

Event-Related Potentials induced by Cuts in Feature Movies and their Exploitation for Understanding Cut Efficacy

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Abstract—In this paper, we analyse the Event-Related Potentials (ERPs) produced by cuts where the scenes before and after the cut are narratively related. In tests with 6 participants and 930 cuts from 5 Hollywood feature movies we found that cuts produce a large negative ERP with an onset 100 ms after a cut and a duration of 600 ms, distributed over a very large region of the scalp. The real-world nature of the stimuli makes it hard to characterise the effects of cuts on a trial-by-trial basis. However, we found that aggregating data across all electrodes and averaging the ERPs elicited by cuts across all participants (a technique we borrowed from collaborative brain-computer interfaces) produced more reliable information. In particular we were able to reveal a relationship between the length of shots and the amplitude of the corresponding ERP with longer scenes producing bigger amplitudes. We also found that amplitudes vary across and within movies, most likely as a consequence of movie directors and editors using different choices of cutting techniques. In the future, we will explore the possibility of turning these findings into a collaborative brain-computer interface for aiding test screening by evaluating whether specific cuts have their intended effect on viewers.

I. INTRODUCTION

Film editors introduce cuts in movies to give viewers the impression of continuity by joining scenes or actions that are not continuous [1], [2]. These edits and other forms of structural features (i.e., characteristics of movies that can be defined independently from the type of content) influence attention and cognitive processes.

Context changes (i.e., cuts in which the scene after the cut is not directly related to that preceding it) and *related cuts* (i.e., cuts in which the scenes before and after the cut are narratively related) affect attention in different ways [3], [4]. The latter provide less new information and thus impose a lower cognitive load than unrelated cuts, facilitating retention of new information. Retention of new information follows an inverted U-shape profile with respect to scene length, showing that introducing more related edits can help retain clip content provided that they are not overused [3], [4], [5].

Electroencephalography (EEG) has been used in the study of cuts to some extent. Alpha blocking (i.e., a decrease of power in the alpha band, which lies approximately between 8–12 Hz) is related to an increase in the intensity of attentional engagement, and has been shown to be associated with scene changes (e.g., [3], [6], [7], [8], [9], [10]). This

increase in attention is (at least partially) caused by the orienting response [3], an automatic shift of attention caused by unexpected stimuli, induced by cuts.

In the presence of cuts that produce very stark discontinuities, e.g., if an unexpected explosion occurs, a defensive (or “fight or flight”) response may occur [2], which has the opposite effects of the orienting response. At the other end of the spectrum, some cuts go completely unnoticed by viewers, a phenomenon known as *edit blindness* [1].

Cuts have also been associated with Slow Cortical Potentials (SCPs) and other Event-Related Potentials (ERPs) [11]. Unrelated cuts (equivalent to switching channels while watching television) produce SCPs that are bigger in amplitude than those produced by related cuts [11]. Moreover, in contrast to unrelated cuts, related cuts do not elicit P300 ERPs (related to involuntary shifts of attention).

Another ERP that has been detected while presenting video stimuli is the N400 [12], [13], which is linked to meaning processing, having bigger amplitudes when a new element is incongruent with the context built by previous stimuli [14]. The N400 is a negative peak with a latency of around 400 ms after the presentation of the stimulus. In movies (where the incongruent information appears as a new scene, following an edit or cut) an N400 can be detected over frontal, central and parietal regions [12].

While these results indicate that cuts produce characteristic ERPs, these have always been studied in either averages or grand averages (i.e., after averaging hundreds of individual responses across several participants). We wondered to what degree it would be possible to detect the ERPs induced by cuts in movies on a cut-by-cut basis through some form of Brain-Computer Interface (BCI). Also, we wanted to perform an analysis of ERPs induced by cuts in feature movies: something that surprisingly had not been done before, to the best of our knowledge. Of course, the real-world nature of the stimuli makes this a very hard task.

Because of the noise affecting EEG recordings, in BCI it is common to perform ERP averages across a small set of repetitions of the same stimuli (typically 3–6 repetitions). This has the benefit of increasing the signal-to-noise ratio (SNR) of the signals, leading to more accurate decisions. However, there are cases where this technique cannot be used. This is certainly the case when studying the brain’s response to specific events in movies, because the reaction to the first presentation of an event is often different from those produced in further repetitions of the event [15], [16].

For this reason, in this study we decided to borrow a technique commonly used in collaborative BCIs (cBCIs) [17],

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[18], [19], [20], [21], [22]: *averaging EEG signals from multiple participants on a trial-by-trial basis* in order to increase the SNR. This is done very rarely, if at all, in psychophysiology studies.

This paper is organised as follows: section II describes the setup of the experiment and the processing that was performed after data collection. In section III we present the results of our ERP and statistical analysis of epochs. Section IV presents a discussion of the results obtained. Finally, section V ends the paper with some closing remarks and some ideas for future work.

II. METHODS

A. Data Acquisition

We gathered data from 6 volunteers (aged 24–31, mean age = 26.5 years old, 1 female) with normal or corrected-to-normal vision. They all signed the consent form approved by the Ethics Committee of the University of Essex.

Participants were seated at approximately 100 cm from a 20" LCD screen where the stimuli were presented. EEG data were acquired by using a BioSemi ActiveTwo system with 64 electrodes mounted in a standard electrode cap following the international 10-20 system (impedance <15 k Ω). The EEG was referenced to the mean of the electrodes placed on the earlobes. The initial sampling rate was 2048 Hz. Data were band-pass filtered between 0.15 and 40 Hz before down-sampling to 128 Hz.

Correction for eye blinks and other ocular movements was performed by applying the standard subtraction algorithm based on correlations [23] with the average of the differences between channels Fp1 and F1 and channels Fp2 and F2.

B. Stimuli

We used 12 movie clips extracted from several 5 feature movies (see Tab. I). We restricted our study to related cuts as these are the most interesting and frequent.

The clips were displayed at full screen at a 1680×1050 resolution. Audio was played by means of a pair of high quality desktop speakers (Edirol Roland MA-15D). The average sound level measured from the participant's position (2 m from the sound sources) with an Arco CR:262 device was 55.1 dBA, with a maximum level of 64.6 dBA (the reference sound level in the quiet room was 30.7 dBA).

Since we wanted to look at ERPs that are spontaneously elicited in response to cuts, participants were asked to watch the movies, without performing any specific task.

C. Signal Processing

For ERP analysis, 1000 ms epochs were extracted from the signals. For the "cut" condition, epochs started at the time of a cut that was not followed by another cut within 1000 ms. The first scene of each clip was discarded. This resulted in 930 "cut" epochs (from the original 1429 cuts). For the "non-cut" condition, epochs were the 1000 ms preceding cuts that did not have another cut within the 1500 ms before them so as to minimise the effect of ERPs from previous cuts. This resulted in 566 "non-cut" epochs. Epochs were referenced to the mean of the 200 ms interval preceding them.

TABLE I
DETAILS OF THE MOVIE CLIPS USED IN THE EXPERIMENT.

Movie	Beginning	Duration (sec)	# cuts used
Iron Man 1 (IM1)	0:02:16	83	34
	0:38:34	137	49
	1:17:16	124	43
Iron Man 3 (IM3)	0:22:45	61	13
	0:25:29	51	13
	0:34:09	330	133
	1:41:59	846	330
Sherlock Holmes (SH)	1:23:30	152	17
The Expendables (Exp)	0:43:08	89	42
	1:22:15	429	179
V for Vendetta (Ven)	0:10:18	46	20
	2:01:55	155	57

III. RESULTS

A. ERP Analysis

Fig. 1 shows the grand average of the ERPs at FCz (a representative channel) for the cut and non-cut conditions and the scalp distribution of voltages at 190 ms and 500 ms after a cut for each participant.

A large negative ERP starting 100 ms after the cut and extending until after 700 ms is clearly present in Fig. 1(a) in the cut condition that is not present for non-cuts. The scalp maps in Fig. 1(b) show that this component is present in frontal and central electrodes, extending, in most participants, also to posterior sites.¹

In order to attempt a more detailed, cut-by-cut, analysis, we then used the cBCI technique of averaging signals across participants. For each epoch in the averaged signals, we calculated the median amplitude in the time interval 380–420 ms across all electrodes, which we will term *Post-Cut Negativity* (PCN) hereafter. We then compared these quantities for cut and non-cut conditions with a two-sample Mann-Whitney test. Median amplitudes of the PCN for cuts and non-cuts were -1.77 and 0.09 μV respectively; the distributions in the two groups differed significantly ($W = 369, 415$, $p < 2.2 \times 10^{-16}$).

B. Influence of Movie and Cut Characteristics on Post-cut Negativity

We found that PCNs vary across movies as illustrated in Tab. II which reports the p values obtained from a two-sided Mann-Whitney test comparing PCNs across different movies for the cut condition.

We explored whether scene length and cut luminance could be factors in determining such differences in PCNs:

1) *Scene Length*: We studied the effects of scene or shot length (period between two cuts) on PCNs. Fig. 2 shows that the median scene length and the median PCN for different clips and movies are correlated (Spearman's $\rho = -0.7$, $S = 486.3$, $p = 5.6 \times 10^{-3}$). Due to noise, the PCN for individual cuts shows a smaller correlation with the length of the shot

¹This ERP is unlikely to be associated with eye blinks because these would manifest as large positive deflections at frontal electrodes with much reduced effects at central and posterior sites (neither of which is the case in Fig. 2), and we have corrected for ocular movements and eye blinks.

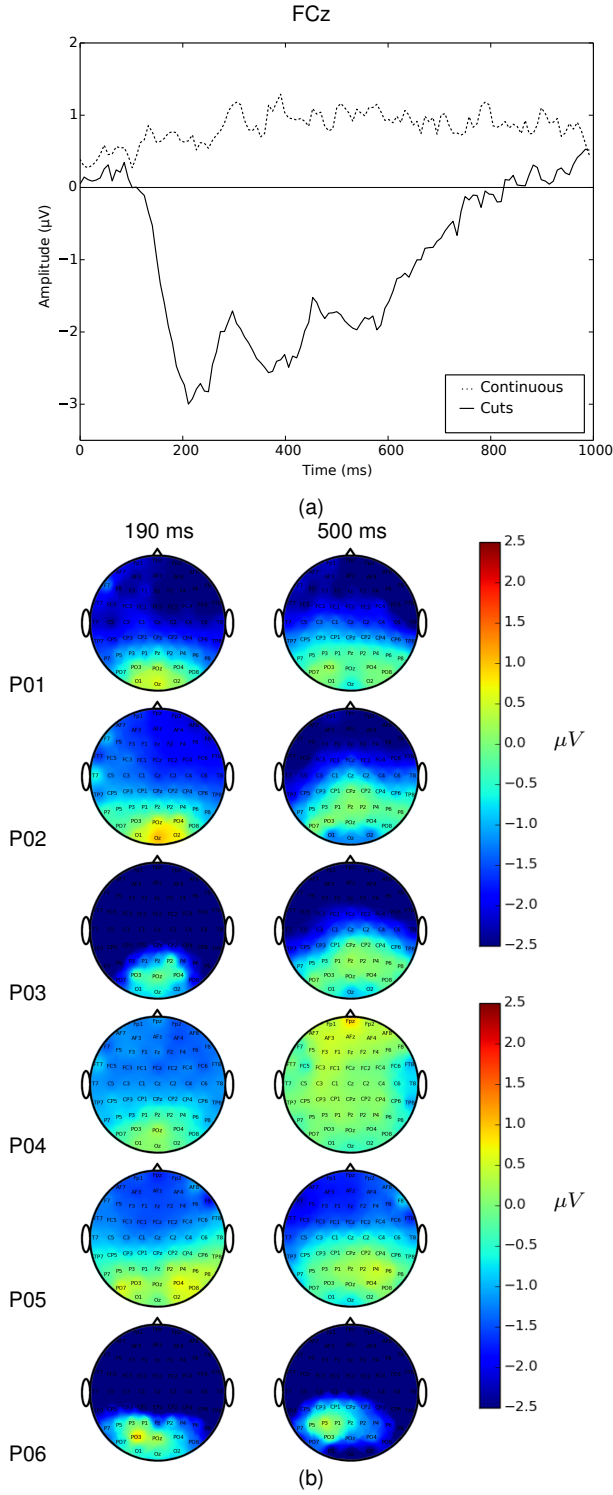


Fig. 1. (a) Grand average plot for cuts and non-cuts at electrode FCz; (b) scalp distributions of voltage amplitudes at 190 and 500 ms.

but this is highly statistically significant (Spearman's $\rho = -0.23$, $S = 1.7 \times 10^8$, $p = 2.4 \times 10^{-13}$).

2) *Luminance*: We calculated the correlation between PCN and the difference in average luminance between the last frame preceding a cut and the first after the cut, but

TABLE II
P VALUES FROM A TWO-SIDED MANN-WHITNEY TEST WITH BONFERRONI CORRECTION FOR PCNs ACROSS DIFFERENT MOVIES.

	<i>IM3</i>	<i>SH</i>	<i>Exp</i>	<i>Ven</i>
<i>IM1</i>	0.39	4.9×10^{-2}	5.2×10^{-3}	1.9×10^{-2}
<i>IM3</i>	–	1.7×10^{-2}	1.1×10^{-2}	5.7×10^{-2}
<i>SH</i>	–	–	1.5×10^{-3}	3.1×10^{-3}
<i>Exp</i>	–	–	–	0.74

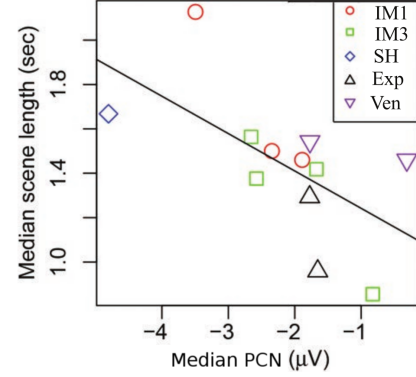


Fig. 2. Median scene length as a function of median PCN.

found no correlation between these two factors (Spearman's $\rho = 0.13$; $S = 1.3 \times 10^8$, $p = 0.13$). Similarly, no correlation was found between the average luminance of the first frame following a cut and PCN (Spearman's $\rho = 0.02$; $S = 1.3 \times 10^8$, $p = 0.57$), nor between the average luminance of the last frame before the cut and PCN (Spearman's $\rho = 0.07$; $S = 1.2 \times 10^8$, $p = 0.03$).

IV. DISCUSSION

In section III we analysed ERPs produced by related cuts in feature movies. We found a large and distinctive negative ERP that is time-locked to the occurrence of scene changes and that is distributed on most frontal and central electrode sites and on several parietal sites in most participants. We believe that this ERP could be either an N400 or the SCP identified in previous research (see section I) with more constrained types of videos, which are linked to processes taking place during the integration of new semantic information acquired after the cut into a context built before the cut.

Because the ERP we found has such wide scalp distribution and an approximate latency of 400 ms, we chose to characterise it by using the median voltage across all channels in a 380–420 ms time window. Also, to further increase the SNR of the ERP, we borrowed the technique of averaging epochs (on a trial-by-trial basis) across participants from the area of cBCIs. We called the resulting value the post-cut negativity.

While the PCN is clearly a very coarse-grained quantity along the spatial and participant axes, it is still maximally sharp in the time domain. That is, we have a PCN value for each cut. This makes it possible to attempt, for the first time, to characterise cuts at a finer resolution than that of the standard taxonomy including only related and unrelated

cuts.

In particular, we were able to highlight a previously unreported relationship between the length of shots and the corresponding PCNs in related cuts. We believe that this may be due to movies with longer scenes having richer plots, resulting in more complex context updates being required following rarer cuts. In contrast, fast-paced movie clips showing rapid sequences of cuts (e.g., due a number of related explosions) would only require smaller context updates (and associated PCNs) after the first cut (perhaps an unexpected explosion).

This is somehow consistent with the behavior of other ERPs, such as the P300, the amplitude of which is modulated by the rarity (and, correspondingly, the waiting time) of target stimuli [24]. However, unlike P300 amplitudes, we found that PCNs do not depend on low-level features such as the changes in luminance necessarily associated with cuts, further indicating the high-level nature of the cognitive processes associated with cuts and represented by the PCN.

In our analysis, we also found that PCNs varied across movies and also, to a lesser extent, movie clips. This makes obvious sense, as it is well known that movie directors and editors use different techniques for joining shots, based on their own style, personality, experience and the intended effect of the cut.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we have performed an ERP analysis of the effects of cuts in feature movies. We combined traditional scalp-averaging techniques with the less standard technique of averaging single ERPs across participants used in some cBCIs. This has made it possible to reveal more detailed properties of cut-related ERPs than ever before.

While we feel that even this further step has only scratched the surface, we think that this research has opened up a number of promising avenues both for the psychophysiology of motion pictures and for applications of cBCIs in cinematography, television, advertising, etc.

Particularly appealing from this latter perspective is the possibility of building cBCIs, perhaps based on a finer features of cut-related ERPs than the simple PCN we used in this paper, that could *objectively* evaluate whether specific cuts in a movie actually achieve the effect intended by the movie editor or director, during the test screening phase of the movie. We will explore this possibility in the near future.

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