fNIRS and Neurocinematics

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ABSTRACT

In the overlap between Human-Computer Interaction (HCI) and Cinematics, sits an interest in physiological responses to experiences. Focusing particularly on brain data, Neurocinematics has emerged as a research field using Brain-Computer Interface (BCI) sensors. Where previous work found inter subject correlations (ISC) between brain measurements of people watching movies in constrained conditions using functional magnetic resonance imaging (fMRI), we seek to examine similar responses in more naturalistic settings using functional Near Infrared Spectroscopy (fNIRS).

KEYWORDS
fNIRS; Neurocinematics; BCI; Inter-subject Correlation (ICS)

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fNIRS has been shown to be highly suitable for HCI studies, being more portable than fMRI and more tolerant of many natural movements than Electroencephalography (EEG). Early results found significant ISC, which gives a lot of hope and potential for using fNIRS in Neurocinematics.

Figure 1: The cinema caravan where the study took place.

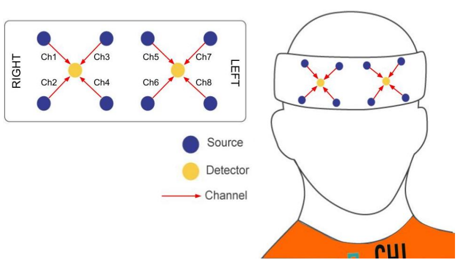

Figure 2: Sensor layout for the Octamon fNIRS device.

INTRODUCTION AND BACKGROUND

As brain and other physiological sensors become more available and transparent, tracking and estimating users' states in the wild is becoming more realistic, allowing researchers in Human Computer Interaction (HCI) and other disciplines to collect data in more ecologically valid conditions [5]. This type of data is highly valuable as it can provide an additional channel of information about the user (their mental state), objectively, without interrupting the user for subjective ratings.

These advances have opened a wide range of multidisciplinary research, including the field of neurocinematics: a paradigm used to describe neuroscientific experiments involving or studying movies. A 2008 paper by Hasson et al. presented research that used functional magnetic resonance imaging (fMRI) in order to investigate the Inter-Subject Correlation (ISC) levels of the brain data of participants watching the same movie sequences. Their results found clear ISCs, and showed that certain moments in movies can "exert considerable control over brain activity and eye movements".

Brain-Computer Interface (BCI) technologies could be of great value to both, movie creators and movie viewers. A study from Sundhara et al. [4] recorded participants' brain data using an Electroencephalography (EEG) based headset while they were asked to watch clips from movies of two genres, comedy and horror. The viewing data of 50 participants was then combined with the H2O deep learning framework, and the data was put into a deep learning algorithm which was able to accurately read participants' reactions with 85% accuracy. The researchers of this study argue that this finding could be of great value to movie studios for gathering feedback on their movies.

Other works in the field of Neurocinematics considered ways to use BCI data to allow participants to create *adaptive* or *interactive* movies. Pike et al [6] created a movie containing 4 parallel channels of footage and used pre-processed levels of attention and meditation from a NeuroSky EEG sensor to influence which footage was displayed next. The experiment showed that in this way, effective combinations of footage were produced, but participants reported feeling the most engaged if they did not actually know how the BCI system worked, or if they stopped trying to be in control, which goes against traditional HCI wisdom. In their subsequent work, Ramchurn et al. [8] created a movie that used the same device to estimate how interested viewers are in each of three characters, and varied which perspectives of each scene were shown accordingly. Therefore, one can argue that these works could also be of great value to movie viewers.

The common trend in the research cited above is that EEG has been a popular choice for BCI-based experiments, due to the immediacy of observable responses, and in some cases the consumer devices available for us. In this paper, however, we use functional Near Infrared Spectroscopy (fNIRS) to

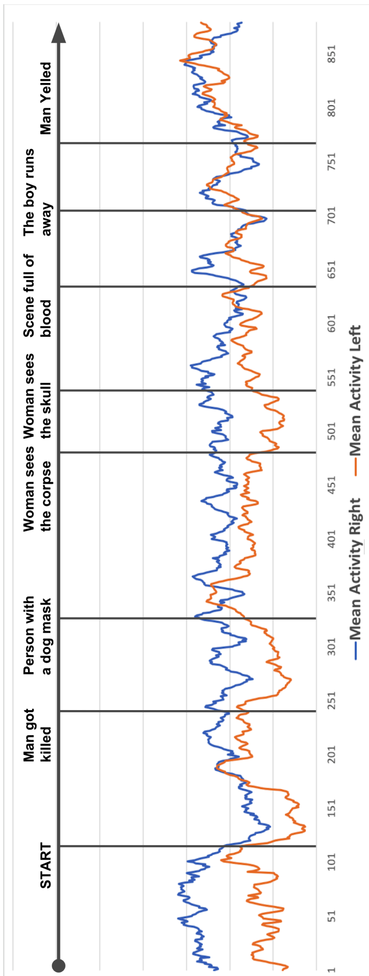

Figure 3: Mean brain activity during the horror clip (across all participants: left vs right hemispheres.

examine ISCs in participants brain responses during movie watching, to find further evidence in support of prior work [3, 7]. Over the last 10 years or so, fNIRS has emerged as a powerful brain sensing technique in HCI studies [5, 9]. fNIRS (see Figure 2) uses near infrared (NIR) light to measure regional hemodynamic responses associated with neuron behaviour, namely changes in blood volume and oxygenation. Because it uses light, rather than measuring the electrical charge of the brain, fNIRS is more resilient to movement artefacts, which makes it a more appropriate technique to measure brain activity in the wild; therefore, highly appropriate for neurocinematics research.

Below, we describe early results from a study driven by two research questions:

- Is there any inter-subject correlation in the fNIRS data during movie watching?
- Is there any correlation between fNIRS data, movie scenes and subjective responses?

EXPERIMENT DESIGN

Movie scenarios

In order to measure participants brain activity during movie watching we first had to select the stimuli clips. In this selection, we considered the genres of the movie clips (ideally triggering different responses), and the length of the clips such that we have enough data while keeping the experiment under one hour. We selected three clips of different genre: horror, silent comedy, and action/violent.

Additionally, we have manually annotated a list of moments of interests during each movie clip. As a professional filmmaker, these were identified by the second author, based upon the 'charge' of the scenes, where they would have a high chance of changing participants physiological responses and brain activity. These were further used as markers later in the analysis.

The Horror clip. This was a 12 minute and 30 second long video clip from The Shining (1980 by Stanley Kubrick). We picked this particular movie because it is one of the most famous horror movie of the 19th century and with a very high IMDb score. It was a cut from 2:07:00 to 2:19:30, which contains the climax of the film.

The Comedy clip. The comedy movie clip corresponds to the first 17 minutes of The Adventurer (1917 by Charlie Chaplin). The story is about a criminal who escapes from an island and saves three rich people from drowning. Finally the main character becomes rich as well. This movie stars one of the most famous comedy actors, Charlie Chaplin, and has a good IMDb score of 7.5/10. The other reason for choosing this clip is because it has been previously studied in a similar context by Hasson et al. [2].

The Violence clip. The action/violent clip is taken from the movie Children of Men by Alfonso Cuarón with a IMDb score is 7.5/10. The 12 min and 45 seconds clip corresponds to the near end of the movie (1:19:14 to 1:31:00), and it is a well known single shot with a highly orchestrated action sequence.

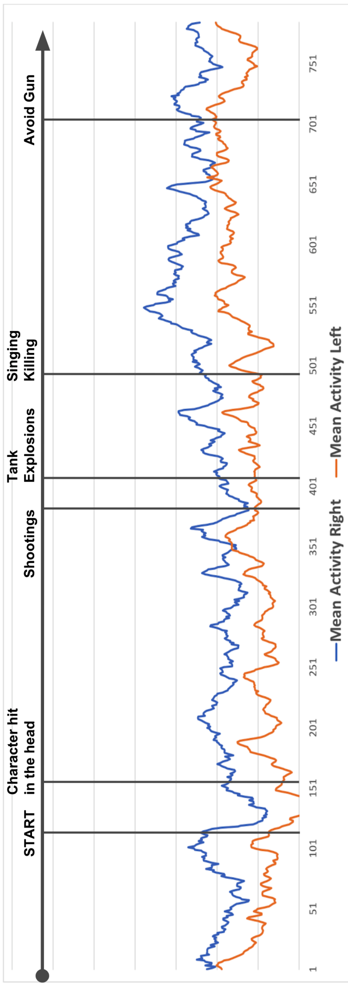

Figure 4: Mean brain activity during the violence clip (across all participants: left vs right hemispheres).

Participants

Participants willing to take part in this study first had to express their interest in watching the three genre movies: horror, action (with relatively heavy violence scenes) and comedy. These criteria was ensured through a questionnaire. We selected 8 healthy participants (3 female participants) between the ages of 22 and 28, all students at the University of Nottingham.

Study Protocol

Each participant was invited to read the information sheet, describing the details of the study, details about the movies they were going to watch and then provide their written consent. Participants were also instructed about their right to withdraw at any time from the experiment. The study took place inside a portable cinema built within a caravan (see Figure 1), where participants were invited to sit comfortably. Soon after consent was provided, we equipped participants with the fNIRS sensors. Before each clip was played, participants had to stare at a cross displayed on the projector screen. During this time, we asked participants to clear their minds and rest for 2 minutes in order to capture a baseline for physiological responses and brain activity. The order of the movie clips (horror, comedy and action) were counterbalanced across participants. Once all clips have been watched by the participants, the experiment ended with a short debrief interview where we asked participants about their experience and emotions during each movie.

Measurements and equipment

Data was primarily collected using our fNIRS device, an the Octamon provided by Artinis, which records 8 localized channels of data based on 8 near infrared light sources operating on a range between 839nm and 751nm and 2 near infrared light receivers (see Figure 2). Measurements of oxygenated and de-oxygenated hemoglobin levels were recorded at a sample rate of 10hz.

Pre-processing the fNIRS data

A visual inspection was performed on the fNIRS data, and selected channels containing heavy noise (typically due to hair obstruction or bad sensor placement) were removed from the analysis. Three pre-processing techniques were then applied to the data. We first used a moving average filter with a window of 1 second to remove low level artefacts and noise such as heart related activity. We then used the CBSI filter [1] in order to remove movement and other artefacts. The pre-processing was then completed with normalizing the resulting data such that it is comparable between participants.

Once these steps were completed, we split the channels into two groups, the left hemisphere containing the average between channels 1 to 4, and the right hemisphere containing the average between channels 5 to 8.

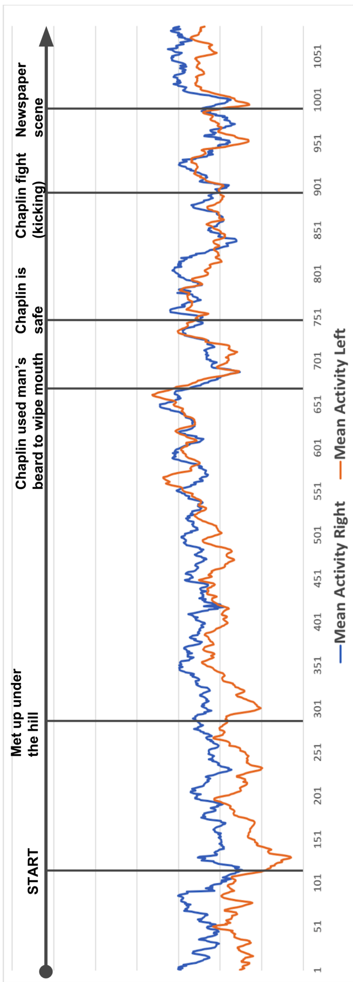

Figure 5: Mean brain activity during the comedy clip (across all participants: left vs right hemispheres).

RESULTS AND DISCUSSION

The aim of this study was to examine ISCs in the fNIRS brain activity measurements of participants watching movie clips from different genres. This analysis was further investigated in relation to the manually annotated moments of interests during each movie clip. These annotated moments can be seen as perpendicular lines in Figures 3, 5 and 4.

Correlation within the movies: ISC analysis

A series of Pearson correlation tests were conducted to check if ISC exists in participants' fNIRS data corresponding to left and right hemisphere activation. This resulted into 2 (left vs right activation) times 28 pairwise correlations (pairs of participants out of the total 8) for each movie. Table 1 shows the number of significantly correlating pairs, and the R value of the higher correlating pair.

We can confirm that we found ISC across all three movies, confirming the work done by Hasson et al. using fMRI [2]. The potential for using fNIRS instead of fMRI or EEG for such studies or experiences could be of great value to both, movie creators and viewers in a similar way to [4] and [6, 8], and may open up many new research directions due to the non-invasive and portability of the technique.

Limitations in this approach. Hasson et al. found varying levels of ISC depending on the ascetic value of film [2]. As one would expect, these correlations would vary between pairs of participants, having more and less strongly linked participants depending on their experiences during the movie clips. It was surprising to us to find that some of our correlations were negative, and in certain cases there were participants experiencing the movie in an "opposite way". Future work may present a more detailed investigation of why negative correlations exist when participants are watching the same movie. We believe that the key would be using the subjective information from the participants to find more about their experience during the movie.

The fact that we consistently found ISC on a relatively long video (45 min) gives a lot of hope and potential for using fNIRS in Neurocinematics. There may be higher correlations inside sections of data that relate to specific shots, cinematic techniques and narrative constructions which could be investigated in the future.

Correlations between movie clips

Participants have experienced the three clips differently as you can see in Figure 3, 4 and 5. The labels displayed in the figures are moments of interest selected by the researchers before this experiment. Some differences were also found in terms of how strong the correlations between participants was in the 3 clips. Table 1 shows how Violence clip generated the strongest correlation between two participants, followed by the Horror and Comedy. One could say that with increased ISC a director could get an overview of the effectiveness of the cinematics techniques used.

Table 1: ISC results including the number of correlations out of the 28 pairs and the correlation coefficient for the strongest correlation.

	Horror		Violence		Comedy	
	Left	**Right**	**Left**	**Right**	**Left**	**Right**
Significant p<0.001	26/28	16/28	22/28	21/28	19/28	21/28
Best ISC Pair	P5-P8	P1-P5	P1-P3	P3-P5	P7-P8	P1-P7
Pearson r=	0.5	0.406	0.531	0.515	0.438	-0.383

Limitations of this approach. Based on the lessons we have learned so far, we propose the following steps to evaluating certain movie clips effectively using fNIRS: (1) Inspect the movie for moments of interest and then consult the data; (2) Inspect the data, identify particular features such as peaks and then inspect the movie; (3) Collect subjective information from participants about interesting parts of the clips, then investigate the fNIRS data correspondent to those parts.

CONCLUSION

Our results confirmed that ISC exists in the fNIRS data while viewers are watching certain movie segments. This is in line with previous works of Hasson et al. [2] done with fMRI. Moreover we identified groups of participants with negative ISC and we propose a deeper analysis of how subjective data can be used to explain this.

Future work may also consider using fNIRS data as input to an interactive film. By identifying levels of ISC an interactive system may be able to sense when is the right time to change the course of a movie.

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