Our analysis excludes those features and shows an overall result; it may not demonstrate the full map of all types of horror consumption, they could be further explored. Future work should aim to address this limitation by incorporating participant-specific differences in fear responses.

Thirdly, we followed a more neuroscientific approach in the study design; compared to other studies in neurocinematics [28, 43] that used ISC methodology to study relatively long stimulus (over 10 min), we used a very short length for the stimuli (60 seconds), we introduced rest periods, we designed and counterbalanced different study conditions, and used more standard fNIRS procedures. One of the major limitations with the fNIRS data analysis was using only the first 30 seconds of the horror stimulus for all study conditions, to allow us to compare with the 30 seconds baseline of rest. Even though the fNIRS results were not strong, we did find initial evidence that brain data can be useful in the context of evaluation of different horror content/modes. Future work should consider the inclusion of larger and more gender balanced sample sizes and include brain sensors to measure brain activity in areas such as the visual cortex and Broca's area, which could provide a more comprehensive understanding of the neural processes involved in horror movie consumption.

ACKNOWLEDGMENTS

This research received funding from the Engineering and Physical Sciences Research Council [EP/T022493/1].

REFERENCES

1. Abrams, D. A., Ryali, S., Chen, T., Chordia, P., Khouzam, A., Levitin, D. J., & Menon, V. 2013. Inter-subject synchronization of brain responses during natural music listening. *European Journal of Neuroscience*, *37*(9), 1458-1469.
2. Ammer, S. M. E. I. 2021. Content analysis of lighting and color in the embodiment of fear concept in horror movies: a Semiotic approach. *Information Sciences Letters*, *9*(2), 135-142.
3. Andrade, E. B., & Cohen, J. B. 2007. On the consumption of negative feelings. *JCR*, *34*(3), 283-300.
4. Aragon, V. G. 2020. Murder Music: Horror Film Soundtracks Throughout History.
5. Bai, Y., Wang, X., Cao, Y., Ge, Y., Yuan, C., & Shan, Y. 2023. DreamDiffusion: Generating High-Quality Images from Brain EEG Signals. *arXiv:2306.16934*.
6. Bantinaki, K. 2012. The paradox of horror: Fear as a positive emotion. *JAAC2012*, *70*(4), 383-392.
7. Barnes, Z. I. 2014. Soundtracks and the moving image.
8. Bartels, A., & Zeki, S. 2004. Functional brain mapping during free viewing of natural scenes. *Human brain mapping*, *21*(2), 75-85.
9. Baumgartner, T., Lutz, K., Schmidt, C. F., & Jäncke, L. 2006. The emotional power of music: how music enhances the feeling of affective pictures. *Brain research*, *1075*(1), 151-164.
10. Bellano, M. 2011. I Fear What I Hear: The Expression of Horror in Film Music. *Fear Within Melting Boundaries*. 67-78. Brill.
11. Cha, H. S., Chang, W. D., Shin, Y. S., Jang, D. P., & Im, C. H. 2015. EEG-based neurocinematics: challenges and prospects. *Brain-Computer Interfaces*, 186-192.
12. Cui, X., Bray, S., & Reiss, A. L. 2010. Functional near infrared spectroscopy (NIRS) signal improvement based on negative correlation between oxygenated and deoxygenated hemoglobin dynamics. *Neuroimage*, *49*(4), 3039-3046.
13. Dreyer, C. 2018. Crafting Fear: The Horror Film Trailer.
14. Durantin, G., Gagnon, J. F., Tremblay, S., & Dehais, F. 2014. Using near infrared spectroscopy and heart rate variability to detect mental overload. *Behavioural brain research*, *259*, 16-23.
15. El-Nasr, M. S.. Projecting tension in virtual environments through lighting. *ACM ACE2006,* 63-es.
16. Gao, C., Weber, C. E., Wedell, D. H., & Shinkareva, S. V. 2020. An fMRI study of affective congruence across visual and auditory modalities. *JoCN*, *32*(7), 1251-1262.

17. Gong, Z., & Zhang, J. 2021. Review of Sound in Horror Movie. *ICLAHD'21*, 767-771. Atlantis Press.

18. Grall, C., & Schmälzle, R. 2020. Neurocinematics. *The International Encyclopedia of Media Psychology*, 1-9.

19. Grøn, N. 2013. The Sound of Horror-Silence & Sound Contrasts in Sci-Fi Horror Movies. *Tidsskrift for Medier, Erkendelse og Formidling*, *1*(1).

20. Hasson, U., Landesman, O., Knappmeyer, B., Vallines, I., Rubin, N., & Heeger, D. J. 2008. Neurocinematics: The neuroscience of film. *Projections*, *2*(1), 1-26.

21. Hasson, U., Nir, Y., Levy, I., Fuhrmann, G., & Malach, R. 2004. Intersubject synchronization of cortical activity during natural vision. *Science*, *303*(5664), 1634-1640.

22. Hudson, M., Seppälä, K., Putkinen, V., Sun, L., Glerean, E., Karjalainen, T., ... & Nummenmaa, L. 2020. Dissociable neural systems for unconditioned acute and sustained fear. *NeuroImage*, *216*, 116522.

23. Karim, H., Schmidt, B., Dart, D., Beluk, N., & Huppert, T. 2012. Functional near-infrared spectroscopy (fNIRS) of brain function during active balancing using a video game system. *Gait & posture*, *35*(3), 367-372.

24. Kinreich, S., Intrator, N., & Hendler, T. 2011. Functional cliques in the amygdala and related brain networks driven by fear assessment acquired during movie viewing. *Brain connectivity*, *1*(6), 484-495.

25. Kuhn, A., & Westwell, G. 2012. *A dictionary of film studies*. Oxford University Press, USA.

26. Lahnakoski, J. M., Glerean, E., Jääskeläinen, I. P., Hyönä, J., Hari, R., Sams, M., & Nummenmaa, L. 2014. Synchronous brain activity across individuals underlies shared psychological perspectives. *NeuroImage*, *100*, 316-324.

27. Lancel, K., Maat, H., & Brazier, F. 2019. EEG KISS: shared multi-modal, multi brain computer interface experience, in public space. *Brain Art: Brain-Computer Interfaces for Artistic Expression*, 207-228.

28. Maior, H. A., Ramchurn, R., Martindale, S., Cai, M., Wilson, M. L., & Benford, S. FNIRS and Neurocinematics. *CHI 2019 Ext. Abstracts* (1-6).

29. Malik, A. S., Fawzy, S. M., Osman, D. A., & Khairuddin, R. H. R. Effect of movie clips on human brain. *ICIAS 2012* (Vol.1, 95-99). IEEE.

30. Martin, G. N. 2019. (Why) do you like scary movies? A review of the empirical research on psychological responses to horror films. *Frontiers in psychology*, *10*, 2298.

31. Soundtrack vs. score: Learn about the two types of film music. 2023. MasterClass. www.masterclass.com/articles/soundtrack-vs-score

32. McAndrew, F. T. 2020. The psychology, geography, and architecture of horror: How places creep us out. *EISC 2020*, *4*(2), 47-62.

33. Mehrabian, A. 1980. Basic dimensions for a general psychological theory: Implications for personality, social, environmental, and developmental studies.

34. Midha, S., Maior, H. A., Wilson, M. L., & Sharples, S. 2021. Measuring mental workload variations in office work tasks using fNIRS. *IJHCS*, *147*, 102580.

35. Muir, J. K. 2004. *Wes Craven: The Art of Horror*. McFarland.

36. Mustonen, V. 2019. Genre analysis of contemporary horror movie trailers.

37. Nummenmaa, L. 2021. Psychology and neurobiology of horror movies.

38. Phillips, K. R. 2005. *Projected fears: Horror films and American culture*. Bloomsbury Publishing USA.

39. Pike, M., Ramchurn, R., Benford, S., & Wilson, M. L. # scanners: Exploring the control of adaptive films using brain-computer interaction. *CHI 2016*, 5385-5396.

40. Pike, M., Wilson, M. L., Benford, S., & Ramchurn, R. # scanners: a Bci enhanced cinematic experience. *CHI 2016 Ext. Abstracts,* 293-296.

41. Pöhlmann, K. M. T., Maior, H. A., Föcker, J., O'Hare, L., Parke, A., Ladowska, A., & Dickinson, P. I think I don't feel sick: Exploring the Relationship Between Cognitive Demand and Cybersickness in Virtual Reality using fNIRS. In *CHI 2023,* 1-16.

42. Prete, G., Laeng, B., & Tommasi, L. 2022. Environmental risks to humans, the first database of valence and arousal ratings for images of natural hazards. *Scientific Data*, *9*(1), 303.

43. Ramchurn, R., Martindale, S., Wilson, M. L., & Benford, S. From Director's Cut to User's Cut: to Watch a Brain-Controlled Film is to Edit it. *CHI 2019,* 1-14.

44. Ramchurn, R., Wilson, M. L., Martindale, S., & Benford, S. # Scanners 2-the MOMENT: a new brain-controlled movie. *CHI 2018 Ext. Abstracts,* 1-4.

45. Santosa, H., Zhai, X., Fishburn, F., & Huppert, T. 2018. The NIRS brain AnalyzIR toolbox. *Algorithms*, *11*, 73.

46. Sbravatti, V. 2019. Acoustic Startles in Horror Films: A Neurofilmological Approach. *Projections*, *13*(1), 45.

47. Strangman, G., Franceschini, M. A., & Boas, D. A. 2003. Factors affecting the accuracy of near-infrared spectroscopy concentration calculations for focal changes in oxygenation parameters. *Neuroimage*, *18*(4).

48. Wang, Y., & Wang, Y. 2020. A Neurocinematic Study of the Suspense Effects in Hitchcock's Psycho. *Frontiers in Communication*, *5*, 576840.

49. Winter, B. 2014. Horror movies and the cognitive ecology of primary metaphors. *Metaphor and Symbol*, *29*(3), 151-170.

50. Xu, K. 2022. Analysis of the Roles of Film Soundtracks in Films. In *CACC 2022*, 351-355. Atlantis Press