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Methodology for the neurocinematic analysis of film transitions through cuts to the next shot using the electroencephalogram

Metodología para el estudio neurocinemático del cambio de plano por corte a través del electroencefalograma

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Resumen:
El objetivo de este artículo es exponer el planteamiento metodológico para desarrollar un estudio neurocinemático del cambio de plano por corte. Concretamente, el estudio se realiza mediante el análisis del *event-related desynchronization/synchronization* del electroencefalograma registrado sobre espectadores. Se parte desde una perspectiva general describiendo las implicaciones de aplicar las metodologías neurocinemáticas al análisis fílmico, para finalizar con las peculiaridades que implica nuestra investigación. En nuestro caso trabajamos a partir de fragmentos cinematográficos extraídos de

largometrajes ya existentes, realizamos un registro neuronal con 31 electrodos y aplicamos un análisis estadístico basado en el test de permutaciones, el test de correlación de Spearman y el análisis de pendientes sobre la señal registrada transformada al dominio de la frecuencia.

Palabras clave:
Neurocinemática; Corte; Montaje; Electroencefalograma; Metodología

Abstract:
The objective of this paper is to present a methodological approach to develop a neurocinematic study of film transitions through cuts to the next shot. Specifically, the study was carried out by analyzing the event-related desynchronization/synchronization of the electroencephalogram recorded on spectators. It starts by describing the implications of applying neurocinematic methodologies to film analysis, and finalizes with the peculiarities that our research implies. In our case we work from film fragments extracted from existing feature films, we carry out a recording of neural activity with 31 electrodes and apply a statistical analysis based on the permutations test, the Spearman correlation test and the analysis of slopes on the transformed registered signal to the frequency domain.

Keywords:
Neurocinematics; Cut; Edition; Electroencephalogram; Methodology

1. Introduction

Deleuze (1984; 1985) says that cinema does not limit itself to reproducing a filmed reality that evolves in a coincident physical time, but modifies the distances and positions of the bodies that make up the film and alters the temporal evolution of reality. These ruptures, which go beyond simply registering a filmed reality, occur mainly during film transitions through cuts to the next shot, and in the conjunction of these cuts, conforming the filmic space-time experience articulated through editing.

The study and analysis of film transitions through cuts is one of the aspects that most has occupied cinematographic theorists and technicians throughout the history of cinema (Eisenstein, 1949; Burch, 1969; Murch, 1995), having nowadays become one of the main focuses in recent neurocinematic studies (Smith and Henderson, 2008; Heimann et al., 2016; Andreu-Sánchez et al., 2018). The emergence of the Ecological Approach to Cognitive Film Theory (Anderson, 1998) served as the theoretical basis for the appearance of the neurocinematic analysis (Hasson et al., 2008), which redirected film analysis to the possibility of knowing how a viewer reacts biometrically to different cinematographic inputs. This new approach, in addition to allowing a path of discovery, implies a deep review of existing cinematographic knowledge, either to validate it or to qualify it. For instance, it is interesting to bring up the research developed by Calbi and his team (Calbi et al., 2017), which sought to understand in greater depth the cinematographic theory of the Kuleshov effect (Kuleshov, 1934), or Smith (2005), proposing a cognitive explanation for the technical concept of *cutting on action*.

In our study, we are interested in analyzing the filmic creation that occurs during film transitions through cuts, specifically during cuts in continuity[1]. We chose this type of film transitions since it is the least evidenced one during the viewer's perception, and it is of special interest to know what neuronal processes are triggered to generate a sense of continuity from a discontinuous visual material. As we approach our research from a neurocinematic methodology, we carry out our analysis through the study of *Event-Related Desynchronization/Synchronization* (ERD/ERS) of the electroencephalogram (EEG) recorded in viewers who observe film transitions through cuts. This form of analysis through ERD/ERS allows us to know how neuronal excitations and inhibitions evolve in the viewer's brain as a consequence of film transitions, thus knowing the cognitive processes that are triggered.

In this paper, we provide a detailed description of the methodology used to carry out the research. The methodological process can serve as the basis for carrying out neurcinematic studies based on different biometric measurement techniques, as well as for designing an experiment that analyzes other specific cinematographic aspects different from film transitions through cuts.

2. Film analysis design focused on film transitions

As Aumont and Marie say, "[…] the exhaustive analysis of a text has always been considered a utopia: something that can be imagined, but that can never take place in reality." (1988, p. 111). If we want to carry out an in-depth cinematographic analysis, the only way we can achieve it is by clearly defining some technical limits that make it possible to develop such analysis. Therefore, it is important to define the cinematographic universe addressed and the aspect to be studied.

At the same time, as Casetti and di Chio assert: "[…] just like there is no unified theory of cinema, no universal model of film analysis can be provided" (1990, p. 12). Therefore, it is also of great importance to establish the theoretical basis on which the research methodology will be built before undertaking any analysis.

2.1. Limits of the analyzed universe

To carry out our research we focus on fiction cinema, which Plantinga (1997) defines as the one that depends on the imagination and will of the creator, compared to non-fiction cinema, where the association with reality is independent of the narrator despite of the need for the intervention of the creative subject. In addition, we focus on live-action cinema, discarding that which uses filming techniques "[...] that dispense with the mechanical reproduction of phenomenal reality, as well as, in extreme cases, the use of the camera itself" (Rondolino, 1974, p. 15).

[1] Although these cuts may normally be referred to as “normal cuts”, in the present research we will make use of the term “cut in continuity” to explicitly point that they imply a cut in continuity between shots.

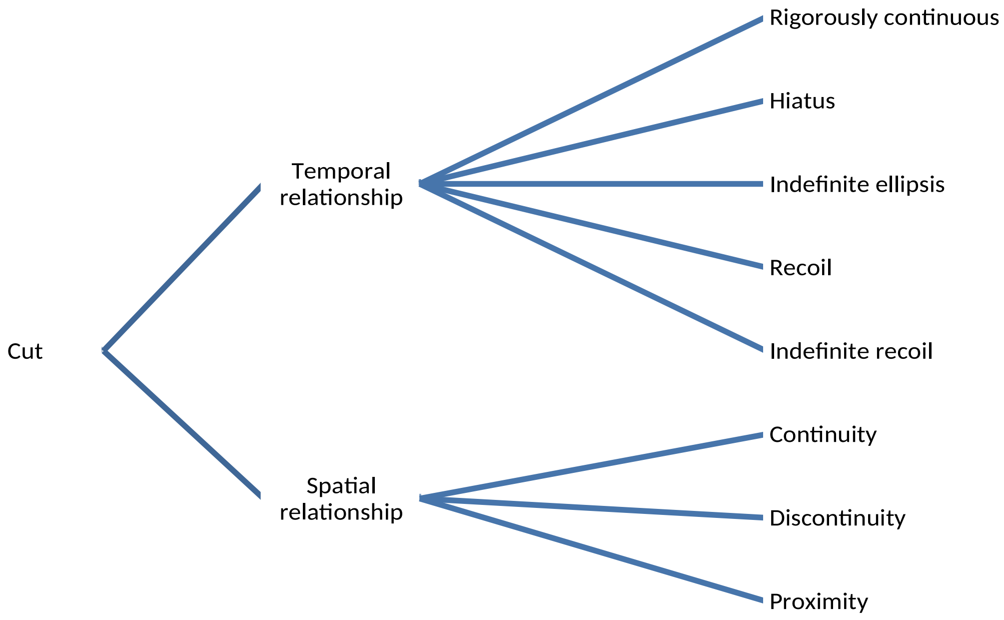
Within the universe of live-action and fiction cinema, we limit ourselves to the study of the institutional mode of representation (IMR) defined by Burch (1987). We take this mode of representation because in it the articulation of shots through cutting fulfills a narrative and dramatic intention, unlike in the primitive mode of representation (PMR). We also discarded all films corresponding to the silent film era, considering that the form of articulation between shots is conformed with the physical and technical possibility of adding a synchronous soundtrack to the film negative (Bordwell and Thompson, 1995).

At the same time, within the existing possibilities of film transitions through cuts, we focus on those ways which are the most unnoticed by viewers and are the least evidenced ones at a conscious level. This way, we intend to delve into the most essential nature of film transition through cutting, approaching it as a cognitive gap that our brain is capable of processing without the need to bring it to the viewer's consciousness (Smith, 2005).

According to Burch (1987), the typologies of cuts are based on the spatial and temporal relationship between the outgoing shot and the incoming one. This way, the classification that we can see in Figure 1 is established:

Figure 1

Types of cut according to Burch



Within the taxonomies defined by Burch, and with respect to the temporal relationship, we are interested in the hiatus and rigorously continuous cut types; with respect to the spatial relationship, we are interested in the continuity and proximity cut types. In the case of the rigorously continuous cut type, a true continuity is shown between actions and their temporal development, so there is no difference with the temporality of the filmed action. A hiatus occurs when –with continuity taking place– a part of the action is suppressed to provide it with visual fluidity. This rupture, despite being a temporal ellipsis, does not alter the virtual space and the viewer is able to assimilate it without being aware of its existence. Regarding spatial continuity, a cut in continuity occurs when the following shot represents a space that we have already seen in the previous one in a total or partial way; while a cut in proximity takes place when –not being a cut in spatial continuity– it is actually intuited that the space is adjacent to it.

Another taxonomic approach to film transitions through cutting is that carried out by Amiel (2001). Based on this classification, we are interested in the two typologies that it encompasses within raccord editing, which are the absolute-raccord editing and the articulated editing. In absolute-raccord editing, it is intended that the viewer does not perceive a narrative break during a cut, assembling shots with the most discretion as possible. In the filmic time, this creates a continuity that practically coincides with the time in which the story is told. Articulated editing occurs when a discontinuity appears in the visual flow, and –through an action in raccord– a cut configures a new temporal order. This can happen by means of small ellipsis evident to the viewer or by maintaining a sound continuity, but contrasting it with a visual discontinuity. However, the analogy between movie time and action time, without being perfect, continues to prevail in its principle of linear succession.

Table 1

Relationship between Amiel's raccord editing types and Burch's cut typologies

Amiel	Burch	
Raccord editing	Temporal relationship	Spatial relationship
In absolute raccord	Rigorously continuous	Continuity
	Hiatus	Proximity
Articulated editing	Hiatus	Continuity Proximity

As can be seen in Table 1, the classifications established by Burch and Amiel are not exclusive, but rather are different groupings that seek to establish a taxonomic group that defines those shots that maintain a virtual space-time that the viewer perceives with a sense of continuity. The type of cuts described based on the proposals of Burch and Amiel are the ones chosen to carry out our study.

2.2. *Theoretical approach to the analysis*

Our analysis is framed within neurocinematic studies. We focus on performing biometric measurements of the viewer shown the proposed cinematographic stimulus; which in this case is the film transition through cutting. From the recorded data we can draw conclusions about the very cinematographic nature of a stimulus. This methodological basis puts the viewer at the center of the study, analyzing the film and its different cinematographic resources depending on how it affects, in a concrete and measurable way, the viewer being shown a cinematographic material. An added advantage of this methodology is that we can obtain objective quantitative data on the viewer's reactions, being able to obtain scientifically supported conclusions.

The theoretical basis of neurocinematics is found in the Ecological Approach to Cognitive Film Theory proposed by Anderson (1998), which has its origin in the naturalistic approach of Bordwell and Carroll (Bordwell, 1989; 1985; Carroll, 1988). The proposal of film cognitive ecology is based on the fact that cinema is one more of reality's stimuli, so the brain processes what happens on the screen in the same way that it would process reality itself, despite the fact that the viewer exists a level of consciousness that understands that everything being envisioned is not real. Anderson states that cinema induces greater immersivity than the rest of the arts due to the large amount of auditory and visual stimuli with a time evolution that the brain must process. Specifically, the need for a quick cognitive processing of the inputs that evolve over time reduces the dedication to more reflective processes, such as keeping in mind that the events happen in a film and not in reality, thus increasing the feeling of immersiveness. Caroll and Seeley (2013) delve into this proposal by stating that not only is cinema perceived as a reality, but that the nature of the ordered, categorized and structured filmic inputs implies that cognitive processes are more effective than in reality itself, which is chaotic, messy and unstructured. They called this condition *uncluttered clarity*.

Neurocinematics originates from this theoretical basis and seeks to detect and make sense of the neuronal processes that are triggered by different cinematographic stimuli. To achieve its goal, there are different ways to collect biometric measurements from viewers. The electroencephalogram (Heimann et al., 2016), the brain scanner (Ben-Yakov and Henson, 2018) and the eye-tracker (Smith, 2013) are the main technologies used to obtain biometric measurements. There are other types of measurements that can be obtained, but nowadays they are not as frequently used as they have not been very effective on their own. Different possibilities of biometric measurements are perceptions of variations in faces (Hubert and de Jong-Meyer, 1990), heart rate measurements (Palomba et al., 2000), respiratory rates (Gomez et al., 2005) or variations of electrodermal activity (Westerink et al., 2008).

Among the different ways that biometric measurements can be obtained, there is a main difference between electroencephalography and magnetic resonance imaging, which directly capture neuronal activity, and the rest of the measurements, which reflect consequences of neuronal processes. Therefore, despite the fact that the study of eye movements and blinks is highly informative, for our research we have chosen tools that allow us to have direct access to neural processes.

The techniques that directly access neuronal activity can be divided into spatial and temporal techniques (Díaz, 2008). Magnetic resonance imaging is a spatial technique since it serves to locate in detail the areas that are excited and inhibited by a given stimulus. On the other hand, electroencephalography is considered a temporary technique, since it has a higher precision in milliseconds when recording neuronal responses. In order to analyze film transitions through cuts, temporal precision is of special interest, since a film transition is a very specific stimulus placed on a specific temporal location; and due to the course of a film, it is preceded by a large number of stimuli that require neuronal processes unrelated to our object of study.

Among all the options that the electroencephalogram analysis allows us, we have chosen the study of *Event-Related Desynchronization/Synchronization* (ERD/ERS). This analysis methodology studies the variations that take place in the frequency domain of the signal recorded by the EEG. By studying variations in frequency, we can detect with temporal precision the inhibitions (ERD) or excitations (ERS) that occur in the brain. These variations can be located spatially depending on the specific electrode where they occur, and can also be located on a frequency basis depending on the range such variations are detected in (alpha, beta, gamma, delta or theta).

The ERD/ERS analysis is common in neurocinematic studies, among which we can highlight the experiments led by Heimann (Heimann et al., 2016; Heimann et al., 2014). In a first experiment, they analyzed the level of immersivity produced by different techniques of bringing the camera closer to what was being filmed (Heimann et al., 2014), and in a second experiment they focused on how a cut involving a 180-degree rule brake affected viewers (Heimann et al., 2016).

3. Experiment design: Materials, methods and analysis of results

The experiment involves designing how biometric measurements will be recorded from viewers and preparing the materials that serve to analyze the desired inputs. This preparation is directly related to how the results will be analyzed, since we may have specific needs that we must anticipate in the biometric registration and the selection of audiovisual material.

3.1. Materials

Two main options arise when preparing the materials that will be the inputs to be analyzed. We may take fragments of existing audiovisual materials, such as films (Costa et al., 2006; Krause et al., 2000), or we may film our own audiovisual materials that contain the inputs to be analyzed (Heimann et al., 2014; Andreu-Sánchez et al., 2018). In the case of taking existing materials, we may select a fragment as it originally is (Krause et al., 2000), or we may manipulate it to make it more suitable for the purpose of our experiment (Costa et al., 2006).

The advantage of analyzing our own filmed material during the experiment is that it enables us to film the same staging with the only variation between different clips being the input under study. An example would be filming a person performing the same action, but using different ways of bringing the camera closer to what is being filmed (Heimann et al., 2014). This approach facilitates the analysis of the results since we assume that the variations between the neuronal registers in the face of the different materials shown are due to the only variable element, which is the issue we wish to study. However, this approach does not allow a film analysis in itself, since we are not analyzing a real film.

Regarding the use of excerpts from existing audiovisual materials, there is an unquestionable difference in quality and, above all, in effectiveness in modifying a viewer's affectivity. Therefore, this type of material is used mainly in experiments aimed at studying the emotions induced in spectators (Costa et al., 2006; Krause et al., 2000). In studies whose purpose is to analyze emotionality, the specific technical aspects are not so important, but rather the emotional effectiveness achieved through the articulation of the different cinematographic resources prevails. That is, what it is analysed is how a set of inputs affect viewers in a concrete way.

Due to the nature of audiovisual materials themselves, materials filmed for an experiment are more suitable to analyze a specific characteristic of the cinematographic medium, while materials extracted from existing films are more practical to analyze the effect of a set of inputs on the viewer. However, in our experiment we want to analyze a specific technical aspect, as is film transition through cutting, without giving up on carrying out our experiment with audiovisual materials extracted from real cinematographic films. Specifically, we are interested in fragments extracted from films without making any modifications on them; that is, keeping the fragments as they were designed for their cinematic viewing. For this reason, a series of constraints arise that we must resolve first during the selection of materials and later during the analysis of the results.

When using real audiovisual fragments, cut events are intertwined with a diverse variety of inputs, so we need to be able to differentiate the neuronal reactions resulting as a consequence of the input under study from the rest. For this reason, during the analysis of our results, we must be able to differentiate the coincident neuronal reactions after a film transition by means of comparisons between the EEG recordings corresponding to different slices in different aesthetic and technical contexts. Consequently, we must carry out our experiment using various films that involve different aesthetic and technical natures. We opted to select fragments corresponding to the films Bonnie & Clyde (Penn, 1967), Centaurs of the desert (The Searchers, Ford, 1956), Whiplash (Chazelle, 2014) and The Law of Silence (On the Waterfront, Kazan, 1954). In Table 2 we can see the technical and aesthetic differences that have led us to make the reported selection.

Table 2

Differential technical and aesthetic characteristics between the different fragments

Film	Colour or Black and White	Remarkable characteristics	Rhythmic ratio[a]	Narrative value[b]	Aesthetics[c]	Filmic style[d]
Bonnie &	Colour	Very choppy	27,24	Inflection	Modern	Transition

Clyde		final rhythm. Contains slow motion shots. Tendency to fragmented editing.		point. Strong conflict.		
The Searchers	Colour	Tendency to open joint shots (Extreme long Shots, Full Shots?). Invisible editing during the entire fragment.	4,79	Character presentatio n. No conflict.	Classical	Classical
Whiplash	Colour	Tendency to close-ups. Contains180-degree rule brakes.	21,89	Inflection point. Strong conflict.	Modern	Post-classical
On the Waterfront	Black and white	Tendency to frontality. Invisible mounting during the entire fragment.	14,45	Scene before an inflection point. Low conflict.	Classical	Classical

*Notes***.** [a] Average cuts per minute contained in the fragment.
[b] Narrative value in relation to the cinematographic narration and the conflict shown in the fragment (McKee, 1997).
[c] Lighting style (Revault D'Allonnes, 1991).
[d] Cinematographic style (Bordwell, 1985; Langford, 2009; Thanouli, 2009).

3.2. *Electroencephalogram recording*

To carry out our experiment, we recorded the electroencephalogram of spectators while they observed audiovisual fragments that contained film transitions through cuts. To achieve this goal, we had the Augmented Cognition Lab, of the Aalborg University in its Technical Faculty of IT and Design headquarters located in Copenhagen. This laboratory has the necessary equipment to emit audiovisual stimuli synchronously to an electroencephalographic recording.

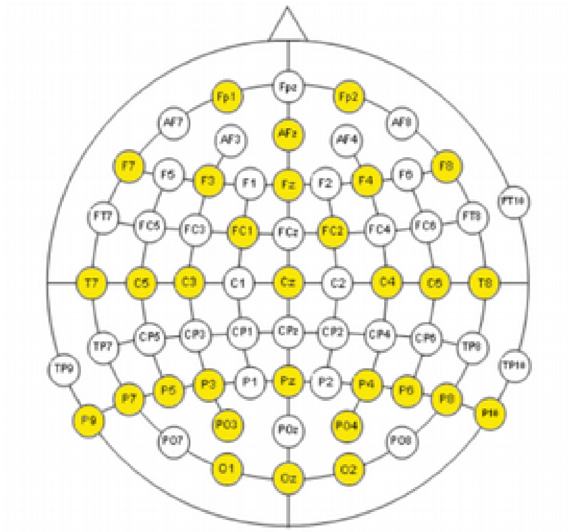
The playing of the video clips was performed through the Unity software on the main computer, while the EEG recording was performed on the secondary computer through the *Simulink*[2] environment of MatLab's software. The different audiovisual clips were played in random order, so that a constant order did not affect the results.

In order to establish a synchronized communication, the information was sent in real time from the main computer to the secondary computer through the *User Datagram Protocol Network*[3]. This system allowed us to coordinate Unity with MatLab, enabling us to perform recordings with synchronization indicators. These indicators, which appear on the EEG recording, identify the video clip, mark the beginning and end of the clip and also locate where a film transition through a cut occurs.

The recording of the electroencephalogram was performed by means of 31 electrodes placed on the scalp, following the international convention of the *American Electroencephalographic Society* in the 10-20 system for EEG-MNC (American Electroencephalographic Society, 1991). In Figure 2, the specific arrangement of the electrodes can be seen.

Figure 2

Electrode distribution shown in a cranial map following the 10-20 international system for EEG-MNC[4]



2 *Simulink* is an application of the *MatLab* environment that allows the simulation of models or systems by means of block diagrams. Using *Simulink*, an initial processing and filtering of the recorded electroencephalographic signal is carried out.

3 Network information transport protocol based on datagrams that contain headers with enough information to avoid delay problems.

4 Nomenclatures according to the *Modified Combinatorial Nomenclature*: Fp = Frontopolar, Af = Anterior-frontal, F = Frontal, Fc = Fronto-central, C = Central, T = Temporal, P = Parietal, PO = Parieto-occipital, O = Occipital.

The electroencephalogram sampling rate was 256 SPS and its signal was amplified by two g.Tec g.Gammabox devices that were connected to two other g.Tec g.USB Amp devices, with 16 channels each. In order to connect 31 electrodes, each pair of devices was interconnected, one being the master and the remaining one the slave, thus allowing a maximum of 32 information channels.

To carry out the experiment, we had the participation of 21 subjects who voluntarily agreed to take part in it. The study subjects assured not to suffer any neurological disorder, psychological problem or to be under medication (Estaban, 1999). Subjects were also asked not to drink any activating substances such as coffee or depressants such as alcoholic beverages, as they could modify their cognitive processes (Costa and Bauer, 1997; Andrews et al., 1998). The subjects who volunteered in the experiment were related to Aalborg University, most of them being undergraduate, master or Ph.D students. They were informed of the characteristics of the study, taking care not to provide any specific information that could condition their perception. They freely gave their written consent for the collection of data and its anonymous non-profit use.

3.3. Analysis of results

Once the EEG recordings have been obtained, the first step is to perform an ICA analysis and to manually clean any artifacts on them. An ICA analysis is a computational process applied to isolate the bioelectric activity of each electrode, while artifacts are distortions in the recorded signal due, for example, to movements from subjects. After this first step, we computed model signals for each audiovisual fragment by grouping the signals from different subjects and grouping the different cuts. This process is explained in more detail in a previous publication (Sanz-Aznar et al., 2020).

With the model electroencephalographic signals prepared, and since the purpose of the experiment is to analyze the evolution of the ERD/ERS, we transformed the signals to the frequency domain and broke them down into the different ranges that we wish to study. The breakdown into frequency bands is carried out as follows: 0.5-3 Hz for the delta, 3-7 Hz for theta, 7-14 Hz for the alpha, 14-32 Hz for the beta and 32-42 Hz for the gamma band. As we are also interested in a more detailed analysis, another more detailed breakdown was made: 0.5-1.5 Hz for the low delta, 1.5-3 Hz for the high delta, 3-5 Hz for the low theta, 5-7 Hz for the high theta, 7- 10.5 Hz for the low alpha, 10.5-14 Hz for the high alpha 14-23 Hz for the low beta, 23-32 Hz for the high beta, 32-37 Hz for the low gamma and 37-42 Hz for the high gamma band.

At this point of the investigation, it is essential to be able to differentiate those parts of the recorded signal that are neuronal reactions to film transitions through cuts from those that are not. To discriminate certain parts from others, the different model signals corresponding to different audiovisual clips were compared in search for models with common neural reactions. Specifically, we compared sections from each signal corresponding to the same time windows of the sample, the same frequency bands and the same electrodes. This way, by applying a permutations test and a Spearman correlation test, we can know –in the frequency domain– which neuronal reactions are triggered by film transitions through cuts. Once these neuronal reactions were located, a slope analysis was performed to identify those that represented a significant variation in neuronal excitation or inhibition. This statistical process, which was applied in an automated way using MatLab software, is explained in detail in the aforementioned previous publication (Sanz-Aznar et al., 2020).

Once the neuronal reactions triggered by a film transition through a cutting event that supposes a significant excitation or inhibition have been located, we can proceed to the study of ERD/ERS. An ERD/ERS analysis displays the variations of neuronal activity with respect to some baseline or equilibrium state (Klimesch et al., 1996; Doppelmayr et al., 1998). This relative value is shown as a percentage, with *synchronization* (neuronal excitation) displaying negative values and *desynchronization* (neuronal inhibition) positive ones. Specifically, we analyze the first second after a film transition through a cut.

To determine the state of non-reaction (or *baseline* activity) to an event under study, a stage prior to the event (Martín-Pascual, 2016) or resting state (Heimann et al., 2016) can be used. Defining the *baseline* activity is of great importance in the study of ERD/ERS since any results are relative to its definition. In our case, we took the second before the cut as the baseline, because being interested in analyzing the articulation that occurs between two planes joined by means of a cut, it is more interesting to analyze variations due to film transitions in the temporal continuum of the film than in a state of neutral rest unrelated to the film. Therefore, for each electrode in each frequency band, the baseline value with respect to which to calculate ERD/ERS was computed as the average value of the signal in the second prior to the point prior to the transition.

4. Conclusions

The methodology applied for the analysis of film transitions through cuts is effective, since we obtain results supported by other investigations carried out through other biometric registration systems. Specifically, we have evidenced activation located in the hippocampus as a consequence of cuts, as found by Ben-Yakov and Henson (2018) through magnetic resonance imaging. In our case, having carried out the experiment with a temporal measurement technique instead of a spatial one, we have more information about how this activation evolves.

Our proposal is novel since it allows us to analyze a specific cinematographic aspect, such as film transition through cutting, from existing filmic material through the recording of the electroencephalogram. Through the steps described, it is possible to overcome the problem of having the specific input that we want to study in parallel with other inputs that may hide the neural responses we seek to study. However, with an adequate methodological design, we show that it is possible to differentiate, through the electroencephalogram, those neuronal responses that are of interest to us from those that pose a problem.

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