Unconsciously Interactive films in a Cinema Environment - a demonstrative case-study

Alexis Kirke, Duncan Williams, Eduardo Miranda, Amanda Bluglass, Craig Whyte, Rishi Pruthi, Andrew Eccleston

Plymouth University, Plymouth, UK

{Alexis.Kirke, Duncan.Williams, Eduardo Miranda, Amanda.Bluglass, Craig.Whyte, Andrew.Eccleston}@plymouth.ac.uk; RishiPruthi91@gmail.com

Corresponding author: Alexis Kirke, Room 310, Roland Levinksy Building, Plymouth University, Plymouth UK.

ABSTRACT

‘many worlds’ is a short narrative live-action film written and directed so as to provide four optional linear routes through the plot and four endings, and designed for showing in a cinema environment. At two points during the film, decisions are made based on audience biosignals as to which plot route to take. The use of biosignals is to allow the audience to remain immersed in the film, rather than explicitly selecting plot direction. Four audience members have a bio-signal measured, one sensor for each person: ECG (heart rate), EMG (muscle tension), EEG (‘brain waves’) and Galvanic Skin Response (perspiration). The four are interpreted into a single average of emotional arousal. ‘many worlds’ was the first live action linear plotted film to be screened in a cinema to the general public utilizing multiple bio-sensor types. The film has been shown publically a number of times, including a cinema premiere, and lessons learned from the technical and cinematic production are detailed in this paper.

Keywords: bio-signal monitoring, immersive interaction, interactive cinema, movies, emotion

1. interactive cinema

This paper documents the design and implementation of an engine for real-time detection of multi-modal biosignal responses from an audience in order to drive live editing of a film and its soundtrack. This generates streaming video for the purpose of audience affective manipulation whist they watch the narrative of an algorithmic short film written and directed by Alexis Kirke: ‘many worlds’. A key vision behind the film is that at fixed points in the plot the audience’s arousal level will be sampled and if it is below a pre-determined threshold, a more intense version of the next scene (as defined by the director) will be selected.

Most films are fixed – they are not changed by the audience during the film, and they in fact do not change once they are distributed. Interactive cinema allows the audience to influence or change elements of the film, so their experience can be different to others’. (Hales 2005) surveys cinematic interaction. Before the wide availability of digital technology, this was done manually. The film Kinoautomat (Činčera, 1967; Willoughby 2007) and the other films in this paragraph involve the audience consciously and explicitly selecting which narrative route to take, unlike 'many worlds'. Kinoautomat involved a moderator who would appear in front of the screen nine times during the film showing. The moderator asks the audience which of two choices they want to be followed for the next scene and there is a vote. Then the next scene is shown. The increasing availability of digital technology led to other solutions as found in the film I’m Your Man. Some mainstream cinemas were actually fitted with controllers for the film to allow people to vote on the main character’s decisions (Bejan 1992; Grimes 1993). However the approach did not take off. A more modern approach to interactive cinema can be found with those utilizing online video. For example ‘The Outbreak’ is an interactive film which is viewed online in a browser (Lund et al 2008; Wong 2008). The user can click to select actions at certain plot points. Discussions of interactive cinema more generally can be found in (Beacham 1995), (Lunenfeld 2004), and (Vesterby et al. 2006). The area of interactive audiovisual entertainment and games also has obvious overlaps with video games and in particular with the history of laser disk games (Fahs 2008) and some innovative highlights like Half Life (Bates 1998) and Dear Esther (Shaw 2012) . However the focus of this paper is on utilizing interactivity in the cinema.

The above examples, and most interactive cinema, has involved the audience consciously selecting film behavior. As observed in (Tikka 2006) and later (Gilroy et al. 2012), this can have the effect of reducing the immersion in the story. This led to Tikka et al. (2006) proposing the concept of enactive cinema where the audience do not consciously choose story directions. Tikka used heart-rate, breathing and movements of the audience to change the experience of an installation called “Obsession” (Tikka 2005). This work also proposed a framework for basing various dimensions of the cinema experience on audience non-conscious inputs. (Tikka et al., 2012) has also investigated the relationship between enactive cinema and neuroscience. Another pioneer in this non-consciously controlled form of story-telling has been Cavazza's group which has used eye gaze (Bee et al. 2010) and emotional neurofeedback (Cavazza et al. 2014) in narratives. Cavazza has also linked his interactive media research to non-entertainment applications. A key element in in Cavazza’s work is the use of “character” agents who inhabit the narrative space and have internal states and interactions. (Vesterby et al. 2006) used eye gaze to control the direction of a two minute video clip. The downside with eye gaze is that the technology is reducing in size and cost relatively slowly, and is still bigger than Google Glass. The use of bio-signals, a technology whose cost and size has been reducing more quickly, and which is now being incorporated into – for example – wearable items (Pantelopoulos et al. 2008).

(Castermans et al. 2012) measured audience bio-signals while they sat in a cinema to see if their emotional reactions could be detected. The results indicated that such detection was possible. (Kierkels et al. 2008) attempted to detect audience interest during movie scenes using various bio-signals but could not quantify the precise nature of ‘interest’. (Gilroy et al. 2012) has also attempted to address this in a simple computer-generated graphical drama using single viewers at a workstation. A related study is found in (Giakoumis et al. 2011) which attempted to detect ‘boredom’ in people playing a video game.

The power of both eye-gaze and bio-sensor approaches is that not only can they maintain peoples’ immersion, but they might potentially increase it by reactively manipulating plot, editing, or adjusting soundtrack elements in response to the audience dynamically. 'many worlds' is an attempt to extend previous work in this area. The work done in most interactive films differs to 'many worlds' by requiring conscious selection. The work done in non-conscious interactive films is extended by 'many worlds' into a public cinema environment with a larger number of sensors. 'many worlds' is also a new artistic experiment in the field of non-conscious interactive films that directly links the topic of the film story (how the observer can unconsciously affect the observed), with the mode of the film showing (in which the viewer unconsciously affects the viewed).

1. AFFECTIVE DETECTION

The ‘many worlds’ engine utilizes a system for detecting one dimension of emotion. The various models of emotion proposed by affective sciences offer complex, and still evolving, representations which can be used to map musical features to mood and vice versa. The dimensional approach to specifying emotion utilizes an n-dimensional space made up of emotion ‘factors’. Any emotion can be plotted as some combination of these factors. The 2-Dimensional ‘circumplex’ model of affect (Russell 1980), with emotion comprised of valence and arousal, is often utilized in emotional evaluation for music (Schubert 1999; Mattek 2011; Doppler et al. 2011; Rubisch et al. 2011). In many emotional music creation systems (Kirke 2011) these dimensions are used. In this model, emotions are plotted on a graph with the first dimension being how positive or negative the emotion is (valence), and the second dimension being how physically excited the emotion is (arousal). For example ‘Happy’ is high valence high arousal affective state, and ‘Stressed’ is low valence high arousal state.

 Self-reporting arousal on such a model (Vuoskoski et al. 2011; Eerola et al. 2010) presents problems for the presentation and development of responsive, immersive music — and particularly as in this case, responsive immersive cinema — in that they force the interruption of any narrative. The use of a range of biosensors to meter affective responses (Trost et al. 2011; Rossignac-Milon et al. 2010) from the cinema audience and respond accordingly presents the opportunity to bypass self-reporting or self-selection of material (for example, in most interactive films or the feature film world when DVD audiences can select alternative endings by a root level navigation menu) in favour of an affectively driven, emotion-synchronous model.

 ‘many worlds’ attempts this with a system that does not utilize valence, focusing on the measurement of arousal as a time-based vector. Important factors of the movie experience (beside emotions) fall outside of what such a system can take into account. Aspects of the viewers’ cognitive processes, aesthetic dimensions, evaluative reactions, etc. – which are central parts of the movie experience – fly under the radar of the system. However arousal was chosen for this initial implementation because most biosensor research in the past has been more successful in detecting emotional arousal than emotional valence (Sammler et al. 2007).

 As has been mentioned, in emotional measurement, arousal is what distinguishes Happy from Relaxed, and Angry from Depressed. It measures the physical activity of the emotion. So if a watcher is feeling positive about a film, an arousal-maximizing strategy will make them feel Happy rather than Relaxed, or Angry rather than Depressed. This is obviously a fairly blunt instrument but provides a first in-road into implementing emotion-control strategies.

 The arousal vector is involved in a constant feedback loop, as ongoing arousal is continuously ‘pinged’ in real-time within the limits of a preset buffer. This vector is evaluated at various time values, mapping the arousal and time value to a video selection, creating a range of possible narrative routes through the film for the audience. The entities involved in this process are time and a high-level arousal estimate (at a lower level, raw bio-signal data), with the relationship between these entities determined by the director in order to sustain or increase audience arousal whilst watching the film.

1. production

**3.1 Story and Pre-production**

Given the planned bio-signal reactivity of the film, the writing of the 'many worlds' script had a number of stages. A concept had already been developed concerning a person putting themselves in a box as a form of Schrodinger’s Cat experiment (Schrodinger 1935). This was combined with the concept of a film that was non-consciously adapted by parts of its audience: “the observer affects the observed”, to implement the desired creative concept of content mirroring form. In other words the film about an issue that was often interpreted as the “observer affecting the observed”, and the technology involved in the viewing gave some form of unconscious power to the audience observer.

 The first part of the process involved writing a normal short film story. Readers and viewers are used to experiencing stories written as an organic whole (Smiley et al. 2005). Thus it was considered that if a multipart multi-branching story was attempted from the outset, such a unity would be hard to achieve. So the process was to first write a single story, and then to develop it into a multi-path experience.

 In summary, here is what the audience experience at the heart of the story: two students Charlie and Olivia arrive at the apartment of Connie on her birthday. They find Connie, a physics student, has sealed herself in a coffin-sized box with a cyanide gas-capsule connected to a Geiger counter. At any time a large enough burst of cosmic rays in the atmosphere could trigger the cyanide and kill Connie; in fact it could already have happened. Charlie – also a physics student – realizes Connie is performing a twisted version of a famous quantum physics experiment about the nature of reality, but one that was never meant to be performed in real-life. During the continuation of the film – through clips from their phones and a "mysterious" camera observing the room – the audience learn the true reason for the experiment.

 After writing the core story various background elements crystalized. These elements had an impact on writing the alternative story routes. Charlie is a narcissist who is dating Connie and treating her very badly, driving a troubled woman to the edge of her sanity. Olivia, Connie’s best and most trusted friend, slept with Charlie as a one-off a few months before the events of the story. But – unbeknownst to them – Connie found out. Connie became obsessed and depressed by the idea that her best friend was now also her greatest enemy. Charlie's betrayal also made her believe that her beloved must despise her. In a bizarre attempt to rationalize these contradictions Connie creates a lethal scenario. Charlie and Connie clearly don’t realize the pyschological damage they have done to Connie, hence their walking into the scenario.

 Connie has set-up the situation so she is sealed in an airtight box, unable to see or hear what is going on in the room. The following information is only revealed during "twists" of certain endings of the film. The room itself is the “box”, and the gas and detector – which Charlie and Olivia think is connected to the box, in fact feeds into the air of the room. Thus Charlie and Olivia are in the “box”. In an analagous way to Schrodinger's cat being alive and dead at the same time in it’s box, Connie wants to come to terms with her friends contradictory attitudes to her, to make them both friends and enemies at the same time. This, together with Connie’s desire to punish them, makes her create a Schrodinger's Box for her closest companions.

 Once the background became clearer, three more versions were written. This involved identifying possible split points in the script. The first split point came from the fact that when Charlie and Olivia arrive at Connie's house, Connie does not answer the door. Charlie has a key (because he is her boyfriend). Olivia says it is rude of them to walk in. So the first split is: whether Olivia allows Charlie to pressure her to come into the house straight away, or otherwise walks in a few minutes later. Another narrative split occurs when Charlie tries to make Olivia drink vodka as part of an experiment he is using to demonstrate the Schrodinger's cat experiment (which he thinks Connie is trying to perform on herself). Olivia either takes a drink or refuses to take a drink. These two splits lead to four possible endings.

 The story is thus driven by Olivia's strength of character in relation to the obnoxious Charlie. She has two main opportunities to resist Charlie's behavior. The route the film takes depends on how many of these opportunities she takes, and thus which of the four endings happen. Olivia thereby controls the narrative direction. The results of the four endings emulate the result of an unentangled two Schrodinger box experiment, where Olivia and Charlie are the two cats: either neither, or one, or both die, as seen in Table 1.

**3.2 Production**

While attempting to transition from four detailed story descriptions to four formal scripts, it became clear how hard it would still be to write full scripts based on the multiple stories. Furthermore the writer had become aware of two feature film projects which were based on guided-improvisation by the actors involved (Goldstein 2013; Doto 2009). He investigated these projects and decided to utilize guided improvisation. The two main actors who were finally chosen both had experience of improvising together. Because of this approach, there was a longer process of rehearsal with the actors than would normally be found for a short film. Once on set the writer / director began to understand why this process worked so much better than the attempt for one person to write four scripts. The human brain is used to considering multiple possible paths into the future (Tanaka et al. 2006; Bubic et al. 2010) when taking actions, but it is not used to developing four different paths based on drama going in to the future. Most of our experience is of telling and reading single path story. This meant that the actors actually developed a better model of the multi-path story than the writer did, as they were thinking more as the agents involved in the actions; whereas the writer was taking a dramatic multi-path overview that does not come naturally to us in our brains or culture. In multiple instances, the director had to ask the actors where they were in the paths, or what happened in such and such a path. In spite of this, one of the feared eventualities came to be. When viewing cuts of the film it was clear that one of the endings was significantly weaker than the others.

 During editing, it took a while to explain what was required of the professional editor. He had never worked in such a multi-path film before, but developed a format for working with standard editing tools to edit a multi-route film.

**3.3 Soundtrack**

A soundtrack was composed by the writer / director for each of the film clips had been marked up for arousal. The electronic composition was generated with binaural beats. These involve two pure tones with frequencies that are slightly different. This creates the psychoacoustic effect of a beating slowly modulating their frequencies. The apparent frequency of modulation increases as the difference in pure tone frequencies increases. Although there has been work suggesting that binaural beats can affect mood (Owens et al. 1998), they are used here as an aesthetic choice by the composer, not with any scientific claims of mood manipulation. The use of such an abstract soundtrack is not so unusual. One key example of how audiences are becoming more used to such soundtracks is the sparse sub-bass soundtrack found in the mainstream feature film Paranormal Activity 2 (Williams 2010).

 The composition for ‘many worlds’ was done intuitively based on scene drama, not based on the arousal mark-ups. However an interesting structure emerged, as shown in Figure 4 (this figure will be explained in more detail later). Given that film Clip 1.2.1 was marked up as having a higher arousal than Clip 1.2.2, it was found in post-analysis that the soundtrack had a maximum higher energy peak for the clip whose arousal was marked up as being higher (i.e. Peak 0.105 > Peak 0.052). Similarly with Clip 1.1.1 being marked up as higher arousal than Clip 1.1.2, the peak energy of the soundtrack turned out to have a higher energy in the higher arousal-marked clip (i.e. Peak 0.0975 > Peak 0.0920).

1. SYSTEM OVERVIEW

Four sensors are used to monitor participating audience members physiological reactions in real-time. These responses are combined in an affective estimation algorithm to give a moving average value for audience arousal, which is compared with an arousal threshold at various decision points in the narrative to give control data that maps the next part of the narrative the audience will watch, seamlessly creating an edit ‘on-the-fly’. Previous computer music research has made use of similarly collected bio-signal data as control inputs for music with emotional correlations. Such affective correlations to the selected bio-signals are well documented in literature (Le Groux et al. 2009; Salimpoor et al. 2009). A flow-chart illustrating the complete signal flow is given in Figure 2. The system broadly comprises three sections: Biosignal metering, Arousal estimation, and Video editing (arousal synchronous narrative selection). These sections are explained in more detail below.

 Four biosensors were utilized, all of which have implicated in detecting affective arousal:

1. Electrocardiograph (EKG), indicating mean heart rate from the participant above calibration threshold, averaged over 2-10 beats (Salimpoor et al. 2009)
2. Electromyograph (EMG), indicating muscle tension from the right forearm of the participant, as a mean within each buffer(n) (Hoehn-Saric et al. 1997)
3. Electroencephalograph (EEG), using three electrodes to indicate frontal brain activity, filtered to give only the alpha region using a band-pass 8-12kHz two-pole filter (Schmidt et al. 2001; Owens et al. 1998). As in (Owens et al. 1998) the natural logarithm of the alpha data was calculated and multiplied by -1
4. Galvanic skin response (GSR), giving a normalized value for perspiration on the left wrist and forefinger of the participant (Salimpoor et al. 2009)

Much research has indicated that GSR (Kim et al. 2008) is almost linearly related to emotional arousal. Similarly there have been multiple studies that relate EEG asymmetry to valence, and EEG frontal power to arousal (Schmidt et al. 2001; Reuderink et al., 2013). Heart rate has been linked to emotional positivity and negativity (Ekman et al. 1983). In particular (Kim et al. 2008) supported that higher heart rate was linked to increased fear and anger, both high arousal emotions. Thus a detection of increased EEG frontal power, skin conductivity and heart rate, are indicative of increased emotional arousal. Muscle measurements (ECG) have also been used to detect tension (Kim et al. 2008).

* 1. Bio-signal metering

Sensor responses are digitized and passed to Max/MSP as raw data in real-time. Each data stream is calibrated to remove background noise using adjustable maximum and minimum input level outliers with EEG and GSR responses, and a simple noise-gating threshold for EKG and EMG responses. The responses from each sensor were then passed to an affective estimation routine to determine an instantaneous audience arousal value with which to carry out video selection.

* 1. Arousal estimation routine

Affective arousal is estimated from the four biosensors as a moving average. The output from each sensor is normalized before being summed across a nominal buffer, as shown in below, where A(n) = estimated arousal for buffer (n):

 

 The values of the four inputs are normalized between 0 and 1, however they are not transformed in any other way. This means that in essence four non-linear processes with different dynamics are being linearly combined. To mitigate against the effects of this, each process can be adjusted during calibration with the four audience members. Thus the faster moving dynamics of the muscle tension monitor can be reduced in effect so it does not overwhelm the slower moving GSR. Similarly any single measure can be prevented from saturating the sum. Another issue is that there is a difference between muscle tension and the other three measures. Frontal EEG, GSR and heart rate have all been related to higher arousal. Whereas the muscle tension measure is in this case based on a less standard concept, which has not been tested, which is the idea of arm tension caused by gripping - for example a seat arm. It is planned in future work to investigate the advantages of non-linearly transforming and combining the four inputs.

 Results from the arousal estimation algorithm are compared with a pre-determined arousal threshold (AT) in order to generate a control message for selection of video playback in the video mapping portion of the code.

* 1. Video editing: arousal-synchronous narrative selection

The first iteration of the Jitter-based video playback engine was designed in order to switch between three different narratives ‘on-the-fly’ by direct comparison of arousal values with the pre-determined arousal threshold (AT). In the finished system, video timecode is also used as a mapping entity such that time and arousal are mapped to video selection and playback, creating an arousal-synchronous method of video narrative selection. 7 clips in total are used in this system, as illustrated in Figure 3.

 Table 2 and Figure 3 shows that the 7 clips present four possible ‘routes’ for the audience, through two branches or ‘split’ points based on timecode values, t(s2) and t(s3) respectively. The arousal buffer, (n), is reset after each of the split points as part of the affective estimation algorithm. This real-time detection of arousal allows the filmmaker to select narrative according, and in direct response to, the audience’s arousal. This allows the film to adapt to the audience, and the filmmaker to discretely target the induction of arousal in the audience, maintaining or increasing arousal through the narrative. The choice of trying to increase audience arousal was an artistic decision by the filmmaker (writer / director). Other strategies that could have been chosen include minimizing arousal or creating a certain arousal trajectory.

 The marking-up of video clips as to which expressed higher or lower arousal, was done by the filmmaker. This was a subjective process and part of the artistic decision making, as there are no agreed methodologies for measuring such ‘plot arousal’. The story involves three lead characters, and takes place in two locations: one outside and one inside in a single room. Clips 1.1 and 1.2 in Figure 3 are differentiated by action taking place with one or with two people respectively. The two-person clip was considered to have a higher arousal due to their interactions. Clip 1.2.1 was considered to be higher arousal than Clip 1.2.2 for reasons which will not be documented here, so as not to reveal the endings: the writer / director judged Clip 1.2.1 to be higher arousal for dramatic reasons. Similarly with the decision that Clip 1.1.1 was higher arousal than Clip 1.1.2.

 Four modifier values were applied to ensure correct clip selection at the pre-determined split point timecode values:

*[beginning of film +1]*

*[first clip reached timecode +1]*

*[reached first split point +2]*

*[reached second split point +3]*

which, combined with a modifier value for arousal (determined by comparing the moving average arousal with the selected arousal threshold):

*[arousal >= arousal threshold +1]*

*[arousal < arousal threshold +0]*

generate a unique reference number for each of the decision points. This unique reference is used as a control message to select the relevant clip and begin playback in the Jitter video engine.

*clip URN 1 = +1 (beginning of film, no arousal)*

*clip URN 2 = +1 (beginning of film) +1 (first clip reached timecode)*

*clip URN 3 = +1 (beginning of film) +1 (first clip reached timecode) +1 (arousal>threshold)*

*clip URN 4 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point)*

*clip URN 5 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point) +1 (arousal>threshold)*

*clip URN 6 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point) +3 (reached second split point)*

*clip URN 7 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point) +3 (reached second split point) +1 (arousal>threshold)*

1. RESULTS

**5.1 Laboratory Environment**

An experiment was done with 6 viewers: five males / one female, ages 20-25. The bio-sensors were calibrated for each participant by setting the threshold separately. This was done manually by observing their bio-signal activity for a few minutes after they first put on the sensors. By the time of these experiments a significant amount of informal experience had been gained by the experimenter in various applications with the final software. The viewers watched the film in a laboratory environment on a computer monitor, with the system adapting to their bio-signals. After completion of a full film viewing, the participants watched the other three endings which they had not yet seen. This time without wearing biosensors, as it did not make much sense to take biosensor readings out of context, i.e. without the preceding parts of the film. The experiment was not repeated multiple times with a single participant, as narrative impact would change over multiple viewings in unpredictable ways.

 After watching the film the participants filled out a questionnaire anonymously. The questions were:

*1. Which ending (or type of ending) did you find had the highest physical intensity?*

*2. Which ending (or type of ending) did you find had the lowest physical intensity?*

*3. Did you feel any of the endings were particularly narratively weak? If yes, which one(s)?*

*4. Did you feel any of the endings were particularly narratively strong? If yes, which one(s)?*

*5. Which was your favourite ending?*

*6. Which was your least favourite ending?*

*7. Did you find Olivia’s agreement to drink the vodka a more intense narrative experience than Charlie’s drinking of it? Or no difference?*

*8. Do you have any memory / comments on the soundtrack or its impact?*

*9. Do you have any general comments?*

 Tables 3 and 4 highlight answers to a number of the questions. The first thing ascertained was whether the writer / director’s mark-ups of ending intensities had any relationship to those experienced by the viewers. Table 3 shows the result. The Table shows that 4 of the 5 who responded agreed with the writer/director’s interpretation of the ending with least arousal (ending A). 3 of the 5 agreed that D was the highest arousal ending. Another viewer said that C was the highest arousal, whereas the director said that C was the second highest arousal ending. So only 1 respondent out of 5 entirely disagreed with the writer/director’s interpretation of arousal. In fact – respondent 3 takes the entirely opposite view to the writer / director, but for a specific reason. They said: “Strangely, I found ending A to be the highest. I believe this was a result of the acting in the other endings being weak, which made them feel a bit silly and took away from the intensity of the situation” and “Ending D, just felt the acting and the filming shot made it feel silly.”

 When asked if they felt any of the endings were particularly narratively weak, only participant 2 stated a preference – that ending C was weakest. The opposite question was asked (narratively strong endings) and there was no consensus. Though interestingly one respondent stated that ending C was strongest, contradicting the two participants mentioned above that found it the weakest ending. This highlights the well-known subjectivity of the experience, but also shows that the results of Table 3 – which support a broad agreement between the writer/ director and the viewers on arousal – are not trivial. When the question was put in a different form – what was their favorite ending and least favorite ending – there was once again no consensus at all.

 The viewers were also asked if they perceived a difference in arousal between the two mid-point selections. None of them did. This raises the question of the validity of the whole mid-point selection. There were also no strong feelings about the impact of the soundtrack. But there was a general opinion – when asked for general comments in the final question – that a higher production budget could have significantly improved the experience.

 In terms of the functionality of the bio-sensor readings, Table 5 details the biosensor responses at the key decision point. Participants 1, 4 and 6 all were shown the lowest arousal ending by the system (which 4 and 6 concurred was actually the lowest arousal ending). Participants 3 and 5 were shown the higher of A and B in terms of arousal. As detailed earlier, the system could only choose between A and B, or between C and D – depending on the mid-point choice. So all participants except number 2 were shown the lower arousal of the mid-point choices; thus all participants except one were over the arousal threshold at the mid-point.

 Then after this point – focusing on the five participants excluding number 2 – participants were roughly equally divided in whether they were shown A or B, though one more was shown A (the lowest arousal). The fact that most participants followed the lowest arousal story route could be because they felt unrelaxed in the laboratory environment – thus increasing their arousal measurements. Normal film viewing environments would be much more comfortable. It can be seen that arousal on average increases between the mid-point end credits. Ideally we would want it to decrease for participants 1, 2, 4 and 6, and increase for 3 and 5. However it only decreases or stays the same for 2, though does increase as desired for 3 and 5. So participants 1, 4 and 6 – 50% of the participants – did not react the system as designed.

 There could be a number of reasons for this: the threshold approach, the processing and implicit weighting of raw bio-data, the experimental environment, and the production budget of the film. Further work would need to be done to test these elements. The results so far support that it is feasible for a writer / director to assign arousal levels to parts of a film, but the results either:

1. Do not support that the changing of plot based on this can actually impact viewer arousal in the expected way; and/or
2. Do not support the arousal measure used with the bio-signals.

**5.2 Public Cinema Environment**

Outside of the laboratory environment, and in terms of sensor usage in the cinema environment, it became clear that the length of sensor leads needed to be extended. Some of the four audience volunteers were found to have to sit in a less comfortable position because of the lead lengths. In later showings this was corrected and the volunteers were much more comfortable. Some people also found the EEG headset uncomfortable, and one person found the muscle tension monitor uncomfortable. The sensors most amenable to calibration were heart rate, and also the muscle tension monitor, as the audience member could be asked to directly flex the area of muscle involved. EEG was the most difficult to calibrate because of the noisiness of the data and its artifacts, in fact a key addition to the system in future would be an artifact removal algorithm. GSR was also difficult to calibrate quickly because it was such a slow moving signal. The GSR also contributed the least to story pathway selection because of its slow-moving nature. The heart rate sensor, as well as being simple to calibrate, was the simplest to use. The downside was there was sometimes a false triggering of a heartbeat, so a suitably long averaging window needed to be used to filter these out.

1. CONCLUSION

This paper has described the motivation, pre-production, production, and technical development behind a multi-biosensor live action film 'many worlds', designed for and shown in a cinema environment. Issues of story, direction, and biosensor interpretation have been discussed. Additionally an artistic motivation concerning the analogy of story content and mode of viewing has been highlighted. Small scale laboratory tests support that directors may be able to predict which endings an audience member would find most "arousing", but were inconclusive concerning how appropriately the bio-sensor metering was selecting them.

 The system described is capable of playing back full HD video and synchronous audio whilst monitoring and calculating the arousal estimate in real-time and was premiered to a live cinema audience at the Peninsula Arts Contemporary Music Festival, UK, on February 23rd 2013. Further showings were later given at BBC Research and Development at MediaCity UK, London Free Film Festival, and at PrintScreen Festival in Tel Aviv, Israel. Footage from the premier is available (Al Jazeera 2013).

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|  |  |  |  |
| --- | --- | --- | --- |
|  | **At front door:** | **Olivia weak** | **Olivia strong** |
| **Vodka drinking:** |  |
| **Olivia weak** |  | O -C - | O -C + |
| **Olivia strong** | O -C - | O +C - |

**Table 1**. Results of Olivia's various decisions. O for Olivia, C for Charlie. +/- refers to live or die.

|  |  |  |
| --- | --- | --- |
| **Pathway** | **Clips Played** | **Arousal <> Arousal Threshold** |
| 1 | 1, 1.2, 1.2.1 | Low arousal, Low arousal |
| 2 | 1, 1.2, 1.2.2 | Low arousal, High arousal |
| 3 | 1, 1.1, 1.2.1 | High arousal, Low arousal |
| 4 | 1, 1.1, 1.2.2 | High arousal, High arousal |

**Table 2**. Showing four possible routes through seven video clips, with corresponding arousal estimations

|  |  |  |  |
| --- | --- | --- | --- |
| **Participant**  | **Their Perceived Highest Arousal Ending** | **Their Perceived Lowest Arousal Ending** | **Writer / director’s perceived arousal for endings from high to low** |
| 1 | No response | No response | D (highest) |
| 2 | D | A | C |
| 3 | A | D | B |
| 4 | D | A | A (lowest) |
| 5 | D | A |  |
| 6 | C | A |  |

**Table 3**. Writer / Director and Viewers’ perception of arousal of different endings

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Participant**  | **Highest Ending** | **Lowest Ending** | **Ending Seen** | **Narr.****Strongest** | **Narr. Weakest** | **Favourite** | **Least****Favourite** |
| 1 |  |  | A  |  |  |  |  |
| 2 | D | A | C |  | C | D | A |
| 3 | A | D | B |  |  | A | D |
| 4 | D | A | A | D |  | A | D |
| 5 | D | A | B  |  | C | B | C |
| 6 | C | A | A | C |  | C | B |

**Table 4**. Relationship between Viewers’ Responses

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Participant** | **Pre-final Segment Normalized Arousal** | **Normalized Arousal at Credits** | **Final Film Segment****Auto-selected** | **Highest or Lowest** |
| 1 | 1.06 | 1.08 | A |  |
| 2 | 0.87 | 0.87 | C | Neither |
| 3 | 0.846 | 0.854 | B | Neither |
| 4 | 0.64 | 0.93 | A | Lowest |
| 5 | 0.72 | 0.83 | B | Neither |
| 6 | 0.69 | 0.77 | A | Lowest |
| Mean | 0.80 | 0.89 |
| SD | 0.15 | 0.11 |
| Var | 0.02 | 0.01 |

**Table 5**. Biosignal responses

**Figure 1**. Section of script used by actors; near the top of this page the two possible paths each split into two again.

**Figure 2**. Flow chart overview of system: Biosignal inputs are calibrated, normalized, and averaged to determine values for synchronously selecting video outputs

**Figure 3**. Illustrating arousal threshold and ‘split’ points – editing decisions are made at predetermined timecodes by comparing the estimated audience arousal from the four biosensors to an arousal threshold and selecting a bipolar route through to four separate narratives.

**Figure 4.** Parallel soundtrack structure using binaural beats sounds. Peaks indicate the maximum sample peak in the soundtrack in a clip.