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BRAIN PROCESSES UNDERLYING THE PERCEPTION OF AUDIOVISUAL CONTENT

by

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Doctoral Thesis supervised by José María Delgado-García and Rocío Leal Campanario

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CERTIFICAN:

que el presente trabajo titulado **"Brain processes underlying the perception of audiovisual content"** ha sido realizado bajo su dirección y supervisión por Dña. Celia Andreu Sánchez, Doctora en Comunicación por la Universidad Rey Juan Carlos de Madrid, y consideran que éste reúne las condiciones de calidad y rigor científico suficientes para ser presentado y defendido como Tesis Doctoral.

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José María Delgado García　　　　　　Rocío Leal Campanario

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The Doctoral Thesis entitled "Brain processes underlying the perception of audiovisual content" that is presented by Celia Andreu Sánchez to obtain the degree of PhD in Neuroscience corresponds with a compendium of scientific articles already published. The articles are listed below.

- **Study 1**

Looking at reality versus watching screens: Media professionalization effects on the spontaneous eyeblink rate.

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Journal: *PLoS ONE*, 12(5): e0176030.

Year: 2017

- **Study 2**

Eyeblink rate watching classical Hollywood and post-classical MTV editing styles, in media and non-media professionals.

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Journal: *Scientific Reports*, 7: 43267.

Year: 2017

- **Study 3**

Chaotic and Fast Audiovisuals Increase Attentional Scope but Decrease Conscious Processing.

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Journal: *Neuroscience*, 394: 83-97.

Year: 2018

- **Study 4**

Viewers Change Eye-Blink Rate by Predicting Narrative Content.

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Journal: *Brain Sciences*, 11: 422.

Year: 2021

- **Study 5**

The Effect of Media Professionalization on Cognitive Neurodynamics During Audiovisual Cuts.

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Journal: *Frontiers in Systems Neuroscience*, 15: 598383.

Year: 2021

- **Study 6**

Brain Symmetry in Alpha Band When Watching Cuts in Movies.

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Journal: *Symmetry*, 2022, 14: 1980.

Year: 2022

ABSTRACT

Audiovisual perception has been traditionally addressed from social, psychological, semiotic, and anthropological perspectives. In the recent years, a novel approach from neuroscience has raised. Under the field of neurocinematics, neuroscience techniques are used to understand the brain processes underlying the perception of audiovisual content. This Doctoral Thesis studies these processes under three main perspectives: (1) finding differences in perceiving a narrative content in a real performance or on a screen; (2) learning how the style and the content of audiovisual works affect viewers' perception; and (3) determining if media professionalization has an impact on visual perception. With electroencephalographic and electrooculographic techniques, eyeblinks and electrical brain activity were recorded from participants. The main findings from these works are the following. Regarding the first perspective, differences in perceiving reality and performance were found. A narrative content in a video provokes a lower eyeblink rate of viewers compared with the same content within a real performance. Regarding the second perspective related to the style and the content of audiovisual works, it was found that: (i) eyeblink rate of viewers changes depending on the style of edition of audiovisual works, the more chaotic the style, the lower eyeblink rate; (ii) cuts inhibit eyeblinks immediately after them, avoiding the possibility of working in a synchronization of cuts with eyeblinks to avoid the loss of visual information made by both processes; (iii) cuts affect media perception and provoke a potential spread of activity from occipital areas to frontal areas of the brain at around 200 ms after the cut; (iv) the style of edition where cuts are inserted has an impact on viewers' decoding and chaotic and fast audiovisuals increase attentional scope but decrease superior cognitive processing; (v) there are specific narrative content that synchronizes increases and decreases of viewers' eyeblink rate, regardless the style of edition in which they are presented; and (vi) cuts in audiovisuals do not provoke any specific asymmetrical brain activity in the alpha band in viewers, suggesting that brain asymmetry when watching audiovisuals may be more related with narrative content than with formal style. Finally, regarding the third perspective related to media professionalization, it was found that: (i) media professionals pay higher attention to both screens and the real world than non-media

professionals do; (ii) media professionals decrease more their blink rate after the cuts, suggesting that they can better manage the loss of visual information that blinks entail by sparing them when new visual information is being presented; and (iii) effective brain connectivity occurs in a more organized way in media professionals. In conclusion, audiovisuals modulate visual perception of viewers, based on several parameters, such as style, content, and professionalization. Learning about brain processes underlying the perception of audiovisual content can be useful in multiple areas as the communication, the clinical, or the training, among others.

RESUMEN

La percepción audiovisual ha sido tradicionalmente abordada desde perspectivas sociales, psicológicas, semióticas y antropológicas. En los últimos años ha surgido un enfoque novedoso desde la neurociencia. En el campo de la neurocinemática, las técnicas de la neurociencia se utilizan para comprender los procesos cerebrales que subyacen a la percepción del contenido audiovisual. Esta Tesis Doctoral estudia estos procesos bajo tres perspectivas principales: (1) encontrar diferencias en la percepción de un contenido narrativo en una representación real o en una pantalla; (2) aprender cómo el estilo y el contenido de las obras audiovisuales afectan a la percepción de los espectadores; y (3) determinar si la profesionalización en los medios tiene un impacto en la percepción visual. Con técnicas electroencefalográficas y electrooculográficas, se registraron los parpadeos y la actividad eléctrica cerebral de los participantes. Los principales hallazgos de estos trabajos son los siguientes. En cuanto a la primera perspectiva, se encontraron diferencias en la percepción de la realidad y el audiovisual. Un contenido narrativo en un video provoca una menor tasa de parpadeo de los espectadores en comparación con el mismo contenido dentro de una actuación real. En cuanto a la segunda perspectiva relacionada con el estilo y el contenido de las obras audiovisuales, se encontró que: (i) la tasa de parpadeo de los espectadores cambia según el estilo de montaje de las obras audiovisuales, cuanto más caótico el estilo, menor la tasa de parpadeo; (ii) los cortes de plano inhiben los parpadeos inmediatamente posteriores a ellos, evitando la posibilidad de trabajar en una sincronización de cortes con parpadeos para evitar la pérdida de información visual realizada por ambos procesos; (iii) los cortes de plano afectan la percepción de los medios y provocan una posible propagación de la actividad desde las áreas occipitales hacia las áreas frontales del cerebro alrededor de 200 ms después del corte; (iv) el estilo de edición donde se insertan los cortes tiene un impacto en la decodificación de los espectadores y los audiovisuales caóticos y rápidos aumentan el alcance atencional pero disminuyen el procesamiento cognitivo superior; (v) existen contenidos narrativos específicos que sincronizan aumentos y disminuciones de la tasa de parpadeo de los espectadores, independientemente del estilo de edición en que se presenten; y (vi) los cortes en los audiovisuales no provocan ninguna actividad cerebral asimétrica específica

en la banda alfa en los espectadores, lo que sugiere que la asimetría cerebral al ver audiovisuales puede estar más relacionada con el contenido narrativo que con el estilo formal. Finalmente, con respecto a la tercera perspectiva relacionada con la profesionalización de los medios, se encontró que: (i) los profesionales de los medios prestan más atención tanto a las pantallas como al mundo real que los que no son profesionales audiovisuales; (ii) los profesionales de los medios disminuyen más su tasa de parpadeo después de los cortes de plano, lo que sugiere que pueden manejar mejor la pérdida de información visual que implican los parpadeos evitándolos cuando se presenta nueva información visual; y (iii) la conectividad cerebral efectiva ocurre de una manera más organizada en los profesionales del audiovisual. En conclusión, los audiovisuales modulan la percepción visual de los espectadores, en función de varios parámetros como el estilo, el contenido y la profesionalización. Conocer los procesos cerebrales que subyacen a la percepción de contenidos audiovisuales puede ser útil en múltiples ámbitos como el comunicativo, el clínico o el formativo, entre otros.

LIST OF ABBREVIATIONS

ANOVA Analysis of Variance

ASD Autism Spectrum Disorders

ASL Average Shot Length

CEEAH Ethics Commission for Research with Animals and Humans

CSV Computer Vision Syndrome

DMN Default Mode Network

EEG Electroencephalography, Electroencephalographic

EMG Electromyographic

EOG Electrooculography, Electrooculogram, Electrooculographic

ERD Event-related Desynchronization

ERP Event-related Potential

ERS Event-related Synchronization

ERSP Event-related Spectral Perturbation/Perturbances

fMRI functional Magnetic Resonance Imaging

GC Granger Causality

GLM General Linear Model

HD High-Definition

IMR Institutional Mode of Representation

IRTVE Institute of Spanish Public Television

ISC Intersubject Correlation Analysis

JCR Journal of Citation Reports

PLV Phase-Locking Value

PMR Primitive Mode of Representation

RTVE Radio Televisión Española, Spanish Public Television

SBR Spontaneous Blink Rate

CONTENT

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1. INTRODUCTION

This Compendium Thesis studies the brain processes that underlie the perception of audiovisual content. It consists of six scientific publications, all of which correspond to articles in journals indexed within the Journal Citation Reports (JCR), of which I am the first author and the corresponding author.

All the publications presented here have the common purpose of learning more about what happens in the brains of viewers when they are consuming audiovisual content. Among the perspectives addressed by the six publications, we can distinguish three: (1) the study of the difference of perceiving a narrative content within a real performance or on screen; (2) the study of the perception of audiovisuals based on the formal style and the narrative contents of the audiovisual works; and (3) the study of the impact that audiovisuals can have on media professionals.

The interest in investigating the brain processes that underlie the perception of audiovisual works is threefold. In the first place, it is relevant in the field of communication sciences to have solid tools on the perceptual effects that audiovisual creations have on their viewers. In this way, it seems possible to pursue greater effectiveness in terms, for example, of attention, of audiovisual works. That is, a screenwriter, a director, or an editor, beyond working based on their own experience and psychological and sociological studies on the perception of audiovisual works, can count on results from neuroscience. These can be very useful when designing and managing these types of works.

Secondly, given that the consumption of audiovisuals has been growing in recent decades, studying the impact it has on media professionals (who have been working for many years on a daily basis with the creation and consumption of audiovisuals, as well as decision-making associated with them) is interesting for several reasons. On the one hand, it is interesting to know the impact that audiovisuals can have on their professionals for occupational health reasons. On the other hand, the professionalizing effect of audiovisual consumption complements previous studies on the brain effects of other professions (such as musicians, athletes, taxi drivers, etc.). And, no less important, it is intuited that knowing the impact of audiovisual professionalization on brain processes can be applied to training and attention management diagnoses (or other variables) in the clinical setting, in environments in which perceptual processes are seen altered or deteriorated.

Thirdly, there is an increasing number of studies, in the field of neuroscience and psychology, using audiovisual works as stimuli to address certain objectives. The selection and/or elaboration of the audiovisual stimuli for these investigations is developed based on, mostly, logical criteria of the researchers. However, it would be good to be able to count on a bulk of scientific evidence that would determine for this type of researchers the impact of, for example, putting a cut, or making the protagonist of the narrative disappear from the scene. For this reason, I consider that the work carried out to understand the brain processes that underlie the perception of audiovisual content can be of great relevance for other researchers interested in using audiovisual content as a stimulus.

Below, the reader can find a brief theoretical framework about the Thesis, followed by the research hypothesis and objectives that encompass the papers presented. Afterwards, a summary of the materials and methods used in the works is presented. And then, a brief reference to the six scientific publications, their main results and their correlation with the highlighted objectives are shown. Next, the discussion section is addressed, highlighting some ideas of the selected works, as well as a global view of the connection between them. Finally, future research is presented that, being linked to these works, can show direct applications that are already being worked on. The six scientific publications can be found in the Appendix section of this document.

2. THEORETICAL FRAMEWORK

The presented works within this Doctoral Thesis are framed in the neurocinematics, as well as in the study of brain effects of professionalization. Find a brief approximation below.

2.1. Neurocinematics

The study of the moving image using neuroscientific tools dates back to the 1950s. By that time, a group of neuroscientists analysed changes in the electrical brain activity of people while watching audiovisual contents (Cohen-Séat, Gastaut, & Bert, 1954; Gastaut & Bert, 1954). In a very innovative approach, researchers distinguished the effects of movies projections on the electrical brain activity of the viewers, based on the areas of the brain and the narrative contents of the presented films. They found a relation of a block of a brain rhythm, named as rhythm "en arceau" (in arch), with the image of boxers in action (Cohen-Séat et al., 1954). Today, we think that this rhythm that they described can be the known as mu rhythm (8-13 Hz) that has been correlated with motor activity, empathy and the mirror neuron system (Pineda, 2005). Despite this early junction, for decades, neuroscience and communication studies have not worked together. While neuroscience has been very dedicated to basic and clinical research, communication studies have not relied on neuroscientific tools to learn how the communication processes are made.

However, by the beginning of XXIst century, some works started to use neuroscientific tools to approach communication processes and strategies again. For instance, in 2004, an investigation studied that the neural correlates of behavioural preference for culturally familiar drinks as Coca-Cola® and Pepsi® was published in the journal *Neuron* (McClure et al., 2004). And also by that time, a group of neuroscientists from Israel, led by Uri Hasson, published in *Science* the study of the brain activity of viewers while perceiving a film (Hasson, Nir, Levy, Fuhrmann, & Malach, 2004). They found an intersubject synchronization of cortical activity during natural vision of a movie. A few years after, in 2008, Uri Hasson and colleagues (Hasson, Landesman, et al., 2008), based in this publication, coined the term neurocinematics in a social sciences journal named *Projections*. They proposed this as a new interdisciplinary field of study, joining cognitive neuroscience and film studies. The appearance of this research with the title 'Neurocinematics: The Neuroscience of Film' in a journal of film theory marks a turning point for transdisciplinary neuroscientific work with the film studies, with new tools for studying different aspects of films and filmmaking (Hasson, Landesman, et al., 2008). Although there has been criticisms, neurocinematics is a very productive pathway for neuroscience and understanding of perception in the brain (Poulaki, 2014). During the last couple of decades, various works have studied brain activity of viewers, regardless they have explicitly talked about neurocinematics term or not. And, while several authors from Social Sciences have paid attention to the term and the interdisciplinary proposal of research (Poulaki, 2014), researchers from a more Natural Science perspective have also shown interest in approaching the neurocinematics challenges (Cha, Chang, Shin, Jang, & Im, 2015).

2.2. Registration techniques used for studying cognitive processes when watching audiovisual contents

There are available different techniques used for registering brain activity and detecting brain patterns of viewers when watching audiovisuals.

One way to study visual perception patterns when watching audiovisuals is through hemodynamic responses with functional magnetic resonance imaging (fMRI). This approach has given some interesting results already. Narrative segmentation in films rises a neural cascade that is perceived as the boundary between two events (Zacks, Speer, Swallow, & Maley, 2010). Also, the social perspective-taking with which a narrative is presented to viewers modulates brain activity (Bacha-Trams, Ryyppö, Glerean, Sams, & Jääskeläinen, 2020). One of the most relevant approach in neurocinematics has been through intersubject correlation analysis (ISC) with fMRI (Hasson, Furman, Clark, Dudai, & Davachi, 2008; Hasson et al., 2004; Kauppi, Jääskeläinen, Sams, & Tohka, 2010). The idea is to measure the effectiveness and overlap of the film's cognitive and perceptual emotional effects on viewers. Through an analysis of the correlation between subjects, the spatiotemporal similarities of the responses of spectators' brains are studied. For instance, it has been found that suspense in narratives increases dynamic ISC of viewers (Schmälzle & Grall, 2020) proving that content in film can manage audience brain responses collectively. This ISC proposed analysis method has been compared with the traditional General Linear Model (GLM), obtaining that ISC offers results very similar to those of traditional fMRI analysis but that facilitate the application in situations that, until now, could not be analysed (Jääskeläinen et al., 2016; Pajula, Kauppi, & Tohka, 2012). This fact has caused Hasson's team to be widely recognized for their contribution to the union of neuroscience with film research.

Cognitive processes when watching audiovisual works can also be approached from an electrophysiological activity, with the help of electroencephalography (EEG). It is commonly addressed by analysing the event-related potentials and frequency bands' activity with electrical brain analysis of viewers (Cochin, Barthelemy, Lejeune, Roux, & Martineau, 1998; Makeig & Onton, 2009; Poulsen, Kamronn, Dmochowski, Parra, & Hansen, 2016). The idea consists in presenting audiovisual events to viewers and analysing the brain reactions to the structural features of an audiovisual message, studying stimulus-evoked neural responses. For instance, it has been studied that related and unrelated cuts provoke different electrical brain signatures (Francuz & Zabielska-Mendyk, 2013), while continuity edits and cuts-across the line also differ (Heimann et al., 2016), showing that there may be different processing mechanisms involved in processing movie cuts, depending on the narrative content of the shots. Also, electrical brain synchronization among viewers has been detected during video presentation (Poulsen et al., 2016).

Another way to approach viewers' cognitive perception is through electrooculography (EOG) registering eyeblinks (Ponder & Kennedy, 1927). We blink around 15-20 times per minute (Hall, 1945; Nakano, Kato, Morito, Itoi, & Kitazawa, 2013; Ousler et al., 2014).

Blinking has a double function: it protects the cornea by wetting it (Doane, 1980) and it manages attention (Recarte, Pérez, Conchillo, & Nunes, 2008). The higher the attention and workload, the lower the eyeblink rate (Zheng et al., 2012). Eyeblinks hide visual information for between 150-400 milliseconds (Shapiro & Raymond, 2008; Skotte, Nøjgaard, Jørgensen, Christensen, & Sjøgaard, 2007; Stern, Boyer, & Schroeder, 1994; VanderWerf, Brassinga, Reits, Aramideh, & Ongerboer de Visser, 2003). So, it is important to decide which is the best moment to blink since visual information is going to be lost (Bristow, Haynes, Sylvester, Frith, & Rees, 2005), also when watching movies. Besides, to media editors it is of high interest to know how to predict when viewers are going to blink. The moments of the blinks have been predicted to be the best ones to insert cuts, since they are break points of the narrative and can have an impact on viewers' perception and comprehension (Murch, 1995). Thus, visual information loss could be minimized. Synchronized blinks occur during scenes that require less attention to understand, such as conclusions of actions, absences of main character, or repeated presentations of similar scenes, while there is not such synchronization when watching a background video of landscapes or tropical fishes with no narrative on it (Nakano, Yamamoto, Kitajo, Takahashi, & Kitazawa, 2009). Blinks synchronization correlates with the interest level of the watched narrative content, which suggests that blink synchronization is an involuntary index to assess a person's interest (Nakano & Miyazaki, 2019).

2.3. Perception of screens versus reality

We perceive reality making constant low-level sensory predictions about what we expect to see, hear, and feel. Correct predictions result in understanding, while incorrect ones result in confusion and prompt us to pay attention (Hawkins & Blakeslee, 2004). But since reality is dynamic and plenty of events, we are being constantly challenged. A famous study that tested participants to watch a video with people passing basketballs around, while a person wearing a gorilla costume walked around the scene, showed that the likelihood of noticing an unexpected object depends on the similarity of that object to others in the display and on how difficult the task being performed is (Simons & Chabris, 1999). We know there is a network of brain regions (including a larger bilateral region in posterior cortex and smaller region in right frontal cortex) tuned to perceptually salient event boundaries, this network of cortical areas show task-independent transient changes in activity correlated with perceptual segmentation (Zacks et al., 2001). But, while reality may or may not have events that interrupt continuity, films have cuts that constantly interrupt it.

Today, we are surrounded by screens and the average time that people spend per day watching screens (TV, tablets, smart phones, PC, multimedia devices, video game consoles,…) has recently increased (Nielsen, 2016a, 2016b). Several studies have proven that watching screens has an effect on people (Rosenfield, Jahan, Nunez, & Chan, 2015; Van Cauwenberge, Schaap, & Van Roy, 2014), especially in children (Sigman, 2012). It has been studied how screens affect viewers' eyeblink rate (Cardona, Gómez, Quevedo, & Gispets, 2014; Skotte et al., 2007). And despite people can clearly distinguish between what is reality and drama on the screen, and we do not call the police when a murder happens in a movie (Carroll & Seeley, 2013), we know little about differences in perceiving the very same narrative content in a live performance or on a screened representation.

2.4. Cognitive processing of content and style in audiovisuals

Audiovisuals are plenty of narratives that conform the content and of formal events that conform the style. Those content and style-related elements have an impact on viewers' perception. Regarding the style, cuts are events that always present new visual information. They involve spatial, temporal, and action narrative changes. It has been reported a decrease of eye movements following a cut, followed by an increase 200-400 ms after it (D'Ydewalle, Desmet, & Van Rensbergen, 1998; D'Ydewalle & Vanderbeeken, 1990). And there seems to be a mechanism for controlling timing of blinks to minimize the chance of losing critical information while viewing visual events. The visual perception of new visual information in natural scenes activate primary visual zones for brain processing (Thorpe, Fize, & Marlot, 1996), with a progression of the activity from the occipital to the frontal areas, as in other visual processing (Hegdé, 2008). However, the consistency of the narrative in films overrules the effects of cuts in transitions (Germeys & D'Ydewalle, 2007). And despite the discontinuity that cuts present, narratives in films are comprehensible for viewers even if they have not experienced media content before (Schwan & Ildirar, 2010). The known as 'edit blindness effect' may be also related to this. Edit blindness is a phenomenon according to which viewers hardly are aware of changes derived from film editing (Smith & Henderson, 2008). Besides, regarding the narrative, while some scripted actions manage viewers' attention, videos without any story do not synchronize viewers' eyeblink rate (Nakano et al., 2009). This management of the attention made by the narrative content of video stories seems to be done in an unconsciously, but commonly, way.

2.5. Brain effects of professionalization

Expertise and professionalization require a long-time training. With experience, a person gains the ability to visualize tasks in a more effective way and expert performers no longer rely on analytic principles to understand a situation (Klein & Hoffman, 1993). Professionalization's effects have been studied in several areas of interest. For instance, it has been studied that professional athletes have a great ability to learn how to process complex dynamic visual scenes (Faubert, 2013). Looking at people dancing has different effects on dancers compared with non-dancers (Orgs, Dombrowski, Heil, & Jansen-Osmann, 2008), proving the impact of the expertise in dancing. Expertise in baseball also provokes different brain activity in motor learning tasks (Muraskin et al., 2016). Taxi drivers show navigation-related structural brain changes in hippocampi (Maguire et al., 2000; Maguire, Woollett, & Spiers, 2006). Also, several correlations in cognitive processing and expertise have been found in aesthetics (Kirk, Skov, Schram Christensen, & Nygaard, 2008) and music (Gaser & Schlaug, 2003; Lotze, Scheler, Tan, Braun, & Birbaumer, 2003; Paraskevopoulos, Kraneburg, Herholz, Bamidis, & Pantev, 2015).

According to these studies, developing a task repeatedly steady during an extended period, as professionals do, changes cognitive processing of developing that specific task or of looking at others doing it. It has also been proven that this can provoke structural changes in the brain, as in the mentioned case of taxi drivers. In a society where media consumption has dramatically increased during the last years, learning the impact that audiovisual professionalization can have on people is of interest. It can reveal not only interesting information for media professionals, but also for the great demanding society of the screens.

From this framework, this Thesis has one hypothesis and five investigation objectives, presented in the next section.

3. HYPOTHESIS AND OBJECTIVES

The main **hypothesis** of the present study is that formal, stylistic, and narrative characteristics of audiovisual content have different, significant, and neuroscientifically measurable impact in viewers' perception. In the junction of audiovisual communication research and neurosciences, this Thesis responds to a general research objective and five specific ones. These are pursued along the six publications that make up this work.

As a **general research objective**, this Thesis aims to find brain processes underlying the perception of audiovisual content. Using neuroscientific techniques, this Thesis wants to understand cognitive processes of viewers looking at video content. This general goal is address in all six publications.

Besides, five specific research objectives are addressed:

- **Objective 1.** To find out if there are differences in cognitive processing between watching a narrative through the screen or in a real performance.
  This objective is addressed in the Publication 1 (Andreu-Sánchez et al. 2017, *PLoS ONE*).

- **Objective 2.** To determine if the style of the audiovisual editing has any kind of impact on the cognitive processing of the viewers.
  This objective is addressed in the Publications 2 (Andreu-Sánchez et al. 2017, *Scientific Reports*) and 3 (Andreu-Sánchez et al. 2018, *Neuroscience*).

- **Objective 3.** To determine what type of modulation in the cognitive activity of the viewers causes the cut in audiovisuals.
  This objective is addressed in the Publications 3 (Andreu-Sánchez et al. 2018, *Neuroscience*) and 6 (Andreu-Sánchez et al. 2022, *Symmetry*).

- **Objective 4.** To find out if there is narrative content that, regardless of editing style, synchronizes the viewers' blink rate.

  This objective is addressed in the Publication 4 (Andreu-Sánchez et al. 2021, *Brain Sciences*).

- **Objective 5.** To find out if there are perceptual differences between media professionals and non-media professionals.

  This objective is addressed in the Publications 1 (Andreu-Sánchez et al. 2017, *PLoS ONE*), 2 (Andreu-Sánchez et al. 2017, *Scientific Reports*) and 5 (Andreu-Sánchez et al. 2021, *Frontiers in Systems Neuroscience*).

4. MATERIALS AND METHODS

Each one of the six presented publications presented for this Compendium Thesis has its own methods section. Here, I am presenting a summary of some common materials and methods elements. Find detailed information about methods in each paper (available in the Appendix section).

4.1. Data acquisition

The interest of these works was to register brain activity and ocular activity of participants. To do so, we used electroencephalography (EEG) and electrooculography (EOG) systems. We used a Enobio 20 device from the brand Neuroelectrics (Barcelona, Spain), with 20 electrodes. We used the International 10/20 system to locate the electrodes in the scalp of participants [O1, O2, P7, P3, Pz, P4, P8, T7, C3, Cz, C4, T8, F7, F3, Fz, F4, F8, Fp1, Fp2, and an external electrode used for electrooculogram (EOG) recording] referenced to electronically linked mastoid electrodes (Figures 1 and 2) (Martín-Pascual, Andreu-Sánchez, Delgado-García, & Gruart, 2018).

The EOG electrode was positioned vertically at the infraorbital ridge and the lower outer canthus of the left eye and was used to monitor eyeblinks. Data were sampled at 500Hz. In order to have a good quality of EEG signal, participants were asked to wash their hair before attending the session and to avoid any chemical product (such as a hair spray or similar) on it. An HD-video camera (Sony HDR- GW55VE, Sony Corporation España, Barcelona, Spain) recorded at 25 frames/s participants' faces with a close-up for contrasting their eye movements and eyeblinks during the analysis of the eyeblink rate (Figure 3).

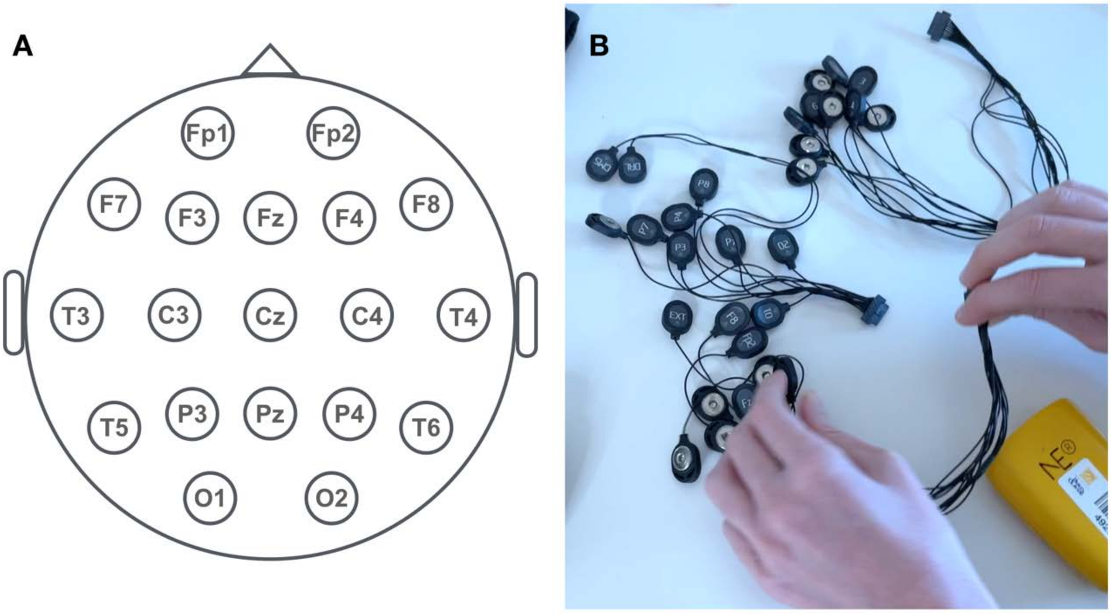

Figure 1. (A) Location of electrodes used in the works, following a 10/20 system. (B) Electrodes and EEG device used for the experiments (Enobio, Neuroelectrics).

Figure 2. A participant to whom I am putting the EEG cap in the lab.

Figure 3. A participant watching at the visual presentation of a screened stimulus, while his face is being recorded with a frontal HD-video camera, for contrasting purposes in the eyeblink counting.

To manage all the devices while the data acquisition, we developed a connections map and evaluated it to make sure all the devices were properly synchronized.

4.2. Experimental stimuli

All presented stimuli were created ad-hoc in our lab for the investigations. Based on the independent variables of interest, we created the stimuli. Basically, we presented videos (scripted, recorded and edited by ourselves) and a real performance (scripted and played by ourselves) played for each participant. The reason to create ad-hoc stimuli was precisely for having a high control of the elements presented to the participants and being capable of clearly distinguish and compare the independent variables of interest for the different analysis. Stimuli were always randomly presented to participants to avoid neural habituation to the stimulus (Sternberg, 2009).

4.3. Experimental set-up

Data were registered in an experimental set-up, developed in Barcelona (Figure 4). The set-up consisted in different areas with their own purposes. There was an area for the participant, where he could look at the presented stimuli while seated in a chair. There was an area for the researchers, where we could have access to the continuous data that was being registered and to all the technical apparatus presenting the stimuli, registering the data, and synchronizing all the computers used. We made a black structure that involved participant's area for helping participants to concentrate in the tasks of looking at the stimuli. This black structure had a hole in the middle of the frontal area with a clear purpose: to put the screen when video-stimulus was presented and to put it away when a performance was played. When the screen was put in the thole, video-stimuli were presented, when the screen was put away, the hole showed the performance area framed in the black structure, allowing the participant to concentrate just in the real performance without seeing other non-stage elements from the room.

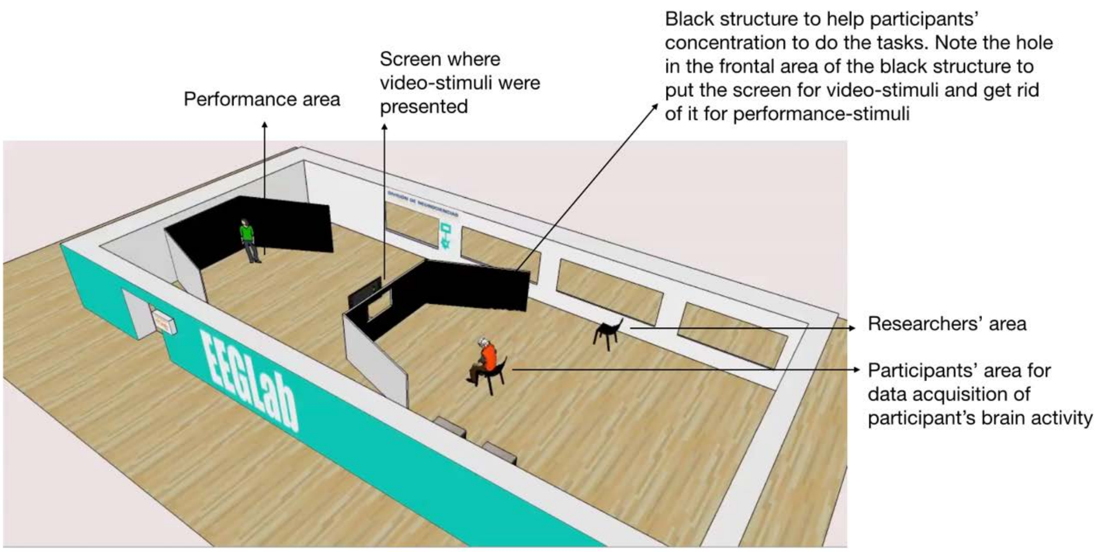

Figure 4. Experimental set-up design for the research works.

4.4. Ethics statement

Experiments were conducted following guidelines, procedures, and regulations for human research of the University Autònoma de Barcelona and approved by its Ethics

Commission for Research with Animals and Humans (CEEAH), meeting all applicable standards for the ethics of experimentation and research integrity. All participants gave prior written informed consent to participate.

4.5. Data analysis

Data were analysed following different variables of interest. These are the most important that can be found in the different works:

- SBR, spontaneous blink rate. We analysed SBRs of participants while looking at the stimuli, based on different independent variables like cuts or style of edition of the video-stimuli. SBR indicate cognitive state variables and attentional resources for visual processing images (Stern, Walrath, & Goldstein, 1984).
- ERP, event-related potential. We studied ERPs for brain activity corresponded to some events (or independent variables) of interest. ERPs indicate changes in electrical brain activity in response to stimulus (Sternberg, 2009).
- ERSP, event-related spectrum perturbances. We analysed ERSPs of participants for brain activity study of brain frequencies. ERSPs indicate time-frequency transforms of EEG epochs time locked to experimental events, measuring event-related modulation of EEG amplitude at a range of frequencies and time scales of interest (Makeig & Jung, 1996).
- Power spectra. In the works, we analysed different power bands (or rhythms) based on previous literature related to each of the variables and objectives in each study. Power spectra of epochs of electrical fields represent membrane voltage fluctuations of millions of neurons recorded by scalp electrodes that can be analysed in a brain-behaviour relations perspective (Buzsáki, 2006).
- PLV, phase-locking value. We studied PLV for functional brain connectivity of participants. PLV detects synchrony in a precise frequency range between two recording sites (Lachaux, Rodriguez, Martinerie, & Varela, 1999).
- GC, Granger causality. We studied GC for effective brain connectivity of participants. GC stands that for two simultaneously measured signals, if one can predict the first signal better by incorporating the information from the second

signal, then the second signal can be called causal to the first (Granger, 1969; Niso et al., 2013; Wiener, 1956).

- Brain asymmetry. In one of the papers, we approached brain asymmetry in viewers when watching brand-new visual content that follows cuts in movies. To do so, we compared brain activity in both hemispheres of viewers computing the natural-log transformed power at homologous sites of the brain (Davidson, 1992; Mathewson et al., 2015).

4.6. Software

We used several software and plug-ins for developing the presented research. These are the most important ones:

- ADJUST plug-in (Mognon, Jovicich, Bruzzone, & Buiatti, 2010) for EEGLAB for artifact detection in the EEG.
- Adobe Premiere Pro (Adobe Inc., Mountain View, CA, USA) for editing the video stimuli.
- Brainstorm (Brainstorm, University of Southern California, Los Angeles, CA, USA), running on MATLAB, for isolating and analysing participants' eyeblinks.
- DIPFIT plug-in (Oostenveld & Oostendorp, 2002) for EEGLAB for source location in the EEG.
- EEGLAB (Delorme & Makeig, 2004), running on MATLAB, for cleaning and analysing the EEG datasets.
- HERMES (Niso et al., 2013), running on MATLAB, for analysing brain connectivity.
- MATLAB (The Mathworks Inc., Natick, MA, USA) for analysing the data and running other software programs like EEGLAB, Brainstorm and HERMES.
- NIC (Neuroelectrics, Barcelona, Spain) for recording the EEG and EOG activity from participants.
- Paradigm Stimulus Presentation (Perception Research System Incorporated, Laurence, KS, USA) for presentation of the stimuli and synchronization of those with the EEG recording system.
- Sigmaplot (Systat Software Inc., San José, CA, USA) for statistical analysis.

5. LIST OF PUBLICATIONS AND MAIN RESULTS

The six publications contributed for this Thesis by compendium are included in the Appendix section of this work and presented below:

- **Publication 1 – *PLoS ONE***

  Andreu-Sánchez, C., Martín-Pascual, M.Á., Gruart, A. & Delgado-García, J.M. (2017). Looking at reality versus watching screens: Media professionalization effects on the spontaneous eyeblink rate. *PLoS ONE*, 12(5): e0176030.
  doi: 10.1371/journal.pone.0176030
  Journal Impact Factor (in 2017): 2.776 (Q1 – Multidisciplinary Sciences)
  Journal Impact Factor (in 2021): 3.752 (Q2 – Multidisciplinary Sciences)

  Abstract
  This article explores whether there are differences in visual perception of narrative between theatrical performances and screens, and whether media professionalization affects visual perception. We created a live theatrical stimulus and three audio-visual stimuli (each one with a different video editing style) having the same narrative, and displayed them randomly to participants (20 media professionals and 20 non-media professionals). For media professionals, watching movies on screens evoked a significantly lower spontaneous blink rate (SBR) than looking at theatrical performances. Media professionals presented a substantially lower SBR than non-media professionals when watching screens, and more surprisingly, also when seeing reality. According to our results, media professionals pay higher attention to both screens and the real world than do non-media professionals.

  Main results

  - Consuming narratives on screens or in real performances provoke differences in viewers' eyeblink rate, with an inhibition in the first case.

- There are differences in cognitive processing of a narrative content depending if we are perceiving it by looking at a real representation or watching it on a screen.
- The lower eyeblink rate while watching screens suggests that looking at screens could have an impact on visual health of viewers due to that decrease blinking avoiding the cornea to be moistened.
- Media professionals show a lower eyeblink rate compared with non-media professionals watching audiovisuals and looking at real performances, suggesting a better management of the loss of visual information that blinks entail.

- **Publication 2 – *Scientific Reports***

  <u>Andreu-Sánchez, C.,</u> Martín-Pascual, M.Á., Gruart, A. & Delgado-García, J.M. (2017). Eyeblink rate watching classical Hollywood and post-classical MTV editing styles, in media and non-media professionals. *Scientific Reports*, 7: 43267.

  doi: 10.1038/srep43267

  Journal Impact Factor (in 2017): 4.122 (Q1 – Multidisciplinary Sciences)

  Journal Impact Factor (in 2021): 4.997 (Q1 – Multidisciplinary Sciences)

  <u>Abstract</u>

  While movie edition creates a discontinuity in audio-visual works for narrative and economy-of- storytelling reasons, eyeblink creates a discontinuity in visual perception for protective and cognitive reasons. We were interested in analyzing eyeblink rate linked to cinematographic edition styles. We created three video stimuli with different editing styles and analyzed spontaneous blink rate in participants (N = 40). We were also interested in looking for different perceptive patterns in blink rate related to media professionalization. For that, of our participants, half (n = 20) were media professionals, and the other half were not. According to our results, MTV editing style inhibits eyeblinks more than Hollywood style and one-shot style. More interestingly, we obtained differences

in visual perception related to media professionalization: we found that media professionals inhibit eyeblink rate substantially compared with non-media professionals, in any style of audio-visual edition.

Main results

- The style of edition used for the editing of movies impacts on viewers cognitive processing.
- The higher number of cuts an audiovisual work has, the lower eyeblink rate the viewers present.
- An organized and classic style of edition as the Hollywood style decreases viewers' eyeblink rate compared with a chaotic and disorganized style of edition as the MTV style.

- **Publication 3 – *Neuroscience***

Andreu-Sánchez, C., Martín-Pascual, M.Á., Gruart, A. & Delgado-García, J.M. (2018). Chaotic and Fast Audiovisuals Increase Attentional Scope but Decrease Conscious Processing. *Neuroscience*, 394: 83-97.

doi: 10.1016/j.neuroscience.2018.10.025

Journal Impact Factor (in 2018): 3.244 (Q2 – Neurosciences)

Journal Impact Factor (in 2021): 3.708 (Q3 – Neurosciences)

Abstract

Audiovisual cuts involve spatial, temporal, and action narrative leaps. They can even change the meaning of the narrative through film editing. Many cuts are not consciously perceived, others are, just as we perceive or not the changes in real events. In this paper, we analyze the effects of cuts and different editing styles on 36 subjects, using electroencephalographic (EEG) techniques and the projection of stimuli with different audiovisual style of edition but the same narrative. Eyeblinks, event-related potentials (ERPs), EEG spectral power and disturbances, and the functional and effective connectivity before and after the cuts were analyzed. Cuts decreased blink frequency in the first second following

them. Cuts also caused an increase of the alpha rhythm, with a cortical evolution from visual toward rostral areas. There were marked differences between a video-clip editing style, with greater activities evoked in visual areas, and the classic continuous style of editing, which presented greater activities in the frontal zones. This was reflected by differences in the theta rhythm between 200 and 400 ms, in visual and frontal zones, and can be connected to the different demands that each style of edition makes on working memory and conscious processing after cutting. Also, at the time of cuts, the causality between visual, somatosensory, and frontal networks is altered in any editing style. Our findings suggest that cuts affect media perception and chaotic and fast audiovisuals increase attentional scope but decrease conscious processing.

Main results

- Cuts inhibit viewers' eyeblink rate during the following 1000 ms after them.
- The brain activity after a cut depends on the style of edition of the audiovisual work.
- Cuts in organized style of edition (Hollywood style) increase brain activity in prefrontal areas compared with chaotic styles of edition (MTV style), but activity in visual cortex is higher in the latter.

- **Publication 4 – *Brain Sciences***

Andreu-Sánchez, C., Martín-Pascual, M.Á., Gruart, A. & Delgado-García, J.M. (2021). Viewers Change Eye-Blink Rate by Predicting Narrative Content. *Brain Sciences*, 11, 422.

doi: 10.3390/ brainsci11040422

Journal Impact Factor (in 2021): 3.333 (Q3 – Neurosciences)

Abstract

Eye blinks provoke a loss of visual information. However, we are not constantly making conscious decisions about the appropriate moment to blink. The

presence or absence of eye blinks also denotes levels of attention. We presented three movies with the exact same narrative but different styles of editing and recorded participants' eye blinks. We found that moments of increased or decreased eye blinks by viewers coincided with the same content in the different movie styles. The moments of increased eye blinks corresponded to those when the actor leaves the scene and when the movie repeats the same action for a while. The moments of decreased eye blinks corresponded to actions where visual information was crucial to proper understanding of the scene presented. According to these results, viewers' attention is more related to narrative content than to the style of editing when watching movies.

Main results

- In audiovisuals, there are specific narrative actions in which viewers increase or decrease their eyeblink rate based on the attentional level that the narrative content presented needs to be decoded, regardless the style of edition.
- Viewers decrease their eyeblink rate when the movie presents unexpected actions, where visual information is crucial to understand the content.
- Viewers increase their eyeblink rate when the character disappears from scene or with repetitive actions.
- In specific narrative actions, viewers' attention is more related to content than to the style.

- **Publication 5 – *Frontiers in Systems Neuroscience***

  Andreu-Sánchez, C., Martín-Pascual, M.Á., Gruart, A. & Delgado-García, J.M. (2021). The Effect of Media Professionalization on Cognitive Neurodynamics During Audiovisual Cuts. *Frontiers in Systems Neuroscience*, 15: 598383.

  doi: 10.3389/fnsys.2021.598383

  Journal Impact Factor (in 2021): 3.785 (Q3 – Neurosciences)

Abstract

Experts apply their experience to the proper development of their routine activities. Their acquired expertise or professionalization is expected to help in the development of those recurring tasks. Media professionals spend their daily work watching narrative contents on screens, so learning how they manage visual perception of those contents could be of interest in an increasingly audiovisual society. Media works require not only the understanding of the storytelling, but also the decoding of the formal rules and presentations. We recorded electroencephalographic (EEG) signals from 36 participants (18 media professionals and 18 non-media professionals) while they were watching audiovisual contents, and compared their eyeblink rate and their brain activity and connectivity. We found that media professionals decreased their blink rate after the cuts, suggesting that they can better manage the loss of visual information that blinks entail by sparing them when new visual information is being presented. Cuts triggered similar activation of basic brain processing in the visual cortex of the two groups, but different processing in medial and frontal cortical areas, where media professionals showed a lower activity. Effective brain connectivity occurred in a more organized way in media professionals– possibly due to a better communication between cortical areas that are coordinated for decoding new visual content after cuts.

Main results

- Media professionals decrease their eyeblink rate significantly more than non-media professionals after audiovisual cuts.
- There are cognitive processes, such as brain connectivity (effective and functional) that differ between media and non-media professionals when watching movies.

- **Publication 6 – *Symmetry***

  Andreu-Sánchez, C., Martín-Pascual, M.Á., Gruart, A. & Delgado-García, J.M. (2022). Brain Symmetry in Alpha Band When Watching Cuts. *Symmetry*, 14: 1980.

  doi: 10.3390/sym14101980

  Journal Impact Factor (in 2021): 2.940 (Q2 – Multidisciplinary Sciences)

  Abstract

  The purpose of this study is to determine if there is asymmetry in the brain activity between both hemispheres while watching cuts in movies. We presented videos with cuts to 36 participants, registered electrical brain activity through electroencephalography (EEG) and analyzed asymmetry in frontal, somatomotor, temporal, parietal and occipital areas. EEG power and alpha (8–13 Hz) asymmetry were analyzed based on 4032 epochs (112 epochs from videos × 36 participants) in each hemisphere. On average, we found negative asymmetry, indicating a greater alpha power in the left hemisphere and a greater activity in the right hemisphere in frontal, temporal and occipital areas. The opposite was found in somatomotor and temporal areas. However, with a high inter-subject's variability, these asymmetries did not seem to be significant. Our results suggest that cuts in audiovisuals do not provoke any specific asymmetrical brain activity in the alpha band in viewers. We conclude that brain asymmetry when decoding audiovisual content may be more related with narrative content than with formal style.

  Main results

  - Regardless, we found positive asymmetry in the somatomotor and the temporal area, because of a higher right hemisphere alpha power that corresponds with a higher left hemisphere activity and a negative asymmetry in frontal, parietal and occipital areas, suggesting the contrary, these results were not significant.
  - Cuts in audiovisuals do not evoke any specific and significant asymmetrical brain activity in the alpha band in viewers, suggesting that

brain asymmetry when watching videos may be more related to narrative content and emotions than to the style.

The publications address the stated objectives as indicated in the following table:

Publication	**Addressed objectives**
1 – *PLoS ONE*	1 and 5
2 – *Scientific Reports*	2 and 5
3 – *Neuroscience*	2 and 3
4 – *Brain Sciences*	4
5 – *Frontiers in Systems Neuroscience*	5
6 – *Symmetry*	3

As abovementioned, the publications can be found in the Appendix section, at the end of this document.

6. DISCUSSION AND CONCLUSIONS

This Doctoral Thesis proposed five main research objectives. The objective 1 of this work was to find out if there were differences in cognitive processing between watching a narrative through the screen or in a real performance. The Publication 1 (Andreu-Sánchez, Martín-Pascual, Gruart, & Delgado-García, 2017b) approached this objective by presenting the same narrative content in a real performance and in videos. It was found that real screened videos inhibit viewers' eyeblinks compared with real performances. This is coincident with the works that show that watching screens steadily over time decrease viewers' eyeblink rate, drifting into the collectively called Computer Vision Syndrome (CVS) (Blehm, Vishnu, Khattak, Mitra, & Yee, 2005), suggesting that a main factor for this inhibition of eyeblinks is the format of the screen itself rather than the presented content.

The second objective was to determine if the style of the audiovisual editing had any kind of impact on the cognitive processing of the viewers. According to the results obtained in the Publication 2 (Andreu-Sánchez, Martín-Pascual, Gruart, & Delgado-García, 2017a) and Publication 3 (Andreu-Sánchez, Martín-Pascual, Gruart, & Delgado-García, 2018), different styles of edition provoke different cognitive processing in viewers. MTV style of edition with a discontinuous and disorganized style of presenting the visual shots, and shorter shots, inhibits eyeblinks more than classical Hollywood style of edition, with an organized and clearer style of visual presentation and longer shots, and more than one-shot style movies with no cuts. Since eyeblinks are attentional markers –the higher the rate, the lower the attention– this result is of high interest for media creators who, by managing the style of the edition, can manage viewers' attention.

Suspecting that the cut would have an important role in this different perception regarding the styles of edition, the third objective of this work consisted in determining what type of modulation in the cognitive activity of the viewers causes the cut in audiovisuals. The Publication 3 (Andreu-Sánchez et al., 2018) proved that brain activity after the cut potentials spreads from the occipital area to the frontal area at around 200 ms after the cut, as the perception of the stimulus progresses to more complex areas of process and feedback. This is consistent with the feedforward event during early visual processing (Del Cul, Baillet, & Dehaene, 2007; Wyatte, Jilk, & O'Reilly, 2014). Also, it was found that the cut in different styles of edition provokes different brain activity in viewers. While cuts in a chaotic and non-organized style of edition, such as MTV style, provokes a higher activity in visual areas, organized and continuous style of edition such as Hollywood style, impacts more on the prefrontal and higher processing areas. This suggests that the predictability of the new visual information from the organized style of edition requires less work from the visual cortex, allowing a higher cognitive processing of the narrative content. Meanwhile, the chaotic visual presentation of the narrative would need higher visual processing from the visual cortex, delaying or eliminating the higher cognitive processing (or understanding) of the narrative. On the other hand, since brain asymmetry had been found when watching audiovisual content (Jones & Fox, 1992; Ohme, Reykowska, Wiener, & Choromanska, 2010; Tomarken, Davidson, & Henriques, 1990), in the Publication 6 (Andreu-Sánchez, Martín-Pascual, Gruart, & Delgado-García, 2022) we wondered if processing brand-new visual information that follows cuts in movies would be asymmetrical in alpha band. Some interesting asymmetries were found, however, when doing the statistics those were not significant, so, it was concluded that cuts do not provoke significant asymmetries in viewers, suggesting that brain asymmetry when decoding movies previously found would be more related with the narrative and emotional content than with formal style.

After knowing that the style of edition impacts viewers processing of the same narrative content, the fourth objective of this Doctoral Thesis was to find out if there were narrative content that, regardless of the editing style, synchronized the viewers' attention. To do so, in Publication 4 (Andreu-Sánchez, Martín-Pascual, Gruart, & Delgado-García, 2021b), eyeblink rate of viewers was analysed. According to this study, there are narratives that synchronize increases and decreases of viewers' eyeblink rate, regardless the style of edition in which they are presented. This is something that would happen only with some specific narrative actions, meaning that in global, the style of edition affects viewers' eyeblink rate, as seen above in objective 2, but, in particular, some narrative actions manage viewers' attention more strongly that the editing style. The moments of increased eyeblink found here correspond with the actor leaving the scene and with the repetition of an action. And the moments of decreased eyeblink rate correspond to actions where visual information is crucial to proper understand the narrative content presented. These results are coincident with a previous study (Nakano et al., 2009), where the narrative content also synchronized viewers eyeblink rate in the same line as here. This suggests that, unconsciously, viewers need to decide which is the best moment to blink and thus avoid losing visual information. This would be coherent with the memory-prediction framework proposed by Jeff Hawkins (Hawkins & Blakeslee, 2004), according to which the human cortex is constantly predicting what one will see, hear, and feel, mostly, in non-conscious ways. When watching audiovisuals, the brain would be making predictions about whether any important content is about to happen to avoid losing information by blinking. If nothing important is expected to happen, for instance, while the character is out of scene or the action is repetitive, blinking would be presented as a good option. This shows a strong potential to be a way to approach conscious processing.

Finally, the objective 5 of this Doctoral Thesis was to find out if there were perceptual differences between media professionals and non-media professionals when looking at narratives. Publications 1 (Andreu-Sánchez et al., 2017b), 2 (Andreu-Sánchez et al., 2017a) and 5 (Andreu-Sánchez, Martín-Pascual, Gruart, & Delgado-García, 2021a) approach this topic. Initially, it was found that media professionals inhibit eyeblink rate in a very significant way when watching screens and when seeing reality compared with non-media professionals (Andreu-Sánchez et al., 2017b). It was also found that this lower eyeblink rate also happens when watching any style of edition (Andreu-Sánchez et al., 2017a). These results suggest that media professionals may need to face eye health problems derived from a lack of moisture in the cornea for a low eyeblink rate. Further research should be done to approach this as an occupational risk problem for media professionals. It was also found that the decrease of eyeblink rate of media professionals is maintained when looking at the activity after the cuts (Andreu-Sánchez et al., 2021a). This lower eyeblink rate suggest that media professionals, unconsciously, avoid the loss of visual information that is so important in their everyday job. Cuts trigger similar activation of basic brain processing in the visual cortex of the two groups, but different processing in medial and frontal cortical areas was found, where media professionals show a lower activity, while the effective brain connectivity is much more organized in media professionals (Andreu-Sánchez et al., 2021a). This suggests a better connectivity within areas that are coordinated for decoding new visual information after the cuts in media professionals.

This Thesis started with the hypothesis that formal, stylistic, and narrative characteristics of audiovisual content would have different, significant, and neuroscientifically measurable impact in viewers' perception. Based on the results discussed here, we can confirm that all three, the formal presentation, the style, and the narrative content of audiovisual works, have an impact on viewers' perception that can be measured with neuroscientific tools.

In summary, these studies have approached brain processes underlying the perception of audiovisual content. Neurocinematic studies bring new perspectives to the study of the communication process. It needs from a junction of different backgrounds, the study of different tools, methods, and theories, but it can improve different knowledges in relevant areas such as the communication studies, the psychological perception, and the clinical investigation, among others. First, these types of studies can be used in Communication Sciences to improve the knowledge that we have about the impact that contents and styles have on cognitive processes of viewers. Based on these results, media creators could improve their strategies for managing viewers' attention and visual processing using the scripting and the edition of movies as solid strategies. Second, these results could be used in clinical environments where visual processing and attention deteriorate as a consequence of some pathology. These methods could be used to quantify and track patients' visual behaviour over time with the help of audiovisuals. Third, all the research studies that use movies as stimuli for analysing any type of visual variable could improve their strategy for designing the audiovisual works based on the results of the six publications that form part of this Doctoral Thesis.

7. FUTURE RESEARCH

Regarding the different perception between reality and screens, I would like to keep looking at some specific markers that may be different between both ways of perceiving narratives. In particular, I am interested in studying mu rhythm (8-13Hz) differences between reality and screens. I have the hypothesis that the cerebral pattern mu, desynchronized when seeing motor activities, is different when we look at motor actions on screens or at reality, and that those differences can be quantified and standardized. In case this was confirmed, mu rhythm could be understood as a reality criterion in audiovisual industry and clinical environment.

I would also like to keep looking and studying narrative and style variables within audiovisuals that correlate with different visual perception patterns. I believe that learning those correlations would have a substantial impact. On one hand, media creators could manage their main tools (narrative scripts and style elements) based on scientific patterns. On the other hand, media production for people with special needs could be adapted based on the management of the attention.

Learning about media professionalization has been especially useful for understanding not only the effects of working with audiovisual works steadily over time, but to open my research to the study of differences in visual perception among different groups. Now, I am very interested in learning differences in visual perception between people suffering from diseases, starting with those with Autism Spectrum Disorders (ASD) and the rest. By learning brain patterns (I am interested in mu rhythm –8-13 Hz– and eyeblink rate) in children with ASD that differ from control children, we could help to develop quantitative and non-invasive tools for early diagnosis of ASD through audiovisuals. Those could complement currently available diagnosis scales. This procedure could also be applied to other diagnosis protocols.

8. REFERENCES

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9. APPENDIX

9.1. CONTRIBUTED PUBLICATIONS

RESEARCH ARTICLE

Looking at reality versus watching screens: Media professionalization effects on the spontaneous eyeblink rate

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Abstract

This article explores whether there are differences in visual perception of narrative between theatrical performances and screens, and whether media professionalization affects visual perception. We created a live theatrical stimulus and three audio-visual stimuli (each one with a different video editing style) having the same narrative, and displayed them randomly to participants (20 media professionals and 20 non-media professionals). For media professionals, watching movies on screens evoked a significantly lower spontaneous blink rate (SBR) than looking at theatrical performances. Media professionals presented a substantially lower SBR than non-media professionals when watching screens, and more surprisingly, also when seeing reality. According to our results, media professionals pay higher attention to both screens and the real world than do non-media professionals.

Introduction

Due to the recent expanded digitalization of our world, we are surrounded by screens. In the US, for example, adults spend an average of 8 hours and 47 minutes per day watching screens—with tablets, smart phones, PCs, multimedia devices, video game consoles, DVDs, time-shifted TV, and live TV [1, 2]. Despite media works being composed of an apparent continuity of fixed pictures, on many occasions they seem real to us. However, we can distinguish between reality and drama on the screen, so no one calls the police when seeing a murder in a movie [3]. We know that perception of any narrative (live or on-screen) is divided into segments of attention processed independently by the viewer [4–6]. This segmentation of autonomous narrative elements can be done with some freedom during the perception of the real world. However, when we are watching an audio-visual work, we are also giving attention to segmentations made by the director through edition [7]. It is, then, to be expected that we perceive reality and screens differently. A way to investigate those visual differences is through the quantification of the respective spontaneous blink rates (SBR). Indeed, the emergence of personal computers, giving rise to long periods of intensive work with screens, has a high incidence in SBR: people inhibit their eyeblink rate between 50% and 60% when watching the screen of a computer [8].

Computer Vision Syndrome, linked to screen use, has been well characterized through vision problems, visual accommodation problems, blurred vision, fatigue, and dry eyes [9–12]. Likewise, it is well known that eyeblink rate is affected by performing tasks that require attention. Wong and colleagues, for instance, noted that the rate in ophthalmologic surgeons decreased during the execution of surgery, from 16 to 4 eyeblinks per minute [13]. The connection between eyeblink and attention has been proven in various circumstances [14] including the use of screens [15, 16], or for diagnosis in Autism Spectrum Disorders [17–20]. In addition, a decrease in eyeblink rate has been linked to symptom worsening associated to dry keratoconjunctivitis or dry eye syndrome [8, 21]. It is well known that the narrative in media works can also affect eyeblink frequency and that SBRs synchronize among spectators watching the same movie [22, 23], contributing to the idea that blinking has not only a physiological function [23–25] but also a psychological one [26]. In fact, the importance of eyeblinks in the communicative process has been proven [19, 27], being understood as an attentional marker linked to the hypothetical Default Mode Network (DMN), which would be active when there is no attentional focus in media works [28]. However, there is controversy about the meaning of DMN [29, 30] and how it would be analyzed in media environments. Eyeblinks are also synchronized between listener(s) and talker in a conversation [27], in particular in the pauses and at the end of the discourse. On the other hand, we know that professionalization is a variable that in previous studies has been shown to change audio-visual perception and to provoke perceptive differences, and even structural brain changes, in—for example—musicians [31], athletes [32], or drivers [33, 34]. In this investigation, we had two specific aims: i) to look for differences in SBR evoked by attending the same narrative across a live theatrical performance or across a movie; and ii) to find out whether there are visual perceptive differences in SBR linked to media professionalization.

Materials and methods

Subjects

Forty healthy adults (20 non-media professionals and 20 media professionals) with normal or corrected-to-normal visual acuity participated in this study. The average age of the group of non-media professionals (15 men and 5 women) was 43.25 years ($SD = \pm 8.59$) and the average time in their professions was 19.4 years ($SD = \pm 10.21$). In the group of media professionals (16 men and 4 women), the average age was 44.15 years ($SD = \pm 7.15$) and the time in their media professions was an average of 20.2 years ($SD = \pm 8.63$). To be included in the media group, it was required that subjects needed to use video edition and to take decisions related to media editing in their everyday work. Thus, media professionals taking part in this experiment were producers, assistant producers, cameramen, image controllers, documentalists, graphic designers, post-production editors, sports commentators, and video editors. Non-media professionals were chosen outside of this criterion. The study had the approval of the Ethics Commission for Research with Animals and Humans (CEEAH) of the University Autònoma de Barcelona, Spain, with reference number 2003. All experiments were performed in accordance with relevant guidelines and regulations. Written informed consent was obtained from all participants.

Stimuli

We created four stimuli with the same narrative, action, character, and duration: three were movies with different video editing styles, and one was a live play, as shown in S1 Video. Stimulus 1 was a one-shot movie with a static open shot and no cuts; stimulus 2 was a Hollywood-editing-style movie, following classical continuity editing rules, with smooth transitions and perceptive continuity [35]; stimulus 3 was an MTV-editing-style movie, also known as post-classical or video-clip style, characterized by short moved shots, sudden moves in the frame, and a continuous motion of the camera [36, 37]; and stimulus 4 was a live performance that was played out in each experimental session. We used the three most common movie-editing styles for the screened stimuli to be in concordance with the habitual consumption of audio-visual narrative on screens. The duration of stimuli 1, 2, and 3 was 198 s each; the duration of stimulus 4 was adjusted to last approximately 198 s for each subject. The action and narrative of the four stimuli were exactly the same: a man entered, sat, juggled with three balls, worked with a computer and books, ate an apple, looked directly at the spectator/viewer, and left.

Stimulus presentation

For the presentation of the four stimuli, two black structures were created to define a flexible space: one black structure (4x2m) as a backdrop for the live play, and a second black structure with the same dimensions and a hole in the middle. This hole was designed to fit a screen (Panasonic TH-42PZ70EA, Panasonic Corporation) for the presentation of the video stimuli at a distance of 150 cm from participants (Fig 1A and 1B). For the representation of the live play, the screen was removed and subjects had visual access to the performance, as shown in S1 Video. Paradigm Stimulus Presentation (Perception Research System) was used for stimulus presentation and synchronization of recording. A pause of 30 s preceded each stimulus. During the pause, subjects had a rest period, received no experimental stimulus, and were not monitored. The presentation of the stimuli was randomized using a tetrahedron. Twenty-one of 24 possible combinations were present in the study (Fig 1C).

Data acquisition and analysis

The EMG activity of the orbicularis oculi muscle was acquired with a wireless system (Enobio®, Neuroelectrics). Silver chloride (Ag/AgCl) electrodes were placed according to the 10–

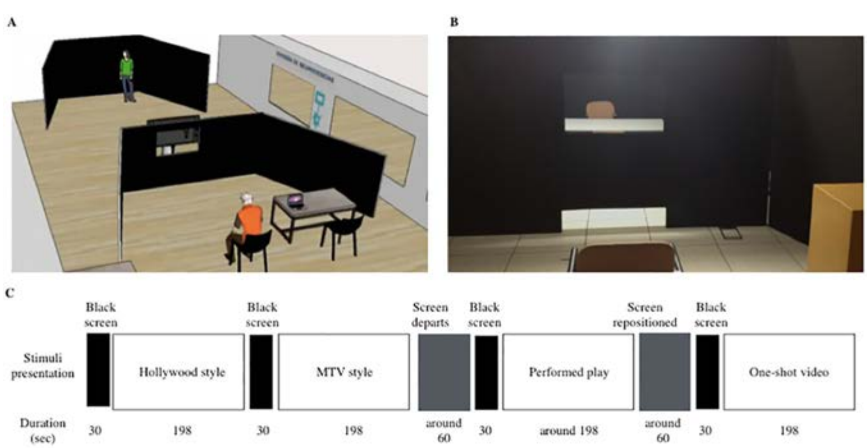

Fig 1. Stimulus presentation. (A) We designed a special stage for carrying out stimulus presentation. It comprised two different areas: at the back, there was a black backdrop with a table where the actor would make the live play presentation; in the front part, there was a black panel with a hole for the screen showing the videos. The screen was placed in the hole for video stimuli and removed for the live play stimulus. (B) The subjects were placed in front of the hole so that they could perceive the play with a black framework. This experimental set-up was aimed at making live and video stimuli experiences as similar as possible. (C) The order of stimulus presentation was randomized over the 24 possible combinations—for example, Hollywood-style movie–MTV-style movie–Performed play–One-shot movie. Each stimulus was preceded by a black screen lasting for 30 s. Whenever the live play had to be presented, the screen used for the videos was removed. It was replaced in the designed hole for the presentation of each video stimulus. The duration of the live play was approximately 198 s, while the duration of each video stimulus was 198 s.

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20 system. Electrooculogram, Fp1, and Fp2 channels were carefully placed to detect eyeblinks and other eyelid movements. The Cz channel was used as reference channel during the recording. The subject's eyes were also visually recorded with an HD video camera (Sony HDR-GW55VE, Sony Corporation). The video camera framed the subject's face in a close-up.

Eyeblinks were analyzed using two different methods. First, we detected them in the EMG signal with Brainstorm [38] running on MATLAB (The MathWorks Inc.). We filtered the signal from 0.5 Hz to 3 Hz, applied Brainstorm's eyeblink detector, and carefully checked the results, as proposed by Tadel et al. [39]. Then, and in accordance with Nakano and Kitazawa [27], we checked the results manually with HD-video recordings of the subject's ocular behavior. Statistical analysis was performed offline using Sigmaplot 11.0 (Systat Software Inc.). We analyzed data following a two-way repeated-measures analysis of variance (ANOVA) and further post hoc analysis using the Holm-Sidak method, with the whole datasets. Data were analyzed for normality and equal variance with the Shapiro-Wilk test. All three video stimuli were analyzed together under the "screen" condition. To avoid inaccuracies in data analysis derived from different duration in the live play stimulus, in each condition we worked with the mean of SBR per minute.

Results

The mean of the SBR in the totality of the subjects (N = 40) during the course of this experiment was 13.92 min^{-1} (*SD* = ± 8.342). In particular, the screened stimuli evoked an average of 13.208 eyeblinks min^{-1} (*SD* = ± 8.897), while the performed play evoked an average of 14.632 eyeblinks min^{-1} (*SD* = ± 7.794). There were big differences between groups: the screened stimuli evoked an average of 9.274 min^{-1} (*SD* = ± 6.453) for SBR in media-professionals (N = 20) and an average of 17.142 min^{-1} (*SD* = ± 9.395) for SBR in non-media professionals (N = 20), while the performed play evoked an average of 11.056 min^{-1} (*SD* = ± 6.042) for SBR in media professionals and 18.207 min^{-1} (*SD* = ± 7.828) in non-media professionals (Table 1, Fig 2). These results reveal a lower eyeblink rate when watching narrative scenes on screens compared with seeing them in a theatrical context. In addition, there seems to be a significantly lower rate of SBR in media professionals compared with non-media professionals in both situations: watching screens and looking at reality. Standard deviations also suggested a greater homogeneity in media professionals than in non-media professionals. We analyzed all these results to look for statistically significant differences.

The statistical analysis between looking at reality and watching screens showed interesting results. We compared SBRs obtained in subjects seeing a live play with those when watching the same narrative on screens. For that, we worked with the three most common video editing styles (sequence shot, Hollywood style, and MTV style). We also made the comparison

Table 1. Spontaneous blink rate per minute.

Stimulus	Subjects	SBR min^{-1}	S.D.
Screen	All subjects	13.208	8.897
Screen	Media professionals	9.274	6.453
Screen	Non-media professionals	17.142	9.395
Performance	All subjects	14.632	7.794
Performance	Media professionals	11.056	6.042
Performance	Non-media professionals	18.207	7.828

Descriptive results of blink rates per minute in screens (having the three editing styles) and in the performed play, in all subjects and by groups: media and non-media professionals.

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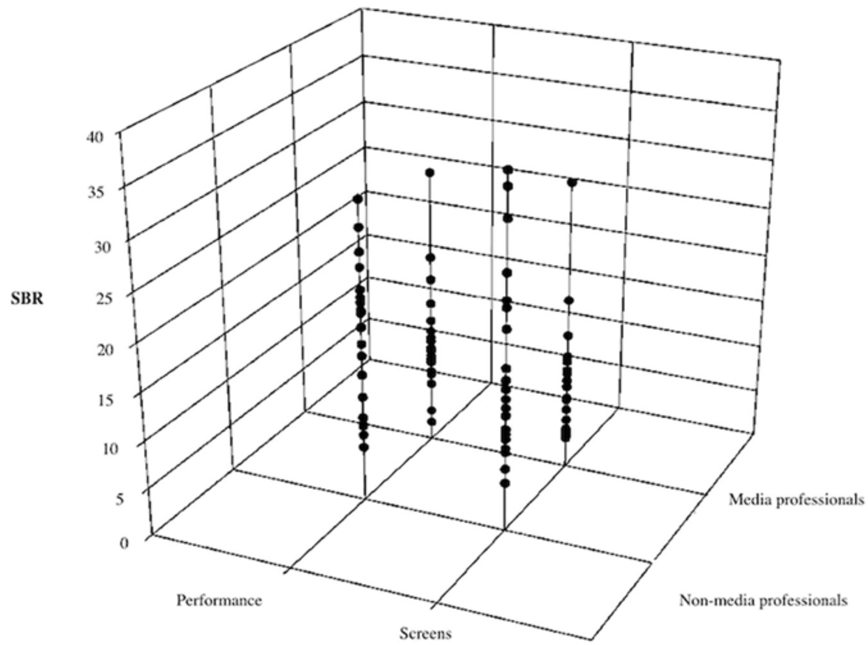

Fig 2. Screen and performance comparisons, in media and non-media professionals. 3D category scatter of SBR for the two factors analyzed: type of subject (media and non-media professionals), and type of stimulus (performance and screens). We can observe the trend of lower SBR in media professionals compared with non-media professionals; and the trend of an increase of SBR in performed play compared with screened stimuli.

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between media and non-media professionals. We obtained significant differences in SBR between screens and reality: $F_{(1,38)} = 5.384$, $p = 0.026$ (two-way repeated-measures analysis of variance, ANOVA, one-factor repetition). We also obtained significant differences related to media professionalization: $F_{(1,38)} = 10.607$, $p = 0.002$ (two-way repeated-measures analysis of variance, ANOVA, one-factor repetition). No significant differences were obtained by crossing the two factors ($p>0.05$). We performed post hoc pairwise multiple comparison procedures following the Holm-Sidak method. We also observed that the type of stimulus (performed live play or on-screen movie), independently of the professionalization of the subject, affected SBR, $p<0.05$. Analyzing by groups, we found that media professionals' SBR was affected by the type of stimulus, $p<0.05$. However, in the group of non-media professionals, the type of stimulus was not relevant, $p>0.05$. Their SBR was not affected whether looking at a live play or watching screens. We also found that media professionalization, irrespective of the type of stimulus, was a significant factor, $p<0.001$, for SBR. Finally, when comparing media professionalization within screens and within reality, in both cases we obtained highly significant statistical differences, $p<0.01$.

Thus, and according to our results, the type of stimulus (live performance or screened movie) in which a narrative is displayed affects the SBR of viewers. However, our results suggest that this is not so for non-media professionals, who seem to perceive live performances and screened movies similarly. The fact that media professionals show significant differences in their SBR in these two conditions may be connected to the higher level of attention that they are used to paying to screened stimuli. This would be coherent with the "dry eyes" problem in people watching screens with a high level of concentration sustained over time [15, 40–42]. Thus, these results suggest professionalization differences in visual perception in media professionals.

We also show here big differences in SBR between media and non-media professionals. Media professionals showed a significantly lower SBR watching screens (which seems logical as, in their everyday work, media professionals spend so many hours in front of audio-visual media making decisions related to edition on screens). Much more surprisingly, media professionals also showed a significantly lower SBR when seeing plays performed in the real world. This would be consistent with the idea that media professionalization affects visual perception.

Discussion

We hypothesized that we would observe SBR differences between looking at the same narrative in reality and on-screen. We also hypothesized that we would find SBR differences in media professionals compared with non-media professionals. Interestingly, while our first hypothesis was partly supported, the second hypothesis was strongly supported. We obtained significant differences in SBRs between looking at reality vs. watching screens. However, in our analysis by groups, the results were not significant for the group of non-media professionals. It can be reasonably accepted that the visual behavior of non-media professionals is not different depending on the type of stimulus in which the narrative runs. They would pay the same attention to any stimulus, regardless of the format. We suggest that this result may be linked to the short duration of each stimulus, and we think that longer stimuli might have evoked differences between watching screens and looking at reality in non-media observers too. On the other hand, according to our results, we can assume that media professionals show a different SBR when watching a movie on a screen and when seeing the same story in a live performance. For media professionals, paying attention to screens is part of their job. Although we did not apply a specific protocol to determine subjects' attention, the relationship between SBR and attention has been proven before [14]. Maybe, for that reason, whenever media professionals were facing screened stimuli their SBR dropped. This could suggest that media workers show a higher attentional level to decode the type of stimulus they are looking at.

As a second output of the present study, it can also be proposed that the viewer's SBR varies depending on media professionalization. Earlier investigations had shown the relationship between professionalization and audio-visual behavior or brain structural changes [31–34]. Here, we found visual perception differences related to media professionalization. Our results showed not only that media professionals and non-media professionals behave differently facing screened stimuli, but that this difference is not restricted to visualization on screens. According to our investigation, media professionals present a lower SBR both when watching audio-visual works on screens and when seeing live plays performed in the real world. However, media workers visually distinguish between these two situations, and their SBR is, as mentioned above, different in each. According to Zheng et al. [43], more attention decreases eyeblinks and increases the level of mental workload. Thus, media professionals seem to present a higher level of attention to both screens and the real world than do non-professional observers. Our results also indicate that audio-visual works receive more attention than live performances. We suggest that advertising and marketing strategies could take this into account when forming communication strategies.

We know that today many non-media professionals also spend many hours a day making decisions related to on-screen content, as is the case of gamers. For that reason, and following this criterion, we wondered whether new experiments with gamers and media professionals would result in the same differences as found here. Our most surprising result is that the watching of screens steadily over time and making concomitant decisions with a high level of attention, as media professionals do, decreases SBR not only in media contexts, but also looking at live events. Taking into account today's increased use of screens, we understand that it is important to keep on doing research following this line. These results invite us to continue searching for visual perception differences in media professionalization.

Supporting information

S1 Dataset. Spontaneous blink rate in screened movie and in live performance.
(XLSX)

S1 Video. Stimuli presentation.
(MP4)

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Writing – original draft: CA-S MAM-P.

Writing – review & editing: CA-S MAM-P AG JMD-G.

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Eyeblink rate watching classical Hollywood and post-classical MTV editing styles, in media and non-media professionals

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While movie edition creates a discontinuity in audio-visual works for narrative and economy-of-storytelling reasons, eyeblink creates a discontinuity in visual perception for protective and cognitive reasons. We were interested in analyzing eyeblink rate linked to cinematographic edition styles. We created three video stimuli with different editing styles and analyzed spontaneous blink rate in participants (N = 40). We were also interested in looking for different perceptive patterns in blink rate related to media professionalization. For that, of our participants, half (n = 20) were media professionals, and the other half were not. According to our results, MTV editing style inhibits eyeblinks more than Hollywood style and one-shot style. More interestingly, we obtained differences in visual perception related to media professionalization: we found that media professionals inhibit eyeblink rate substantially compared with non-media professionals, in any style of audio-visual edition.

Narrative fragmentations in media are reflected through edition. Cinematographic edition was soon considered a generator of connections, ideas, and contents. By joining two shots, new content is created. This surprising result shows the mechanisms organizing our attention and perception of cinematographic phenomena[1]. In some contexts, filmic edition is related to the audio-visual narrative itself and editing rules; on other occasions, cuts in the narration give the narrator the possibility of saving time and space, moving faster in the story. In this article, we study the relation between audio-visual editing styles and the viewer's eyeblink rate. The research also deals with the role of media professionalization in this context.

Evolution of editing styles

The initial analysis of edition is usually ascribed to the 1910 s and the beginning of Hollywood's Golden Age (with D.W. Griffith[2,3]) and the Soviet school of cinema. Kuleshov's[4] and Pudovkin's[5] experiments, and Eisenstein's[6] filmic and written work, are exponents of analytic and metaphoric edition, as well as of visual conflict.

As the history of cinema moved along, so did rules and patterns in edition. According to Burch[7], in the passage from Primitive Mode of Representation (PMR) to Institutional Mode of Representation (IMR), audio-visual language was equipped with details of the scene and was released from the constrictions of theatrical narrative, continuity being effected through editing rules. Such is the importance of the IMR edition system that continuity editing rules are known by the name of the whole: Hollywood style[3,8]. Basically, Hollywood style's rules are based on the relationships between content, rhythm, space, and time in two shots that are linked: high use of general-situation shots, smooth transitions between shots, rhythm in edition guided by shot size, continuity in perceptive space (180° rule), and use of transitions for ellipsis[3,9].

Later, a more intensified edition appeared, known as post-classical style, but which could also be named MTV style because of its extended use in musical video clips. This form included an intensified continuity with faster edition, a distinctive use of extreme focal-length lenses, tight framings, and more movement in camerawork[10,11].

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Understanding film stories, despite cuts

As the filmic language has advanced, multiple prescriptions or "educational" standards among the various styles of audio-visual edition have been discussed. For instance, Dmytryk[12] made some interesting proposals about media edition: not to cut a shot without a reason, to cut in internal movement of actors, the need to start and end the scenes with actions, and—above all—content as a priority over aesthetics. He also talked about the viewer's eyeblink as a sign of distraction to be taken into account[12]. This has also been stressed by the editor Walter Murch[13], who, after working in Hollywood for several years on films such as *The Godfather* (1972) or *Apocalypse Now* (1979), suspected that eyeblink could have a comprehension function in films. He wondered whether there is a predictable and measurable blink that could let him know the best moment to cut a shot. Previously and in parallel, from fields such as psychology and frequently from research detecting failures in human communication, eyeblink has been understood as a reflection of attention and cognitive activity[14–16]. Despite eyeblinks, with their loss of visual input, visual experience is maintained[17], and despite the cuts in a movie, narrative content continues being understood.

Nakano and colleagues[18] have shown synchronization in eyeblinks between and within subjects watching short video stories. Interestingly, viewer's eyeblinks, connected to comprehension[19], seem to be linked not to cuts[18,20] but to narrative. This leads us to suspect that cuts respecting continuity editing rules would not affect narrative comprehension. In 2010, Schwan and Ildirar showed audio-visual fragments with different editing styles and perspectives to isolated people living in the Turkish mountains, who had never before seen an audio-visual work[21,22]. All participants in that experiment understood that what they were watching was a movie, and none of them confused it with reality. Edition kept viewers from confusing screened presentation with reality. Separate shots were understood, but narrative structure was not integrated continuously through the work. Participants also did not perceive the subjective camera as the viewer's angle. Moreover, they never understood that the camera could become a substitution of the observer's view. Some cinematographic discontinuity techniques construct an apparent continuum from reality to abstraction, but previous experience is required for its comprehension[21]. Continuity seems to be related to the spectator's expectation and attention but not to stimulus characteristics[23–25]. So, perceptive continuity in our real world seems to be fundamental for the understanding of ellipsis in edition.

Understanding film stories, despite eyeblinks

We all assume that if we close our eyes, the world will still be there when we open them. Eyeblink hides visual flow for between 150 and 400 milliseconds[26–29]. Thus, visual information is hidden from viewers. Blinks interrupt the viewer's visual perception and are linked not only to corneal wetting and protection, but also to attention and narrative comprehension[18–20,29]. In an audio-visual context, during a conversation eyeblinks are synchronized between listener(s) and talker[30] by narrative pauses of speech. The impact of continuity editing on how people perceive events in a narrative film has been studied in the context of brain networks[31]. However, there are no significant differences in eyeblinks within editing boundaries[20].

Eyeblink while viewing video scenes has also been related to different empathy and engagement in Autism Spectrum Disorders (ASD)[32]. Also, it has been observed while watching videos, that eyeblink is connected with attentional processes, momentarily decreasing cortical activity in the dorsal attention network, but increasing at the same time the—sometimes questioned—Default Mode Network (DMN), involved in introspection processes, when the brain is not engaged in concrete tasks[33]. Likewise, it has been connected to audio-visual consumption via screens[27,34–36]. The correlation and synchronization in cognitive states in subjects watching films have also been studied[30,37]. And there seems to be a synchrony between eyeblink and the interest in the story[18]. With those previous studies, we suspected that eyeblinks may be different depending on the attention given to video works by media and non-media professionals. Recently, the effects of camera movement[38] and the impact of continuity in cinematographic editing[31,39,40] have been analyzed from a cognitive perspective. It has also been proposed that event segmentation is automatic and depends on processing meaningful changes in the perceived situation[41]. These previous investigations made us think that editing style could also affect eyeblinks.

Professionalization

Previous studies have indicated different cognitive patterns linked to professionalization in, for example, musicians[42], surgeons[43], athletes[44], or drivers[45,46]. Wong and colleagues[43] noted that the rate in ophthalmologic surgeons decreased during the execution of surgery, from 16 to 4 eyeblinks per minute. Because of this professionalization effect, and given the vision and attention-related job of media professionals, we expect that media professionalization affects visual behavior. Here, we consider the existence of cognitive differences between media professionals and non-media professionals.

The present investigation addresses two aims. First, to know differences in eyeblink rate according to editing styles; and, second, to find out whether the different editing styles evoke similar patterns of eyeblink rate in media professionals and non-media professionals. The results suggest the presence of specific visual cognitive patterns in media professionalization.

Results

Descriptive results. Participants were presented different editing-style stimuli with different Average Shot Length (ASL): i) a one-shot movie (with no cuts), ii) a Hollywood-style movie (ASL = 5.9 sec), and iii) an MTV-style movie (ASL = 2.4 sec), but all with the same narrative (Fig. 1). Spontaneous Blink Rate (SBR) of the subjects was recorded with an electromyographic (EMG) wireless system and a High-Definition (HD) camera (Fig. 2). The mean SBR (N = 40) was 13.776 min^{-1} (SD = ±9.641) in the one-shot movie; 13.427 min^{-1} (SD = ±9.338) in the Hollywood-style movie; and 12.421 min^{-1} (SD = ±8.283) in the MTV-style movie. However, large differences were found between non-media professionals (n = 20) and media professionals (n = 20) in every stimulus (Fig. 3): the one-shot movie evoked a mean SBR of 18.018 min^{-1} (SD = ±9.917) in non-media professionals

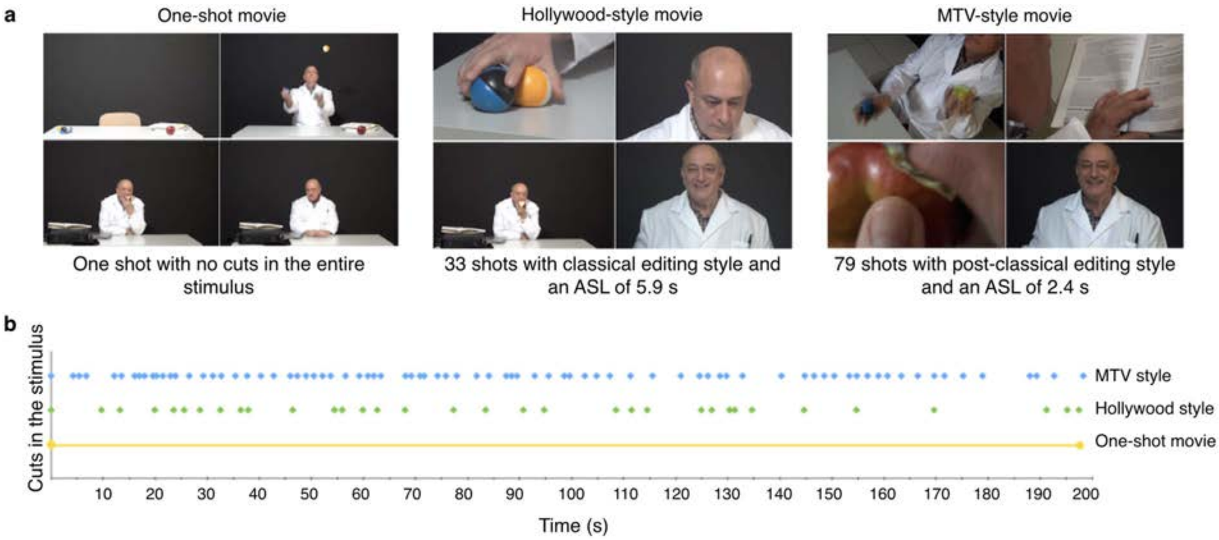

Figure 1. Video stimuli with different editing style. (**a**) Three editing styles were used for the video stimuli creation. The one-shot movie comprised a single open shot where the character was always positioned in the middle of the picture. The Hollywood-style edited movie comprised different classical shots such as close-ups, medium shots, and open shots, following a classical editing style. It was created from 33 shots with an ASL of 5.9 seconds. The MTV-style edited movie was created from 79 shots with an ASL of 2.4 seconds. It had close-ups, big close-ups, full shots, medium shots, open shots, aerial shots, reverse shots, low-angle shots, no time and space continuity, different angles, and a much less homogeneous edition than classical style. (**b**) Each dot represents a cut in the edited movies. The one-shot movie had no cuts in the visual narrative; the Hollywood- and MTV-style movies had repeated cuts. Those cuts were distributed along the videos, as represented by the dots.

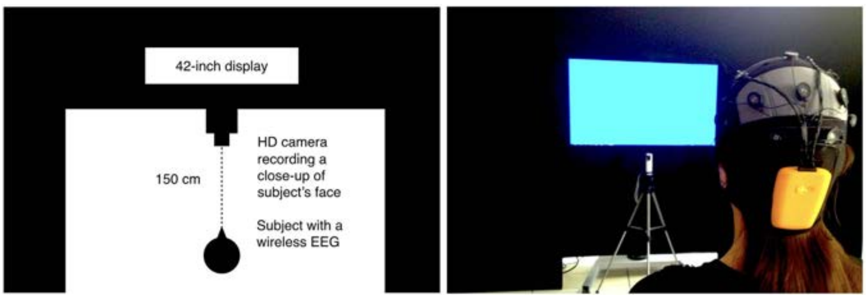

Figure 2. Experimental set-up. The video stimuli were presented on a 42-inch display at a distance of 150 cm from the subject. We recorded the participant's eye movements with an HD camera, and the EMG activity of the orbicularis oculi muscle with a wireless EEG/EMG device.

and of 9.534 min^{-1} (SD = ±7.386) in media professionals, the effect size, d = −0.97 and r = −0.436, exceeded Cohen's[47] convention for a large effect (d = 0.80); the Hollywood-style movie evoked a mean SBR of 17.508 min^{-1} (SD = ±10.108) in non-media professionals and of 9.347 min^{-1} (SD = ±6.462) in media professionals, with an effect size of d = −0.962 and r = −0.433; and the MTV-style movie 15.9 min^{-1} (SD = ±8.899) in non-media professionals and 8.941 min^{-1} (SD = ±6.012) in media professionals, with an effect size of d = −0.916 and r = −0.416. According to these descriptive results, the order in the frequency of evoked SBR depending on the style of movie edition is (from lower to higher): MTV style – Hollywood style – one-shot style. This means that the lower the ASL a film's cuts have, the lower the SBR its viewers present. Our descriptive results also show clear differences in SBR related to media professionalization. We carefully analyzed all these results, looking for significant statistical differences.

Differences in eyeblink based on editing style: one-shot style, Hollywood style and MTV style.

The statistical comparison of the frequency of the eyeblinks evoked by the different movie editing styles, independently of the professional status, showed significant differences between them ($X^2(2) = 7.2$, $p = 0.027$, Friedman Test, non-parametric test). Pairwise comparison showed a substantial statistical difference only between one-shot movie and MTV-style movie ($p < 0.05$, Tukey post hoc Test for Friedman Test, Dunn post hoc Test for Friedman Test, and Student-Newman-Keuls post hoc Test for Friedman Test). By groups, we obtained highly significant differences between editing styles in non-media professionals ($p < 0.01$), ($X^2(2) = 11.1$,

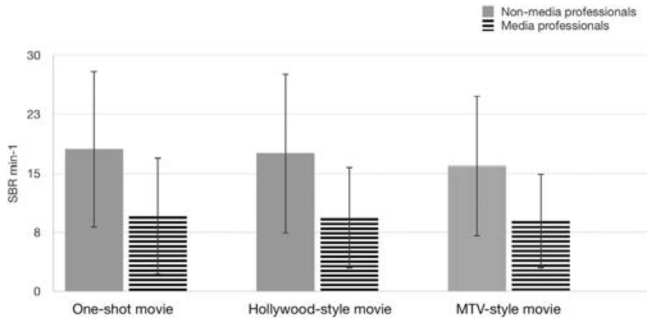

Figure 3. Comparison of spontaneous blink rate (SBR) in non-media professionals and media professionals in different editing styles. According to our results, non-media professionals have a higher SBR than media professionals in every editing-style movie; this may be due to the occupational use of screens by media workers. Our results suggest that the shorter the length of the shots in an audio-visual work, the lower the SBR. Our data show a greater homogeneity in media professional subjects than in non-media professionals in every editing style analyzed: one-shot movie (non-media professionals, SD = ±9.338; media professionals, SD = ±7.386), Hollywood-style movie (non-media professionals, SD = ±10.108; media professionals, SD = ±6.462), and MTV-style movie (non-media professionals, SD = ±8.899; media professionals, SD = ±6.012).

Editing Styles: Pairwise Comparison		p-value	
One-shot movie – *Hollywood-style*	Z = −1.29	0.199	Wilcoxon Signed Rank Test
One-shot movie – *Hollywood-style*, in non-media professionals	t(19) = 0.704	0.490	t-test
One-shot movie – *Hollywood-style*, in media professionals	t(19) = 0.272	0.789	t-test
Hollywood-style – *MTV-style*	Z = −1.909	0.057	Wilcoxon Signed Rank Test
Hollywood-style – *MTV-style*, in non-media professionals	t(19) = 1.760	0.094	t-test
Hollywood-style – *MTV-style*, in media professionals	t(19) = 0.764	0.454	t-test
One-shot movie – *MTV-style*	Z = −2.406	0.016*	Wilcoxon Signed Rank Test
One-shot movie – *MTV-style*, in non-media professionals	Z = −2.464	0.012*	Wilcoxon Signed Rank Test
One-shot movie – *MTV-style*, in media professionals	t(19) = 0.969	0.345	t-test

Table 1. Pairwise comparisons in editing styles. Results from pairwise comparison between the editing styles analyzed in this investigation: one-shot, Hollywood–style, and MTV-style. We applied a Wilcoxon Signed Rank Test for non-normal distributions, and a two-tailed t-test for normal distributions. Previously, we used a Normality Test (Shapiro-Wilk) for analyzing normality distribution of data. We found substantial differences between one-shot movie and MTV editing styles for the whole set of subjects, and for the group of non-media professionals. *$p < 0.05$.

$p = 0.004$, Friedman Test, non-parametric test). We did, again, pairwise comparison between the different editing styles. We obtained substantial differences between one-shot movie and MTV style ($p < 0.05$, Tukey post hoc Test for Friedman Test, Dunn post hoc Test for Friedman Test and Student-Newman-Keuls post hoc Test for Friedman Test) and, also, between one-shot movie and Hollywood style, on one hand, and Hollywood style and MTV style, on the other ($p < 0.05$, Student-Newman-Keuls post hoc Test for Friedman Test. However, media professionals did not show significant differences in eyeblink rate based on editing styles (F (2, 19) = 0.487, $p = 0.618$, one-way Repeated Measures ANOVA).

With the aim of contrasting these results, we also did a pairwise comparison (one-shot movie – Hollywood-style movie; Hollywood-style movie – MTV-style movie; one-shot movie – MTV-style movie) (Table 1). Again, we obtained significant differences between one-shot movie and MTV style in the whole group ($W = -358$, $Z = -2.406$, $p = 0.016$, Wilcoxon Signed Rank Test, non-parametric test), and specifically in non-media professionals ($W = -132$, $Z = -2.464$, $p = 0.012$, Wilcoxon Signed Rank Test, non-parametric test). The rest of the pairwise comparisons did not show significant differences.

According to our results, MTV editing style inhibits eyeblink rate considerably, compared with one-shot movie edition. However, this is not significant in media professionals. Non-media professionals also show substantial (but not so strong) differences in SBR between Hollywood and MTV styles, and between one-shot movie and Hollywood style. Interestingly, media professionals do not change their blink rate depending on the style of the edition, while non-media professionals do.

Differences in eyeblink rate between non-media and media professionals. Several studies have shown cognitive differences related to professionalization in many areas, as mentioned before[43–47].

Here we found that, on the whole, there are statistical differences in eyeblink rate between these two groups ($p < 0.01$), (Mann-Whitney $U = 86$, n = 20, $p = 0.002$, Mann-Whitney Rank Sum Test, non-parametric test). These differences are present in every edited movie style analyzed: one-shot movie ($p < 0.01$), (Mann-Whitney $U = 86.5$, n = 20, $p = 0.002$, Mann-Whitney Rank Sum Test, non-parametric test); Hollywood-style movie ($p < 0.01$), (Mann-Whitney $U = 90$, n = 20, $p = 0.003$, Mann-Whitney Rank Sum Test, non-parametric test); and MTV-editing-style movie ($p < 0.01$), Mann-Whitney $U = 94.5$, n = 20, $p = 0.004$, Mann-Whitney Rank Sum Test, non-parametric test).

In accordance with the results, there is a professionalization of visual perception, related to eyeblink rate, in media workers. They show statistical differences in each type of editing style, with lower SBR than non-media professionals.

Discussion

Differences in the style of edition of an audio-visual work have consequences for the viewers' visual perception. The eyeblink rate decreases with the decrease of the ASL. This may be to lessen the effect of the discontinuity created by the constant cuts. In our results, the MTV-editing-style movie evoked the lowest eyeblink rate, followed by the Hollywood style, and, finally, the one-shot style. These differences were statistically significant when comparing MTV style with a one-shot movie, but no substantial differences were found comparing Hollywood style with MTV style. This may be due to the length of the stimuli used (198 seconds). Probably, longer stimulus duration would have increased differences between these two edition styles. We decided not to use such stimuli in our study in an attempt to avoid participants' boredom during experimentation sessions. However, in the future, we plan to test this hypothesis with different and longer stimuli. Attention has been reported to be connected with the frequency of eyeblink[18]. Thus, according to our results, an MTV editing style should increase the attention level of viewers, though we did not apply an attention-level protocol to determine and confirm this. By groups, while non-media participants showed differences in SBR between each style of edition, media professionals did not. They had a similar eyeblink rate, independently of the ASL.

We suggest that this result may be a consequence of the high level of attention they are used to paying to audio-visual tasks as part of their job. It seems that in their viewing, attention level is more important than the characteristics of the media stimuli.

We found big differences in eyeblink rate between non-media and media professionals in every editing style analyzed. The former presented a higher frequency of eyeblink than the latter, regardless of the style of edition. This could be of interest for media professionals' visual health. Our results, then, suggest that there are differences in visual perception between these two groups, and that media professionalization decreases eyeblink rate, independently of the media work characteristics. Eyeblinks also have physiological functions[48], since they protect the cornea and participate in the visual process[49,50]. An excessive decrease of eyeblink as a result of spending many hours using screens can provoke computer vision syndrome[35], including corneal lesions, blurred vision, or dry eyes. Thus, editing styles linked to an increase in eyeblink rate should be of interest in audio-visual production contexts and to departments of labor charged with workers' safety and health. Making longer shots (with higher ASL) in audio-visual works could help to prevent visual problems for viewers. However, this could also affect their attention. Therefore, media creators should balance these two parameters (eye protection and attention) for the sake of their viewers and of their own success. These results invite us to continue with research to find cognitive patterns in media professionalization. At the same time, we wonder whether different editing styles might also show differences related to the number of hours of media consumption. It would be interesting to compare young people, who spend a lot of time watching media content, with media professionals. We think that media professionalization might also be a factor in that comparison.

Methods

Participants. Twenty media professionals (16 male, 4 female; age 30–56 years) and 20 non-media professionals (15 male, 5 female; age 28–56 years) with normal or corrected-to-normal visual acuity took part in the study. Media professionals were chosen following the criterion of a minimum of 6 years of experience making decisions related to media editing and audio-visual cuts in their everyday work. They were producers, assistant producers, cameramen, image controllers, documentalists, graphic designers, post-production editors, sports commentators, and video editors. Non-media professionals were carefully chosen outside this criterion, being individuals who did not make decisions related to media editing and audio-visual cuts in their work. They were journalists without media editing responsibilities, computer specialists, administrative and management assistants, telecommunication engineers, electronics technicians, stylists, specialists in prevention of occupational risks, and executive producers without artistic profile. All experiments were performed in accordance with relevant guidelines and regulations, with the ethics approval of the University Autònoma de Barcelona (Ethics Commission for Research with Animals and Humans, CEEAH); all participants (N = 40) gave prior written informed consent.

Experimental stimuli. Four stimuli with the same narrative but different video edition style were designed (Fig. 1). Three of them were videos of 198 seconds, and the fourth was a live enactment of around the same duration. The first stimulus was a one-shot movie with an open shot of the action. The second stimulus was edited according to IMR or classical Hollywood style with a total of 33 different shots and an ASL of 5.9 seconds. The third stimulus was edited by post-classical or MTV-style rules; it comprised 79 shots that did not follow classical editing rules, and had an ASL of 2.4 seconds. The fourth stimulus was a live enactment of the same audio-visual storytelling. The four stimuli were presented preceded by 30 seconds of black screen. The narrative in all the videos and the enactment was the same: a man entered a room, sat at a desk, juggled with three balls, opened a laptop, looked up information in some books, wrote in the laptop, closed the laptop, ate an apple, looked directly into camera with alternate friendly and sad expression, and left the room (Supplementary Video S1).

Experimental set-up. The video stimuli were presented on a 42-inch HD LED display (PanasonicTH-42PZ70EA, Panasonic Corporation). Participants were placed 150 cm in front of the screen. The stimuli were presented and synchronized with Paradigm Stimulus Presentation (Perception Research System Incorporated), and stimulus presentation was randomized.

Participants' faces were recorded throughout in a close-up shot, with an HD video camera (Sony HDR-GW55VE, Sony Corporation) at 25 frames per second. Simultaneously, EMG signals were recorded with the help of a wireless Enobio 20 EEG/EMG system (Neuroelectrics®) and of NicOffline software (Neuroelectrics®) for data acquisition. The EMG electrodes were placed according to the international 10–20 system. The experimental set-up allowed participants to be comfortable during the sessions (Fig. 2).

Data analysis. For the analysis of the data, we used results from the three video stimuli. We analyzed eyeblinks following two methods: EMG signals and recorded HD videos. For the EMG signal, we worked with Brainstorm[51], filtered to 0.5–3 Hz, and applied Brainstorm's eyeblink detectors in Electrooculogram, Fp1 and Fp2. Then, we carefully checked the detections obtained, as proposed by Tadel and colleagues[52]. For the recorded HD videos, we manually looked for the eyeblinks in each participant and stimulus, following the guidelines of Nakano and colleagues[18]. We compared one by one results obtained from the two methods to check and get a final list of eyeblinks for later analysis. Statistical analysis was carried out with Sigmaplot 11.0 (Systat Software Inc.) with parametric and non-parametric tests based on Shapiro-Wilk Test results for testing the normality of the data. We used an alpha level of 0.05 for all statistical tests. We worked with the mean of eyeblinks per minute in each stimulus.

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Author Contributions

C.A.-S. and M.A.M.-P. selected the subjects, created the stimuli, collected the data, made the figures, and wrote the paper. All the authors, C.A.-S., M.A.M.-P., A.G., and J.M.D.-G., contributed to the study design, analyzed the data, and participated in the final version of the manuscript.

Additional Information

Supplementary information accompanies this paper at http://www.nature.com/srep

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Chaotic and Fast Audiovisuals Increase Attentional Scope but Decrease Conscious Processing

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Abstract—Audiovisual cuts involve spatial, temporal, and action narrative leaps. They can even change the meaning of the narrative through film editing. Many cuts are not consciously perceived, others are, just as we perceive or not the changes in real events. In this paper, we analyze the effects of cuts and different editing styles on 36 subjects, using electroencephalographic (EEG) techniques and the projection of stimuli with different audiovisual style of edition but the same narrative. Eyeblinks, event-related potentials (ERPs), EEG spectral power and disturbances, and the functional and effective connectivity before and after the cuts were analyzed. Cuts decreased blink frequency in the first second following them. Cuts also caused an increase of the alpha rhythm, with a cortical evolution from visual toward rostral areas. There were marked differences between a video-clip editing style, with greater activities evoked in visual areas, and the classic continuous style of editing, which presented greater activities in the frontal zones. This was reflected by differences in the theta rhythm between 200 and 400 ms, in visual and frontal zones, and can be connected to the different demands that each style of edition makes on working memory and conscious processing after cutting. Also, at the time of cuts, the causality between visual, somatosensory, and frontal networks is altered in any editing style. Our findings suggest that cuts affect media perception and chaotic and fast audiovisuals increase attentional scope but decrease conscious processing.

Key words: visual perception, neurocinematics, brain connectivity, film editing.

INTRODUCTION

Although movies have plenty of cuts, viewers hardly notice them when watching a film and they do not seem to cause people to perceive event boundaries (Zacks et al., 2009). Since the beginning of conceptual analysis of the cinema, cuts in movies have been a matter of interest (Münsterberg, 1916; Bordwell et al., 1985; Gunning, 1994). During the last few decades, shot lengths have got shorter, going from about 10 s in the 1930s and 1940s to below 4 s after 2000 (Cutting et al., 2011a,b). Cuts are, by far, the most common transition between shots (Cutting et al., 2011a,b; Cutting, 2016), and the order and the way that shots are joined by cuts affects the meaning of the story (Eisenstein, 1949; Kuleshov, 1974; Carroll and Bever, 1976). Event segmentation of narrative cinema has been proposed to be an important component in the perception process, as it plays a critical role in the proper understanding of the story (Zacks et al., 2007, 2010). Moreover, editing rules have evolved from the organized classical Hollywood style (Bordwell et al., 1985) to the messy post-classical style (Bordwell, 2002), also known as MTV style due to the style of edition used in video-clips.

Many researchers and theorists have been interested in investigating the perception of cuts in media (Germeys and d'Ydewalle, 2007; Magliano and Zacks, 2011; Francuz and Zabielska-Mendyk, 2013). To determine visual perception of cuts, different approaches have been developed. A widely used method, in a psychological context, is analyzing eyeblinks and eye movements. Many filmmakers have pointed out the narrative functions of blinking and its relation to attentional processes (Münsterberg, 1916; Reisz and Millar, 1971; Huston and Long, 2001). The film editor Walter Murch has explicitly proposed the putative relationships between the frequency of blinking and the moment of cutting (Murch, 1995). In this sense, eyeblinks are involved in the process of attentional disengagement while viewing videos (Nakano et al., 2013). Indeed, a synchronization of spontaneous eyeblinks while viewing video stories occurs

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Abbreviations: ASL, average shot length; EEG, electroencephalography; EOG, electrooculogram; ERP, event-related potential; ERSP, event-related spectral perturbation; PLV, phase-locking value; SBR, spontaneous blink rate.

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when the level of attention required to understand the story is rather low (Nakano et al., 2009), while inhibition of blinking is associated to a higher level of engagement with visual content (Shultz et al., 2011). Recently, eyeblinks have also been linked to the style of edition and cuts: the shorter the average shot length (ASL) between cuts the lower the blinking rate (Andreu-Sánchez et al., 2017a). It has also been proven that viewing a narrative in an edited movie provokes a lower spontaneous blink rate (SBR) compared with receiving the same story in actual performance (live or screened performance) (Andreu-Sánchez et al., 2017b), and some authors have argued that cuts are invisible due to blinks and saccades (Murch, 1995; Cutting, 2005). Although viewers miss many cuts, especially those with continuity of scene or action, the probability that a blink occurs at the moment of an edit is 1.2%, and missed cuts seem not to be linked to blinks (Smith and Henderson, 2008). In spite of the discontinuity that cuts present, by making spatial–temporal, action, narrative, or movement interruptions (Cutting, 2014), narratives present in films are comprehensible for viewers, even those who have not experienced media content before (Schwan and Ildirar, 2010). The pristine understanding of audiovisual cuts is connected to the way the brain processes reality by fragmenting it into events.

d'Ydewalle and Vanderbeeken detected that, after a cut, eye movements initially decreased, and then increased 200–400 ms after it. They proposed a two-stage model in which viewers focus their attention on the new visual information immediately after the cut, subsequently trying to reconstruct and reconnect the new information with that prior to the cut (d'Ydewalle and Vanderbeeken, 1990). Years later, Germeys and d'Ydewalle designed an experiment to discover what happens during the 200–400 ms following the cut. They found that eye movement in the shot following the cut depends on the distance between where the most informative part of the shot is positioned and where the most informative part of the preceding shot is situated in the new one. If there is no distance between them, there is no eye movement in the 200–400-ms interval, while any distance elicits eye movement during that interval, with a peak that is a function of the distance. They concluded that the consistency of the narrative in the film overrules the effects of cuts (Germeys and d'Ydewalle, 2007). That would be compatible with the evoked brain responses found at event boundaries in reality and narrative cinema (Zacks et al., 2001, 2007, 2009, 2010). The cinematographic perception of editing seems to be a particular case of how the brain processes events, the sequences of everyday life, through summaries of simulation for their understanding.

Another way to address visual perception of cuts in movies is through the analysis of electroencephalography (EEG) responses. In a pioneer approach, Gastaut and Bert proposed the study of cinematographic projection through EEG, concluding that the most banal film projection, even without content that can provoke emotional reactions in most subjects, is capable of substantially modifying the EEG of a normal adult (Cohen-Séat et al., 1954; Gastaut and Bert, 1954). Differences between the mean amplitude of potentials evoked by related and unrelated cuts have also been analyzed. The amplitude of event-related potentials (ERPs) in response to cuts in audiovisual material is more positive at the back of the head and more negative at the front, for unrelated cuts (Francuz and Zabielska-Mendyk, 2013). Reeves and colleagues related the presence of alpha waves in central and occipital locations with edits. According to them, alpha reacted (within 500 ms) to the stimulus. They showed that it is possible to predict alpha using only measures of visual structure and concluded that movement and edits produce rapid alpha drops followed by recovery (Reeves et al., 1985). This would be consistent with alpha reactions to simple real-world events and would indicate that physical boundaries of media content may not be an important demarcation in visual perception. According to Magliano and Zacks, there are robust increases in activity in visual processing areas at continuity edits, related to the novel visual information supplied by the shot after the cut (Magliano and Zacks, 2011). Gallese and colleagues (Heimann et al., 2016) have recently reconsidered the differences between cuts that join related shots and cuts that do not, as other investigations had previously done (Geiger and Reeves, 1993; Lang et al., 1993; Francuz and Zabielska-Mendyk, 2013). In their case, they looked for differences between continuity edits and cuts-across-the-line edits. The former respect the 180° rule—which proposes the maintenance of an axis of 180° between shots avoiding spatial visual jumps—, the latter violate it. Making an ERP analysis, they did not find differences between continuity edits and cuts-across-the-line between 140 ms and 380 ms after the cut. However, their results did show differences between 400 ms and 650 ms after the cut, with a significantly higher potential in left anterior regions (P4-6) for continuity edits than for cuts-across-the-line (Heimann et al., 2016).

In our study, we have specifically investigated what happens after a cut depending on the style of edition. We addressed this question by analyzing the SBR and the electrical brain activity and functional connectivity following cuts. Since the cuts are part of edition, we have included the style of movie edition as a factor.

EXPERIMENTAL PROCEDURES

Participants

Thirty-six participants, aged 28–56 (43.97 ± 8.07) years, with normal or corrected-to-normal visual acuity, were recruited for this experiment. Subjects did not receive any economic compensation for participating in this investigation. Procedures were in compliance with relevant guidelines and regulation for human research and approved by the Ethics Commission for Research with Animals and Humans (CEEAH) of the University Autònoma de Barcelona. All participants gave prior written informed consent to participate in the study.

Stimuli and experimental design

For this series of works, we had created four stimuli with the same narrative content but different formats. Three stimuli were videos with distinct style of edition (a one-shot movie, a Hollywood-style movie, and an MTV-style movie) and the fourth stimulus was a live performance. The different stimuli were randomly presented to participants (see Andreu-Sánchez et al., 2017b, for details). The narrative consisted of a man who entered a room with a black background, sat at a desk, juggled with three balls, opened a laptop, looked up some information in books, wrote something in the laptop, closed it, ate an apple, looked directly into camera, and left the room. Since the interest of this investigation is to study the cut, for the present paper we analyzed results only from the two stimuli containing cuts: the Hollywood-style and MTV-style movies, each with a total duration of 198 s (Fig. 1). The Hollywood-style movie had 33 shots with an ASL of 5.9 s, and followed classical continuity editing rules, with smooth transitions and perceptive continuity. The MTV-style movie had 79 shots with an ASL of 2.4 s, and was characterized by short moved shots, sudden moves in the frame, and a continuous motion of the camera. A total of 112 cuts form the sample used in this investigation.

EEG recording and storage

Continuous EEG was recorded using the wireless Enobio® system (Neuroelectrics, Barcelona, Spain) with 20 electrodes placed according to the International 10–20 System [O1, O2, P7, P3, Pz, P4, P8, T7, C3, Cz, C4, T8, F7, F3, Fz, F4, F8, Fp1, Fp2, and an external electrode used for electrooculogram (EOG) recording] referenced to electronically linked mastoid electrodes (see Martín-Pascual et al., 2018, for details). The EOG electrode was positioned vertically at the infraorbital ridge and the lower outer canthus of the left eye and was used to monitor eyeblinks. Data were sampled at 500 Hz. In order to have a good quality of EEG signal, participants were asked to wash their hair before attending the session and to avoid any chemical product on it (such as hair-spray or similar). An HD-video camera recorded participants' faces with a close-up for contrasting their eye movements and blinking during the analysis of the eyeblink rate.

Eyeblink analysis

In this study, we detected and quantified participants' blink rate related to cuts. For detecting eyeblink rate, we processed original data with Brainstorm open-source version 3 running on MATLAB R2013a (The Mathworks Inc., Natick, MA, USA) under a MacOS version 10.9.5 (Apple Inc., Cupertino, CA, USA). We filtered the signal from 0.5 Hz to 3 Hz, applied Brainstorm's eyeblink detector, and carefully checked results (Tadel et al., 2015). For contrast purposes, we also manually checked videos recorded with an HD-video camera looking at the eyeblinks (Nakano and Kitazawa, 2010). For the analysis of the eyeblink rate, we compared the rate of eyeblinks per minute, 1 s after the cut, with the rate during the rest of the stimuli. The statistical analysis of eyeblink rates was developed using Sigmaplot 11.0 (Systat Software Inc., San Jose, CA, USA).

EEG data analysis

For EEG analysis, data processing was carried out using the EEGLAB (Delorme and Makeig, 2004) open-source software version 15.3 running on MATLAB R2013a (The Mathworks Inc.) under a MacOS version 10.9.5 (Apple Inc.). We used a spherical BESA® template for channel location. We computed average reference, and band-passed with filter between 0.5 Hz and 40 Hz. We made the epochs 500 ms before and 1000 ms after the cut, removing the baseline. For rejecting artifacts, bad channels, and wrong data, we used visual inspection and the ADJUST plug-in (Mognon et al., 2010) for EEGLAB, after applying independent component analysis. To locate dipoles, we used a DIPFIT plugin.

We analyzed frontal, somatomotor, and parieto-occipital brain activities related to cuts. For the frontal area, we analyzed the activity recorded with F7, F3, Fz, F4, and F8 electrodes. For the somatomotor area, we analyzed electrodes C3, Cz, and C4. The parieto-occipital area was studied with electrodes P7, P3, Pz,

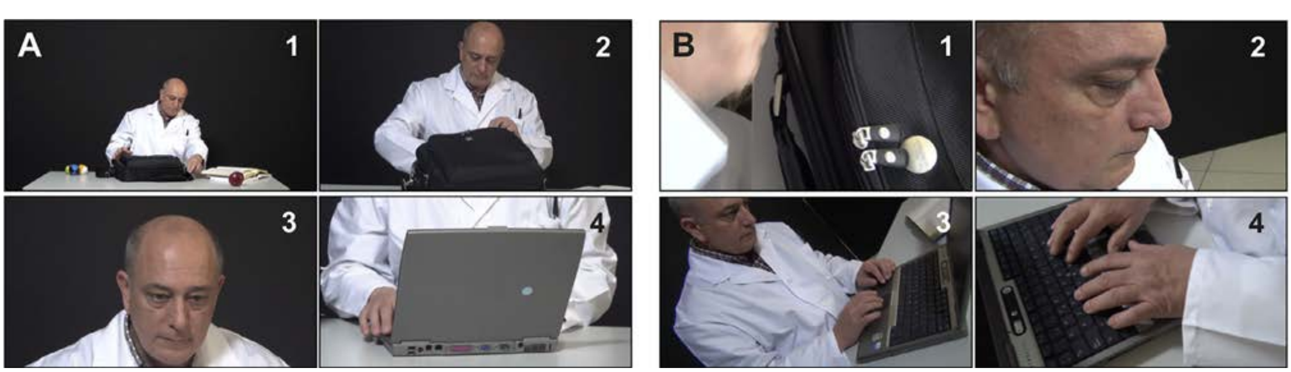


Fig. 1. Frames of stimuli. (A) Four frames of Hollywood-style movie. This stimulus was composed of 33 shots with an ASL of 5.9 s. It comprised different classical shots such as open shots (1), medium shots (2), close-ups (3), and detailed shots (4). (B) Four frames of MTV-style movie. This stimulus was composed of 79 shots with an ASL of 2.4 s. It comprised different MTV-style shots such as detailed shots with abrupt camera movements (1), close-ups with an aerial perspective (2), medium shots from a reverse angle (3), and detailed shots breaking the 180° rule (4).

P4, P8, O1, and O2. Analyses were done to contrast differences before-after cuts. We also looked for differences between the cuts in the two styles of edition applied here. For spectral analyses, we took the time window of -100 ms to 0 ms as condition "before the cut", and the time window of 200–300 ms after the cut as condition "after the cut". We analyzed those conditions in frontal, somatosensory, and parieto-occipital areas, in the alpha (8–12 Hz) band (for comparisons before–after the cut, and Hollywood-MTV-styles of edition). We also analyzed the theta (4–8 Hz) band in event-related spectral perturbation (ERSP) for comparison between the styles of edition. For the analysis of ERP, we took epochs of 1500 ms, 500 ms before the cut and 1000 ms after the cut. Each participant attended 112 cuts, which makes a potential total amount of 4032 epochs before discarding the bad ones. For the statistical analysis of power spectra and ERPs we used EEGLAB Statistics Toolbox and Sigmaplot 11.0 (Systat Software Inc.).

Functional and effective connectivity analysis

To analyze the possible causality of the effects of audiovisual cuts between brain areas, we used a MATLAB toolbox: HERMES (Niso et al., 2013) (see Hermes: open-source toolbox for time series connectivity analysis; http://hermes.ctb.upm.es). We used clean datasets resulting from the described filtering. We chose one approach to determine functional connectivity and another to study effective connectivity. Functional connectivity refers to temporal correlation between two electro/neurophysiological measurements from different parts of the brain (Friston et al., 1993). Effective connectivity should be understood as the simplest experimental, and time-dependent circuit that replicates the timing relationships between the recorded sources (Aertsen and Preißl, 1991). Functional connectivity alludes to statistical dependence between signals and effective connectivity to the causal interactions between them (Friston, 1994; Cela-Conde et al., 2013; Niso et al., 2013). A phase synchronization index has been studied as a functional connectivity and a Granger causality measure as an effective connectivity.

The phase synchronization index used is Phase-Locking Value (PLV). PLV uses responses to a repeated stimulus and looks for latencies at which the phase difference between the signals varies little across trials (phase-locking). Given two series of signals x and y and a frequency of interest f, the PLV method computes a measurement of phase-locking between the components of x and y at frequency f for each latency (Lachaux et al., 1999). We plotted the averaged connectivity of PLV in 36 participants with 100 surrogates of the original data. For the statistical analysis of PLV, we applied a Wilcoxon test with multiple comparisons with false discovery rate of Type 1 ($q = 0.1$) to the data with 100 surrogates. We looked for the significant differences ($p < 0.05$) between time windows, and between styles of edition. Unless otherwise indicated, mean values are followed by the standard deviation of the mean.

We also applied classical linear Granger causality. This index is based on the idea that for two simultaneously measured signals $x(t)$ and $y(t)$, if the first signal can be predicted better by incorporating the past information from the second signal than using only the information from the first, then the second signal can be called causal to the first (Wiener, 1956; Granger, 1969; Niso et al., 2013). Granger (1969) argued that when x is influencing y, if you add past values of $x(t)$ to the regression of $y(t)$, the prediction will be improved. For our analysis of Granger causality, we did a Wilcoxon test with 100 surrogates, with a false discovery rate correction of Type 1 ($q = 0.1$). We looked for and plotted the significant differences ($p < 0.05$), between time windows and styles of edition.

More information about the implementation of these indices in HERMES is available elsewhere (Niso et al., 2013).

Statistical analysis

We performed different statistical analysis for each approach. For the eyeblink study, we performed parametric Student's paired t tests, taking as significant differences those where $p < 0.05$. For the spectral studies in the cut, we applied the non-parametric Wilcoxon Signed Rank Test for "before" and "after" condition, with $p < 0.05$. For spectral studies in the cut, given the style of edition, we performed a two-way repeated measures ANOVA. We used the same approach for ERPs analysis. For multiple comparison procedures we used the Holm-Sidak method with a significance level of $p < 0.05$. In synchronization and causality studies, we did 100 surrogates of data and a non-parametric Wilcoxon test, with multiple comparisons with false discovery rate Type 1 ($q = 0.1$). In all cases, significant differences were studied based on $p < 0.05$.

RESULTS

Temporal relationships between eyeblinks and cuts

Each subject ($n = 36$) was exposed to 112 cuts (33 cuts in a Hollywood-editing-style movie and 79 cuts in an MTV-style movie). To examine the temporal relationship between eyeblinks and cuts, we used the cuts as a trigger and quantified the number of eyeblinks taking place in the 1st second after them. We compared these results with the average of eyeblinks taking place outside this 1-s time window. The mean SBR in the first 1 s after all ($n = 112$) cuts was 11.07 ± 7.66 min^{-1}, while during the rest of the time it was 12.33 ± 7.61 min^{-1}. In Hollywood-style stimulus, the mean SBR 1 s after cuts ($n = 33$) was 11.01 ± 8.23 min^{-1}, while in the rest of the stimulus it was 12.78 ± 8.51 min^{-1}. In MTV-style stimulus, the SBR 1 s after cuts ($n = 79$) was 11.14 ± 7.63 min^{-1}, and in the rest of the stimulus it was 11.87 ± 7.148 min^{-1}.

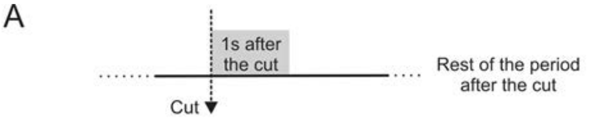
The statistical comparison between eyeblinks 1 s after the cuts and eyeblinks in the rest of movie presentation was statistically significant ($t_{(35)} = -2.719$, $p = 0.01$, Student's paired t test) for all presented cuts. These results suggest that cuts in video editing may inhibit the SBR. In the comparison of SBR 1 s after the cut and during the rest of the time after the cut in the Hollywood-editing-style movie, we also found significant differences ($t_{(35)} = -2.513$, $p = 0.017$, Student's paired t test). However, our results did not show statistically significant differences ($t_{(35)} = -1.482$, $p = 0.147$, Student's paired t test) in MTV editing style. In a previous study (Andreu-Sánchez et al., 2017a), we found that the style of the edition in a movie and the number of cuts affect SBR. According to these previous results, MTV editing style inhibits SBR during the viewing of the whole movie. Here, we also wanted to compare whether SBR 1 s after the cut was affected by the editing style of the work. For that, we compared SBR 1 s after the cut in Hollywood style with SBR 1 s after the cut in MTV style. We obtained no significant differences ($t_{(35)} = -0.813$, $p = 0.856$, Student's paired t test) between the two editing styles (Fig. 2).

The above results suggest that cuts in video editing inhibit SBR during the first second following the cut. In the Hollywood-editing-style movie, we found significant differences, but not in MTV. We compared SBR 1 s after the cut in Hollywood style with SBR 1 s after the cut in MTV style, and no significant differences were obtained. In the style of edition where cuts are not so constant but are narratively consistent –as in classical Hollywood style– a cut provokes a decrease in the eyeblink rate. However, in the style of edition where cuts are more frequent, they do not seem to affect SBR as viewers already show a decreased eyeblink rate during the whole stimulus (Andreu-Sánchez et al., 2017a).

Spectral analysis of EEG recordings after the cut

We wondered whether cuts would provoke a specific brain activity response and, if so, whether such response had any relationship with visual perception. Previous works have linked the alpha band with a change in attention (Reeves et al., 1985; Klimesch et al., 1998; Aftanas and Golocheikine, 2001; Sauseng et al., 2005). In accordance, we quantified the median alpha band (8–12 Hz) power before and after the cut over frontal, somatomotor, and parieto-occipital areas, and looked for differences. For the "before" condition, we took the time window of −100 ms to 0 ms before the cut; for the "after" condition, the time window of 200 ms to 300 ms after the cut. We found significant differences in the parieto-occipital area (P7, P3, Pz, P4, P8, O1, and O2) ($Z = 5.169$, $p \leq 0.001$, Wilcoxon Signed Rank Test) after the cut, with an increase of the power spectra in the alpha band. The cut provoked an increase in the alpha power in the parieto-occipital area. For the somatomotor area, we analyzed C3, Cz, and C4 electrodes in the alpha band. Analyzing the power spectra of these three electrodes together, there was a significant increase ($Z = 3.158$, $p = 0.002$, Wilcoxon Signed Rank Test) after the cut. Due to the known contralateral activity of this premotor area, we analyzed the three electrodes independently, and did not find such differences in either of the electrodes C3 and C4; however, Cz did present a significant increase ($Z = 2.969$, $p = 0.003$, Wilcoxon Signed Rank Test). According to our results, the frontal area (electrodes F7, F3, Fz, F4 and F8) also showed a significant increase in alpha power spectra ($Z = 5.232$, $p \leq 0.001$, Wilcoxon Signed Rank Test) after the cut.

A



B

	Relation to cut	Hollywood style	MTV style	Both styles
SBR (min^{-1})	1 s after the cut	11.01 min^{-1} (SD = ± 8.234)	11.138 min^{-1} (SD = ± 7.634)	11.074 min^{-1} (SD = ± 7.659)
	Rest of the period	12.784 min^{-1} (SD = ± 8.51)	11.873 min^{-1} (SD = ± 7.148)	12.328 min^{-1} (SD = ± 7.609)

C

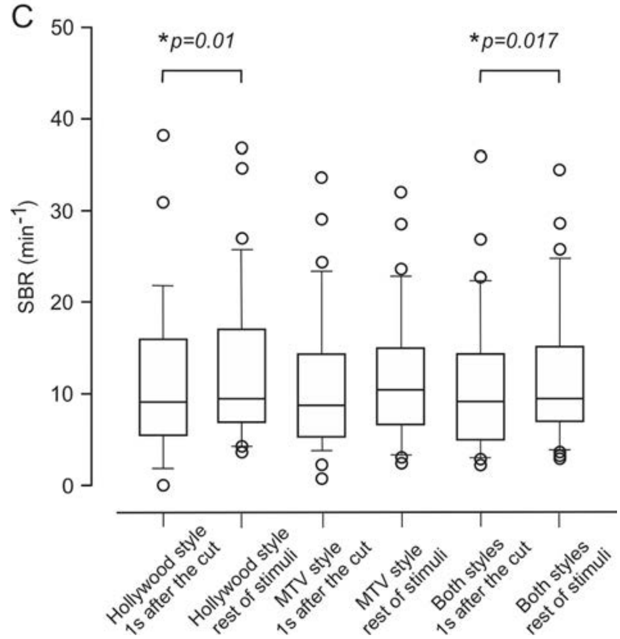


Fig. 2. Temporal relationship between eyeblinks and cuts. (A) We computed SBR 1 s after cuts and during the rest of the movie presentation, and then calculated SBR × min^{-1}, for later analysis. B. Descriptive statistics for eyeblink rate of participants in the mentioned conditions: 1 s after the cut and during the rest of the movie, for the two edition styles. The mean of SBRs was lower 1 s after the cut than during the rest of the movie, regardless of the style of edition. C. Eyeblink rate 1 s after the cut and during the rest of the stimulus, in Hollywood-style movie ($n = 33$ cuts), in MTV-style movie ($n = 79$ cuts), and in both styles of edition ($n = 112$ cuts). Lines denote the median. Circles denote data points. *Denotes significant differences found with Student's t-test comparison, after the cut and during the rest of the period after the cut.

ERPs associated with perception of cuts

We analyzed ERP signatures for epochs of 1500 ms (from 500 ms before the cut to 1000 ms after it) in each of the electrodes. We computed a two-way repeated measures ANOVA. The procedure took as factors the brain area and latency to study ERP progression through the brain. We obtained means of potentials based on three brain areas (frontal, with the mean of electrodes F7, F3, Fz, F4, and F8; medial, with the mean of C3, Cz, and C4; and occipital, with the mean of P7, P3, Pz, P4, P8, O1, and O2), and three latencies for latency factor (400–600 ms, 600–800 ms, and 800–1000 ms). We found a significant effect related to the brain area [$F_{(2,70)} = 10.855$; $p < 0.001$] and to the interaction brain area × latency [$F_{(4,140)} = 6.989$; $p < 0.001$]. According to our results, and as already reported for visual perception (Milner and Goodale, 2006; Hegdé, 2008), as the time after the cut progresses, the potential moves from the occipital to the frontal area (see Figs. 3 and 4).

Differences in power spectra of EEG recordings carried out following cuts performed with Hollywood and MTV styles

For studying the differences between the two edition styles, frequency analyses of interest were defined by comparing their spectral power from 2 Hz to 40 Hz. We found statistical differences in some points of the alpha and theta bands (Fig. 5). To determine whether those differences were solid in the alpha band, we computed a two-way repeated measures ANOVA (with two factor repetitions: style and brain area) comparing the whole epoch of 1500 ms (from −500 ms to 1000 ms). With this approach, we did not find differences between Hollywood and MTV styles in the alpha band (8–12 Hz), [$F_{(35,1)} = 0.416$, $p = 0.523$]. However, we found statistically significant differences related to brain area [$F_{(35,2)} = 24.987$, $p < 0.001$]. The lowest power spectra were found in the somatomotor area, followed by the frontal area, and the highest was found in the parieto-occipital area. To study differences in the theta band, we plotted ERSPs in frontal, somatomotor, and parieto-occipital electrodes, and found statistically significant differences between Hollywood and MTV styles at 200 ms and 400 ms after the cut in frontal and occipital electrodes (some electrodes are shown in Fig. 6).

ERPs evoked by the two different edition styles

With the aim of comparing differences in ERPs after the cut based on the style of edition, we computed four two-way repeated measures ANOVA with four different time windows. The first time window was 200–400 ms after the cut; the second was 400–600 ms after the cut; the third was 600–800 ms after the cut; and the fourth was 800–1000 ms after the cut. In all the analyses, the two factors were brain area and style of edition. For the first factor –brain area– we again obtained means of potentials of frontal (electrodes F7, F3, Fz, F4, and F8), medial (C3, Cz, and C4), and occipital (P7, P3, Pz, P4, P8, O1, and O2) areas. For the second factor –style of edition– we used, per subject, the 33 epochs in Hollywood style and the 79 epochs in MTV style. For each style of edition, each epoch corresponds with a cut (Fig. 7).

In the first time window (200–400 ms after the cut), we found statistical differences related to brain area [$F_{(2,70)} = 4.291$; $p = 0.018$]. Given the time since the new visual information because of the cut, occipital area presented the highest potential, as expected. In that area, a multiple comparison procedure (Holm–Sidak method) shows that the style of editing is a differential factor [$t_{(2)} = 1.99$; $p = 0.05$]. Cuts in MTV style provoke higher potential than in Hollywood style in that brain area.

In the second time window (400–600 ms after the cut), we again found statistical differences related to brain area [$F_{(2,70)} = 10.291$; $p < 0.001$], as seen in the previous section. In this time after the cut, the occipital area presented the highest potential, followed by the medial

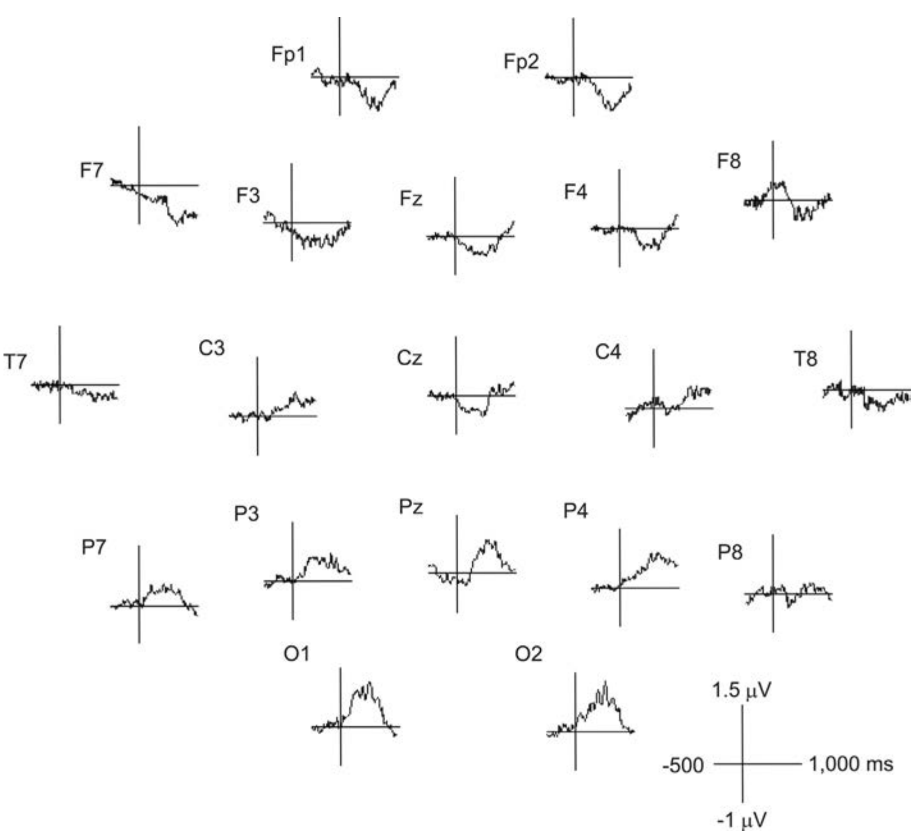


Fig. 3. Topographic display of averaged ERPs for all subjects. ERPs plotted for a 1500-ms period starting 500 ms before the cut. EEG recordings were triggered with cuts (vertical line). Data were obtained from 36 subjects during the viewing of two movies edited with different styles. The horizontal line indicates the 0 level, whereas the positive part of the vertical line indicates the calibration bar. For all traces, positive is up.

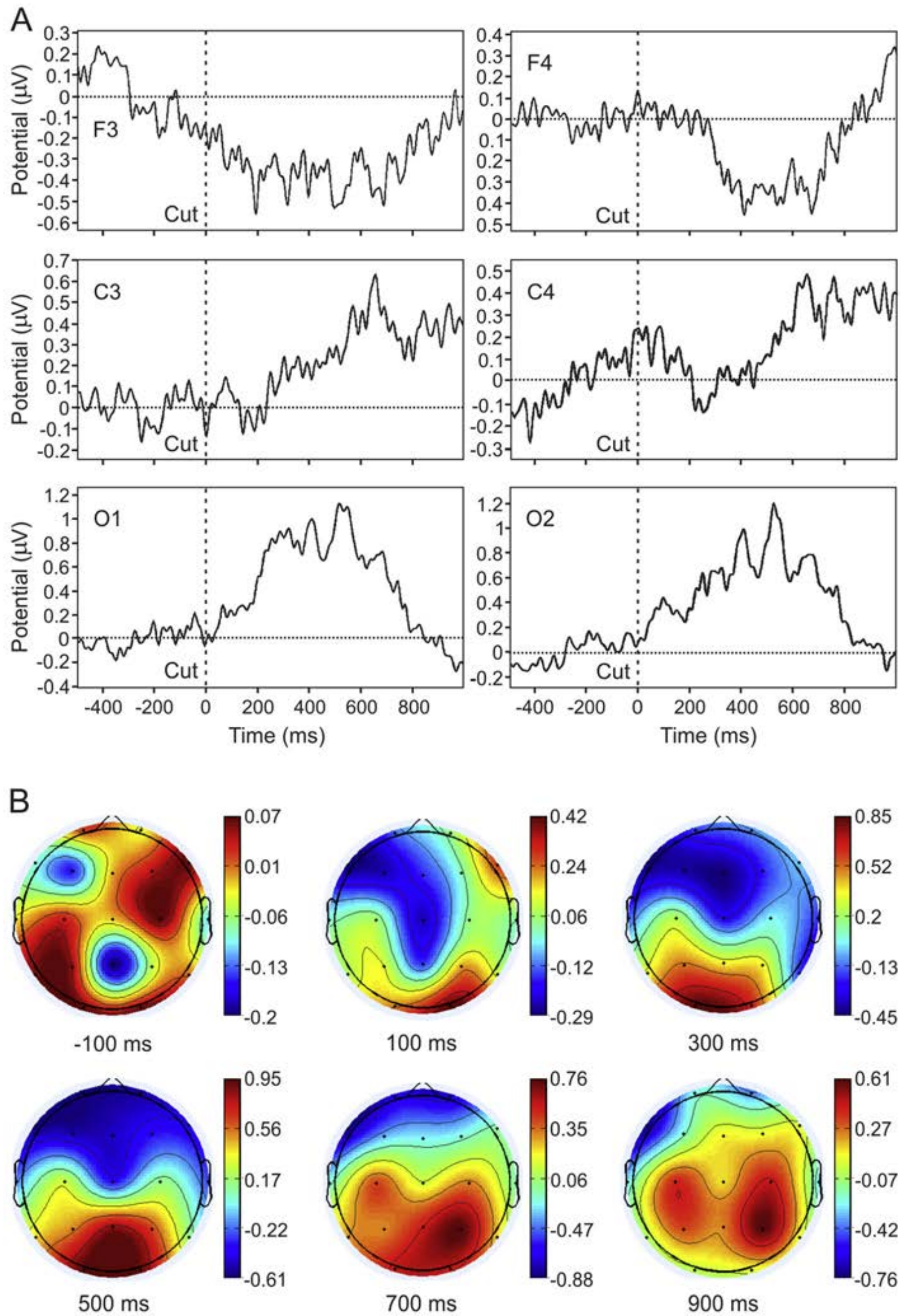


Fig. 4. ERPs related to cuts. (A) EEG potential (in μV) recorded by frontal, medial, and occipital electrodes. For all traces, positive is up. Cuts provoked an increase of the activity of the occipital area starting at the moment of the cut. This increase was maintained during the 800 ms after the cut, reaching a peaking point between 400 ms and 600 ms. After that, activity seemed to stabilize. Around 200 ms after this increase started in the occipital area, an increase of activity appeared in medial areas, and 200 ms after that the increase of activity arrived in the frontal area. According to our results, processing in the cortex of a cinematic cut goes from the occipital area to anterior zones in coherence with what we know about the speed of processing conscious and unconscious stimuli in the human visual system (Thorpe et al., 1996). (B) Topographic maps of mean amplitude of ERP. From upper left to lower right: 100 ms before the cut, and 100 ms, 300 ms, 500 ms, 700 ms, and 900 ms after the cut. All electrodes were analyzed together. With time progression after the cut, the potential moved from the occipital to the frontal area. It was coincident with the change of visual input that a cut provokes, and the appropriate visual work needed to start processing it.

area and the frontal area. We found an almost significant result from the interaction between brain area and style of edition [$F_{(2,70)}$ = 3.017; p = 0.055]. Pairwise multiple comparison procedures (Holm–Sidak method) with a significance level of p = 0.05 showed that, in general, the style of edition had no effect in this time window. However, a more detailed analysis within areas revealed that, for the frontal area, the style of edition was relevant [$t_{(2)}$ = 2.28; p = 0.025]. Interestingly, we also found that while the difference in brain areas does not seem to be significant in Hollywood style, it is very significant in MTV style. From descriptive results, we found that the least square means of potential in frontal and medial areas are higher in Hollywood style than in MTV style, while the opposite occurs in the occipital area. The more continuous and lifelike narrative in the Hollywood style may be responsible for this greater activity in frontal and medial areas.

In the third time window (600–800 ms after the cut), the potential of the occipital area was decreased, while in medial and frontal areas it was increased. This factor continued being statistically significant [$F_{(2,70)}$ = 7.043; p = 0.002]. As in the first time window, we found that the interaction between the brain area and the style of edition produced an almost significant result [$F_{(2,70)}$ = 2.942; p = 0.059]; pairwise multiple comparison procedures (Holm–Sidak method) again indicated that in the frontal area the style of edition is relevant [$t_{(2)}$ = 2.451; p = 0.016]; and the brain area does not seem to affect the results for the Hollywood style of edition, while it does for the MTV style. Again, we found that in Hollywood style, frontal and medial areas presented higher potential than in the MTV style, while in the occipital area it was the MTV style that produced a higher level. These results are coherent with the more aggressive and discontinuous narrative characterizing the MTV style.

The four time window (800–1000 ms after the cut) showed no statistically significant differences related to brain areas, to the style of edition, or to the interaction

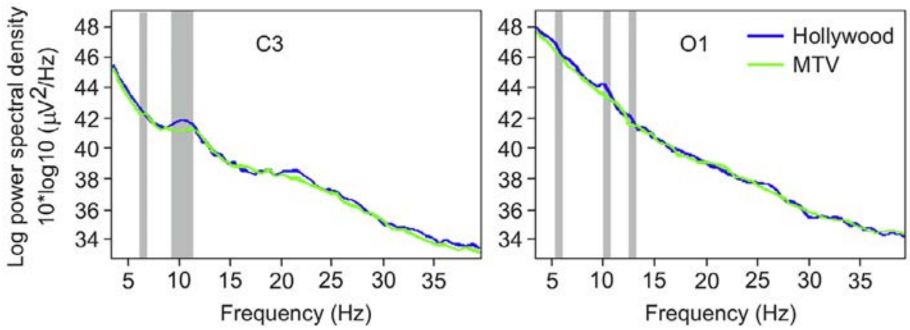


Fig. 5. Spectra decomposition for a somatomotor and an occipital electrode during the cut in the two editing styles: Hollywood and MTV. The gray shaded area indicates the region of statistical differences between the styles of edition ($p < 0.05$, *t*-test). Data were obtained from 36 subjects watching a Hollywood-edited-style movie (33 cuts) and an MTV-edited-style movie (79 cuts). Analyzed epochs are from 500 ms before the cut to 1000 ms after the cut.

of the two. As in the previous windows, from a descriptive approach we found that the Hollywood editing style elicited a higher potential in frontal and medial areas and a lower one in occipital area than the more chaotic or narratively incoherent MTV editing style.

According to our results, the occipital area showed a higher potential after the cut in the MTV-style edition than in the Hollywood one. In contrast, medial and frontal areas presented higher potential in Hollywood movies than in MTV movies (Fig. 8).

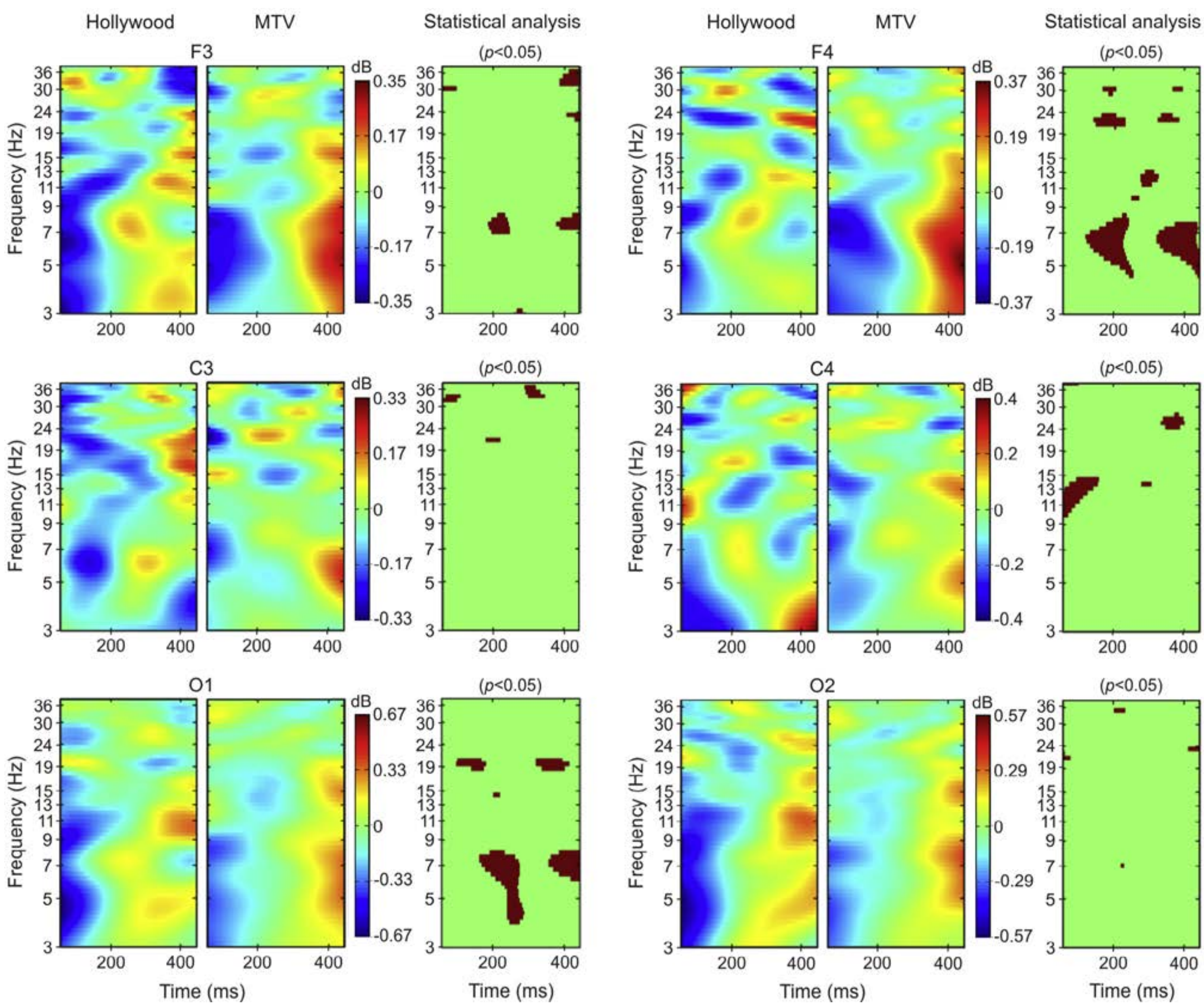


Fig. 6. ERSP for frontal (F3 and F4), somatomotor (C3 and C4), and occipital (O1 and O2) electrodes. Columns in green and brown indicate the results of a parametric statistical approach ($p < 0.05$, *t*-test) between the two previous Hollywood and MTV columns. Green indicates no statistically significant differences, while brown indicates statistical differences at that time and frequency. Note the remarkable correspondence between O1 and F4 and between O2 and F3. The differences in O1 are maintained in F4. These results suggest that the feedforward event in the vision process (Del Cul et al., 2007; Wyatte et al., 2014) may be crossed. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

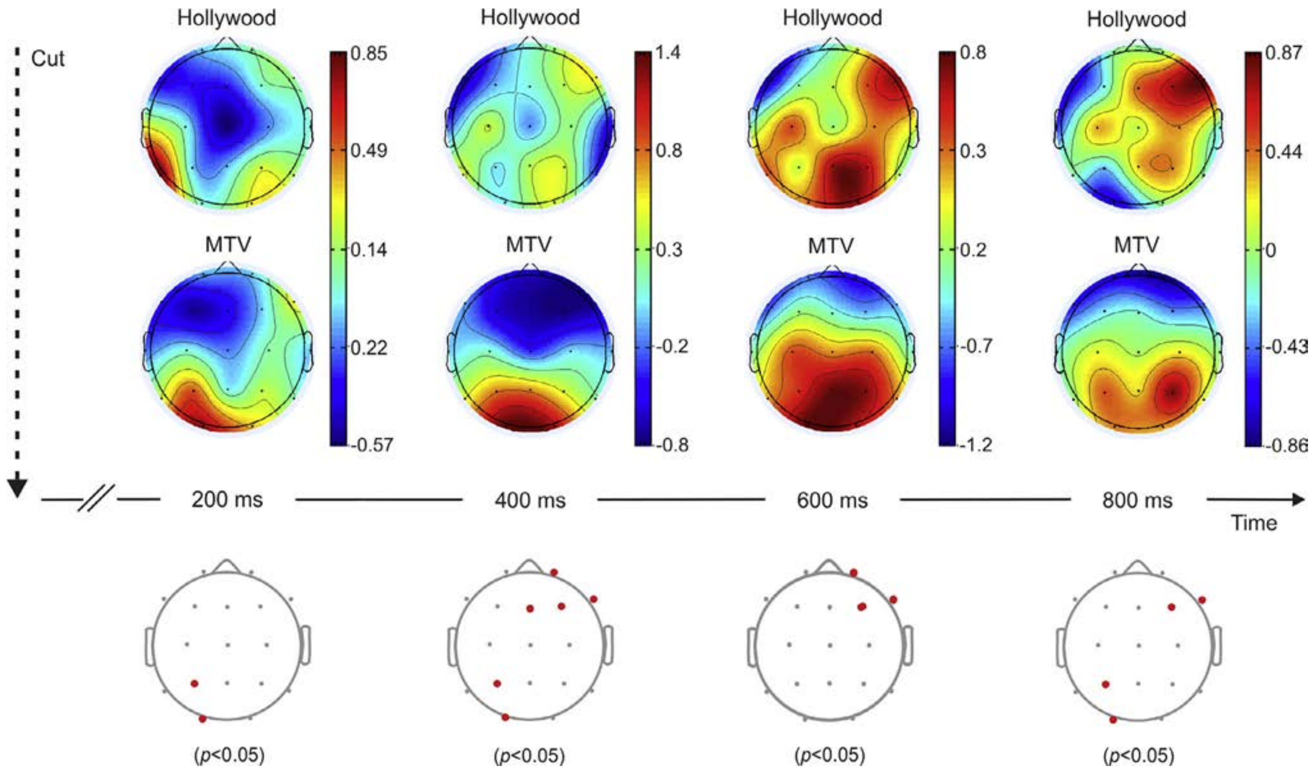


Fig. 7. Topographic maps of mean ERP amplitudes for Hollywood and MTV movies. Reaction at 200 ms, 400 ms, 600 ms, and 800 ms after the cut in Hollywood-style (upper) and MTV-style (middle) movies. A statistical comparison (*t*-test) between the two movie types is illustrated below. Red dots indicate $p < 0.05$. Cuts inserted in Hollywood-style edition caused higher potential in frontal and medial areas and lower in occipital areas compared with cuts presented in MTV-style. This figure also illustrates that the progress of the potential through time, from back to front, seen in the previous section is more evident for the MTV style of edition.

The PLV and phase synchronization index

We decided to evaluate the changes in connectivity between the different recording sites evoked by the cuts. For this, we determined the PLV as a phase synchronization index in the cut, in the theta (4–8 Hz), alpha (8–12 Hz), beta 1 (12–20 Hz), beta 2 (20–28 Hz), and low gamma (28–40 Hz) bands, before (from −500 ms to 0 ms) and after (from 0 ms to 500 ms) the cut. We averaged connectivity of PLV for all subjects in those bands (Fig. 9A). Statistically significant differences in synchronization between "before" and "after" the cut were found. A comparison between EEG recordings collected before (from −500 ms to 0 ms) and after (from 0 ms to 500 ms) the cut showed more synchronization following the cuts between pairs of EEG sensors in theta, beta 1, and low gamma bands (Fig. 9B). Our results for the theta band indicate differences in frontal, central, and occipital electrodes. These differences were especially significant in the left parietal area. For the beta 1 band, we also found higher synchronization after the cut than before it. The connectivity within the occipital area and between occipital and frontal areas is of interest for this investigation. Our results in the low gamma band correspond to a stronger connectivity between electrodes P3 and Pz. For this single connection, we conclude that this difference may be residual, compared with other synchronization values. Overall, these results indicate that brain networks active after a cut in a movie are more intense than before the cut.

In a following step we evaluated the PLV via the style of editing in which the cut appeared to look for phase synchronization differences. Our first approach consisted of comparing PLV after the cut in Hollywood and MTV styles. We did 100 surrogates and a Wilcoxon test with multiple comparisons with false discovery rate Type 1 ($q = 0.1$). We did not find statistical differences between the styles in the time window (from 0 ms to 500 ms). In our second approach we made the same comparison between the styles, taking the whole epoch (from −500 ms to 1000 ms) as the time window. In this case, we found residual statistical differences in the theta band (synchronization between T7 and F7), but no differences in the alpha, beta 1, beta 2, and low gamma bands. We can therefore conclude that the style of edition in which cuts are presented in media contents does not affect brain synchrony.

Granger causality

We also analyzed Granger causality in the cut. For that, we did a Wilcoxon test for 100 surrogates, with false discovery rate correction (Type 1, $q = 0.1$). We found Granger causality before the cut that was statistically

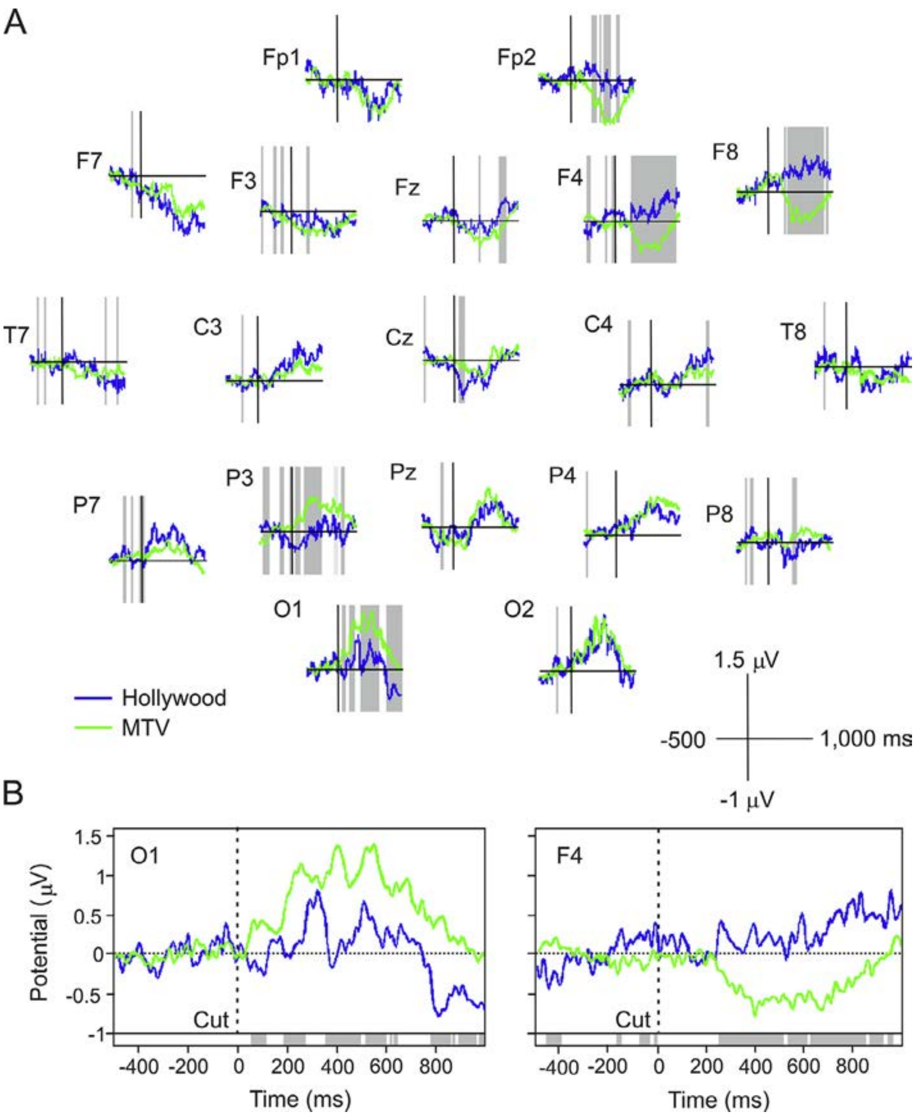


Fig. 8. ERPs evoked with Hollywood and MTV editing styles. (A) Topographic display of averaged evoked potential data for all subjects. ERPs plotted for a 1500-ms period starting 500 ms before the cut. For all traces, positive is up. Data are triggered with cuts (vertical line). Gray shaded areas indicate the region of statistical differences (*t*-test, $p < 0.05$) between the styles of edition. Blue lines correspond to the Hollywood-edited movie ($n = 1188$ trials), and green lines to the MTV-edited movie ($n = 2844$ trials). (B) ERP recorded with occipital (O1) and frontal (F4) electrodes. Time 0 indicates the cut. According to our results, cuts elicit different responses depending on the style of edition in which they are placed. While the chaotic MTV style (in green) provokes a higher activity in the occipital area, it provokes a lower activity in the frontal area than the continuous and more organized Hollywood style (in blue). Gray shaded areas on the x-axis indicate the statistical differences (*t*-test, $p < 0.05$) between the styles of edition. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

significantly higher than after the cut (Fig. 10A). This explains that causality in brain signal activity decreases as a consequence of the change of scene produced by the cut. We also compared Granger causality differences for the 500 ms before the cut and 500 ms after the cut between the styles of edition (Fig. 10B). We did not find higher connectivity before the cut in Hollywood compared with MTV, while a couple of causality connections between electrodes before the cut were higher in MTV than in Hollywood (see Fig. 10B). After the cut, both styles showed higher residual causalities in left hemisphere electrodes. Finally, we also compared differences in Granger causality for the whole epoch between Hollywood- and MTV-editing styles (1500 ms), but did not find significant differences (Wilcoxon test, false discovery rate Type 1, $q = 0.1$).

DISCUSSION

Eyeblinks after cuts

In previous investigations, we found that the SBR is affected by the fragmentation made by the style of edition, and that changes in SBR could be useful as attentional markers in media contexts (Nakano et al., 2009; Andreu-Sánchez et al., 2017a). In this study, we planned to find out whether there is a direct relation between eyeblinks and cuts. The comparison between the SBR 1 s after the cut and the SBR during the rest of the media presentation revealed that a cut inhibits the SBR immediately after it. Interestingly, this decrease is of statistical significance in the life-like style of edition, known as Hollywood style, and not in the more chaotic and discontinuous MTV style. But the fact is that SBR in MTV-style contents is already decreased (Andreu-Sánchez et al., 2017a). Thereby, the moment when a cut is inserted by creators, linked to the style of edition, affects viewers' eyeblink rate. Cuts inhibit eyeblinks during the following second. Thus, we propose cuts as attention managers. Future investigations should tell us whether unusual narrative alterations, while viewing media content in a classical style, affect eyeblink inhibition and attention mechanisms.

Brain activity and attention after the cut

We were interested in finding out whether cuts provoke a specific brain activity and at what moment, also considering the existence of conscious and unconscious perceptions. The so-called edit blindness phenomenon is well known: the viewer of a media content often does not consciously perceive the jumps of the cuts during

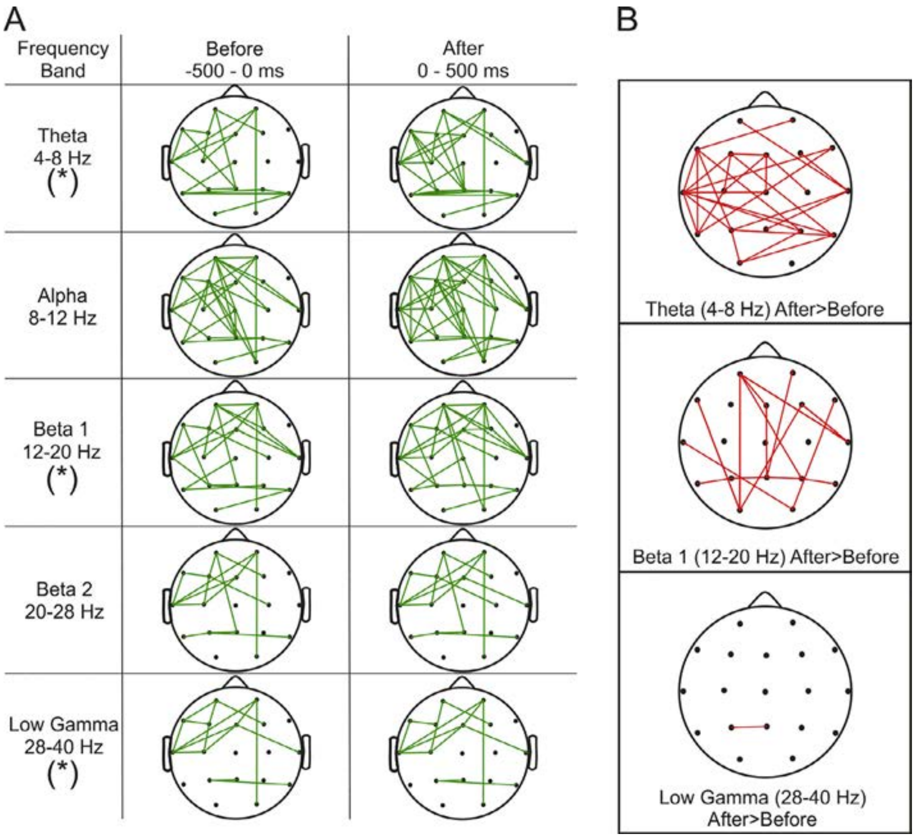


Fig. 9. PLV before and after the cut for the different frequency bands. (A) Average connectivity of PLV for all subjects in theta (4–8 Hz), alpha (8–12 Hz), beta 1 (12–20 Hz), beta 2 (20–28 Hz), and low gamma (28–40 Hz). The ''before'' period runs from 500 ms before the cut to the cut. The ''after'' period runs from the cut to 500 ms after it. Green lines indicate the synchronization (PLV index) between pair of electrodes. *Indicate the presence of significant PLV differences between the two time windows. (B) Significant differences ($p < 0.05$), represented by red lines indicating connections between sensors (electrodes), in the corresponding band in After > Before, Wilcoxon test, false discovery rate Type 1 (q = 0.1) with 100 surrogates. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the viewing (Smith and Henderson, 2008), analogously to the well-known effects of change blindness and inattentional blindness in everyday events (Most et al., 1999; Most, 2010; Rattan and Eberhardt, 2010). Here we found that the cut provokes an increase of alpha power in parieto-occipital electrodes. This is not consistent with previous reports (Reeves et al., 1985) which linked edits with the alpha band in central and occipital locations. They talk about alpha band drops within the initial 500 ms after the edit, followed by a recovery. However, according to our results, the increase in the alpha band is already seen between 200 ms and 300 ms after the cut. Interestingly, there is a general increase in the central areas, which is appreciable in Cz, but not in the somatosensory lateral zones. This finding indicates a non-activation of premotor areas with cuts, possibly due to the nonconscious or real perception of motor actions through the known phenomenon of edit blindness. Frontal zones do acknowledge the change made by the cut with an increase of activity, as expected.

In the ERPs after the cut, the results obtained are coherent with previous studies on early discrimination of visual stimuli. From the primary visual zones, the perceptive reaction to the cut seems to follow the known path for any visual stimulus change. Thorpe's classic studies with ERP to measure the processing time of natural scenes are very clear (Thorpe et al., 1996). They presented different visual stimuli –jungle images with or without animals– for EEG analysis. Initially, participants' responses were similar regardless of the type of image shown, but at 150 ms a clear difference emerged between the potentials in animal and non-animal trials (Thorpe et al., 1996; Hegdé, 2008). The fact that the brain deduces this information does not mean that it is done consciously (Li et al., 2002). It may take longer to decide, at least a quarter of a second, to be able to say that we ''see'' a natural scene and make a conscious decision (Fei-Fei et al., 2007). The spatial, temporal, and action jumps caused by cuts should produce effects in the sensory cortex 60–100 ms after the stimulus (Luck, 2006). Attention would begin to influence at 150 ms, but Thorpe and colleagues have found that at that time the categorization has already been made. Such ability to categorize highly variable natural scenes out of the focus of attention would be an evolutionary advantage that would give more rapid reaction to the classification of contents. According to Luck, attention would be directed spatially between 25 ms and 50 ms later (Luck, 2006). In the case of the cut, if it has been perceived, it is then that the stimulus passes to the attention systems. In our study, potentials spread from the occipital area to the frontal area at around 200 ms after the cut, as the perception of the stimulus progressed to more-complex areas of process and feedback (Fig. 4A). This flow of activity would be consistent with the feedforward event during early visual processing (Del Cul et al. 2007; Wyatte et al. 2014).

Brain activity, attention, and styles of edition

It is interesting to compare the cerebral effect of the cuts in different editing styles. Starting from the two most common styles of edition in media –the organized classic Hollywood style and the one known as post-classic style or MTV style, closer to the intensified and disruptive narrative of video clips– we compared the temporal windows of the cuts in the two styles of edition. We did not find differences around the cut between those styles in the alpha band, when we

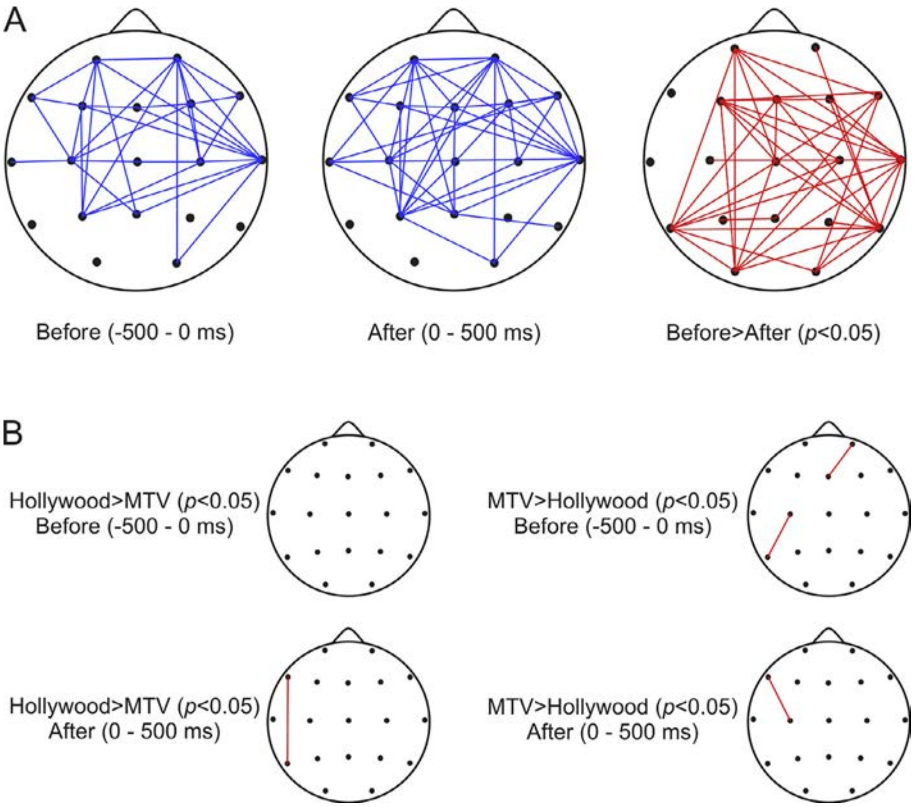


Fig. 10. Granger causality in the cut. Blue lines indicate average causal connectivity found between pairs of electrodes, red lines indicate $p < 0.05$ from a Wilcoxon analysis test with false discovery rate Type 1 (q = 0.1), including 100 surrogates. (A) Averaged Granger causality before the cut (left) and after the cut (center). On the right, red lines indicate statistically higher causality before the cut than after the cut. (B) Statistical differences between the two styles of edition and the temporal windows before and after the cut. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

compared epochs of 1500 ms (from −500 to 1000 ms). However, we did find differences in the theta (4–8 Hz) band at around 200–400 ms after the cut. The cortical theta band in the visual zone has been characterized by its role in working memory –it is believed to form a coherent representation and actively maintain the visual representation, although it is debated whether it corresponds to a specific mechanism, possibly related to spatial navigation (Lee et al., 2005; Buzsáki, 2006; Luo et al., 2014). Interestingly, the differences between the styles of edition obtained in theta showed a crossed pattern, specially between the left occipital area (O1) and right frontal one (F4) (Fig. 6). Those results should be further studied in the aforementioned context of feed-forward events during visual processing.

From the analysis of ERPs, our results suggest the potential in the occipital area in the discontinuous and chaotic MTV style is higher than in the continuous and lifelike Hollywood style, while in frontal areas it is the contrary. These results are coincident with those of previous studies for unrelated cuts (Francuz and Zabielska-Mendyk, 2013). Our results suggest that the cuts in a chaotic and fragmented narrative, such as MTV style, would provoke a higher activity in visual areas, since the visual information would be unexpected and unpredictable. However, that higher visual activity would not have a greater impact in prefrontal zones, indicating that this information does not reach conscious levels (Del Cul et al., 2009). Meanwhile, cuts in a neater and more continuous narrative, such as Hollywood style, would not have such a high impact on the visual zone, maybe because of the inherent predictability from the continuity of the narrative, but the impact on the prefrontal and higher processing areas would be greater (Fig. 8). These results support the two-stage model of conscious access to perceptual information (Del Cul et al., 2009) based on a first stage of perceptual representation and a second stage of transfer of information at > 270 ms spreading from the visual cortex into parietal and prefrontal cortices following a top-down amplification of visual information (Sergent et al., 2005; Del Cul et al., 2007, 2009).

Functional and effective connectivity around the cut

Finally, we analyzed the data to find brain connectivity related to the cut, and differences between the styles of edition and their consequences in frontal areas. There are few studies on connectivity and causality between cortical rhythms during audiovisual viewing. Most join emotional processes or their effects in cortical structures through EEG or in deep regions of the brain, such as the amygdala, with functional magnetic resonance techniques (Cha et al., 2015; Raz et al., 2016). In neurocinematics, the investigations made by Hasson and colleagues with functional magnetic resonance imaging did study the inter-subject correlation in terms of perceptual synchronization between subjects (Hasson et al., 2004). In EEG, one of the most studied hypotheses to analyze connectivity is phase synchronization, in particular the PLV, also known as mean phase coherence. For example, PLV had previously been used to determine esthetic appreciation through the two conditions of "beautiful" and "not beautiful" style (Cela-Conde et al., 2013). In the case of the cut, it seemed useful to evaluate the instantaneous phase differences of the signals generated before and after the cut to see whether they evolve together in time, and whether the style of edition affects them. Regarding functional connectivity, we concluded that there is a higher phase synchronization after the cut than before it in the theta and beta 1 bands. Our results suggest that the cut causes a synchronization effect, since PLV seems to evaluate the synchronization better over a whole band (Bruña et al., 2018). We did not find significant differences of functional connectivity between the styles of editing studied in this investigation.

Granger causality is a model frequently used to measure dependence between points. Granger causality is presented as a framework to quantify the asymmetric causal interactions between regions of the cortex and brain states (Sánchez-Campusano et al., 2011; Courellis et al., 2017). Hence it is useful for describing data in terms of interaction and information flows (Seth et al. 2015). In the analysis of Granger causality before and after the cut, greater connectivity was found before the cut, and it did not show strong differences in effective connectivity between the styles of edition (Fig. 10). These results suggest that cuts interrupt connectivity in brain activity.

Audiovisual content has become quicker, more disrupted and plenty of cuts while media narratives have evolved to get viewers' attention during the past decades. Cuts in video editing inhibit SBR reflecting the increased attention of viewers. Cuts also provoke differences in brain synchronization. However, cuts' processing differs between the style of edition in which they are used. Cuts in MTV style provoke higher potential in visual-processing area than Hollywood style, while the latter provokes higher potential in medial and frontal areas. So, while the chaotic, quicker and disrupted MTV style increases viewers' visual attention, it also decreases their conscious processing. Further research should assess levels of comprehension and understanding of the fastest and chaotic audiovisual contents as action scenes, musical video-clips or war video games, among others.

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Article

Viewers Change Eye-Blink Rate by Predicting Narrative Content

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Abstract: Eye blinks provoke a loss of visual information. However, we are not constantly making conscious decisions about the appropriate moment to blink. The presence or absence of eye blinks also denotes levels of attention. We presented three movies with the exact same narrative but different styles of editing and recorded participants' eye blinks. We found that moments of increased or decreased eye blinks by viewers coincided with the same content in the different movie styles. The moments of increased eye blinks corresponded to those when the actor leaves the scene and when the movie repeats the same action for a while. The moments of decreased eye blinks corresponded to actions where visual information was crucial to proper understanding of the scene presented. According to these results, viewers' attention is more related to narrative content than to the style of editing when watching movies.

Keywords: visual perception; attention; cognitive neuroscience; media content; neurocinematics

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1. Introduction

While watching media content, there is something we do constantly that we hardly notice but that reflects our attention: blinking. On average, humans blink between eight and 21 times per minute while resting [1], but our eye-blink rate changes when we carry out different activities such as talking, listening, looking around, or watching screens. Eye blinks have the primary physiological function of wetting the cornea [2,3]. They also hide visual flow for a short (100–400 ms) period of time [4,5]. As a result, on average, an adult spends ~44 min/day awake but with their eyelids closed [6]. During that period, visual information is not perceived. In accordance, we have to decide, whether consciously or not, the best moment to blink in order to lose the least possible amount of visual information.

There remains a lot to study about the neurobiological basis of eye blinks. For example, it has been suggested that the spinal trigeminal complex is an integral component of the spontaneous eye-blink generator circuit [7]. It has also been suggested that the basal level of corneal afferent input to the spinal trigeminal complex establishes the interblink interval [7]. Spontaneous eye blinks involve a dynamic alteration of brain activity, with a prominent but momentary activation of the bilateral hippocampus and the cerebellum after the blink onset, when subjects view videos attentively [8]. Also, it has been suggested that the eye-blink rate can be used as a noninvasive indirect marker of central dopamine function, with a higher eye-blink rate predicting higher dopamine function [9]. Blink rate has also been associated with enhanced learning from negative outcomes, helping to suggest that lower dopamine levels per se may improve learning from negative choices [10]. A recent study suggested that blink modulation is related to the motivational and biological significance of the stimuli, providing a solid background for the study of emotion–attention patterns using a noninterfering psychophysiological measurement [11].

The blink rate has been linked to attention in several circumstances and varies according to mental activities. Blinks are perceived as communicative signals in human face-to-face interaction, directly influence speakers' communicative behavior in this context [12] and can be used to distinguish liars from truth-tellers [13]. An increase of the eye-blink rate has been correlated with a decrease of attention, and vice versa [14–16]. Compared with a control state, the blink rate is higher during face-to-face conversation but decreases during a classroom examination [17]. Blinks also play an important role in the perception of magic shows [18]. Stemming from these many investigations, eye blinks are used as attentional markers. In the media context, it is known that attention is one of the most important variables to consider when creating a movie, and there are several ways to manage elements in designing a visual work that is attractive to viewers. Two of these elements are content and style.

1.1. Content: Storytelling and Attention

The narrative is the content and the way it is explained to spectators. Both for watching media content and for creating the visual meaning of the world around us, one of the most central internal functions is attention [19]. Since the dawn of media productions, communication researchers have adopted various approaches to determine how to quantify and manage attention in narratives [20–22]. Recent studies have demonstrated that one way to determine viewers' attention to media content is through a proper quantification of involuntary or spontaneous eye blinks [23–26]. Eye-blink patterns are certainly linked to communication processes. While viewers are watching and listening to a speaker, their eye blinks are synchronized with the speaker's blinks, with a delay of around 100 ms [27]. However, such entrainment does not occur when viewers watch speech without sound or listen to the sound of speech without video stimulus. This indicates that blink entrainment is not an automatic imitation of an observed behavior but rather a reflection of narrative comprehension [27]. Blinking has also been linked to autism spectrum disorder (ASD), and it is of interest in the context of linking attention to blinks. While adults without ASD significantly synchronize their eye blinks to those of speakers, ASD listeners do not [28], and non-ASD toddlers inhibit their blinking earlier than toddlers with ASD, thus maximizing access to visual information and anticipating forthcoming events [6]. Based on these results, it has been proposed that measurements of blink inhibition can provide an index of autonomic reactivity and differential engagement, and of the viewer's subjective assessment of the importance of media content. By measuring the timing of blink inhibition relative to content, one can determine the viewer's subjective assessment of the importance of what he or she is watching [6] and, thus, confirm how story-telling affects viewers' attention.

1.2. Style: Media and Attention

Editing is part of the style and the way information is presented visually, consisting of the fragmentation of the content within shots and camera movements. Editing has been studied since the early work by Griffith in the 1910s [29,30] and the Soviet school of cinema. In the latter case, editing was analyzed on the basis of different experiments and theories, such as those of Kuleshov [31], Pudovkin [32], and Eisenstein [33]. Editing is part of the cinematographic language, and media creators use it as a unifying mechanism of projection and identification, and to construct realistic impressions [34]. Despite the interest in creating realistic scenes in media works, real scenes and those in media are perceived differently by spectators. Media content inhibits viewers' eye-blink rate significantly compared with the same narrative in reality [26]. In addition, recent investigations have proven that the style of editing affects viewers' attentional level as indicated by their eye-blink rate [24]. The more chaotic and discontinuous the editing style, the lower the eye-blink rate of viewers and, presumably, the greater their attention. Cuts inhibit viewers' eye blinks, thus media creators can use them to manage attention [25]. One reason why viewers tend, unconsciously, to avoid blinking when cuts are inserted into media content could be that the film whose visual flow is interrupted by the cut "blinked" for them; another explanation is that, when the image changes, viewers avoid losing visual information by inhibiting eye blinks. Cuts break up familiar contexts since they present new visual information to be decoded. The lack of familiarity becomes a lack of prediction, thus decreasing the efficiency of sensory (visual, auditory) perception [35].

Cuts also affect viewers' attention and brain activities, and event boundaries in narrative movies provoke transient brain responses [36]. Event boundaries represent different types of changes in films. Among others, event boundaries include spatial, temporal, object, or character changes, being associated with increased segmentation into parts by viewers for the sake of the proper recognition of objects [37]. The perception of event boundaries would be a side effect of prediction during ongoing perception. Interestingly, cuts are not associated with increases in subjective perception of segmentation [38]. The predictability of incoming information influences event perception and thereby narrative comprehension. However, since cuts are not by themselves associated with increases in event segmentation, it may be understood that formal categories used to classify cuts are predictive of event segmentation [39]. Moreover, the phenomenon of edit blindness means that film viewers are unaware of some film edits [40]. Many film editors and researchers assume that editing in accordance with so-called continuity editing rules favors viewers' edit blindness [40]. This idea suggests that differences could be found in the attention of viewers watching continuous and discontinuous editing styles, and thus, that media editing is highly related to attention.

1.3. Synchronization in Media Perception

In communication contexts, learning about patterns and synchronization is of great interest to media creators. In the 1990s, Walter Murch, a Hollywood film editor, wondered whether there is an optimal moment to insert a cut during the editing process to respect eye blinks and thus avoid the loss of visual information [41]. Murch, who worked on films such as *The Godfather* (1972) and *Apocalypse Now* (1979), suspected that eye blinks could have a comprehension function in the proper understanding of a movie.

During the last few decades, the synchronization in viewers' perception has been proven through the inter-subject correlation model [42,43]. A highly significant tendency for the brains of different individuals to act in unison during free viewing of movie scenes has been reported [42]. Such inter-subject synchronization has been correlated with emotionally arousing scenes [42]. Synchronization of eye blinks while viewing video stories has also been reported [23]. In their investigation, Nakano and colleagues found that the synchronization of eye blinks occurred during scenes in which the narrative required less attention, such as the conclusion of an action, the absence of the main character, or during a repetition of the same scene or the presentation of a similar one. Synchronized blinks have also been found in the perception of magic shows, where such synchronization of blinks between spectators occurs after a seemingly impossible feat [18]. All these results lead us to consider that there may be patterns in media perception and that viewers may control, consciously or not, the timing of their responses, such as blinking, to avoid the loss of important visual information.

Since we know that perception in a media context is synchronized at some points, we wondered what would govern such synchronization: content or style. To investigate this, in this study we compared the eye blinks of viewers while they watched three different movies with the same content but different styles of editing. The aim was to check whether the content of the movie, regardless of the style, can control viewers' eye-blink rate, or, on the contrary, the style governs the perception, regardless of the content.

2. Materials and Methods

2.1. Participants

Forty human subjects (age 43.97 $\pm$ 8.07 years) with normal or corrected-to-normal vision participated in the experiment. Participants gave prior written informed consent to participate in the study. The experiment was carried out in accordance with relevant guidelines and regulations for human research and was approved by the Ethics Commission for Research with Animals and Humans (CEEAH) of the Universitat Autònoma de Barcelona (Barcelona, Spain).

2.2. Stimuli

We created three video stimuli, each of 198 s duration, with the same narrative and content, but different editing styles. One stimulus was a one-shot movie consisting of a single open shot with no cuts. The second video stimulus was a movie with 33 shots and a continuous, classic style of editing, with an average shot length of 5.9 s. This stimulus presented classic shots with smooth transitions in accordance with the 180° rule, by which the same action is filmed following that angle to avoid spatial discontinuity. The third video stimulus was a movie with 79 shots and a discontinuous, chaotic style of editing, with an average shot length of 2.4 s. This third stimulus broke the classic 180° rule, and presented sudden movements in the frame, discontinuities in time and space between shots, constant camera movements, and a large number of different kinds of shots.

The narrative consisted of a man who enters a room containing a desk, goes out, enters again, and sits at the desk. On the desk there are three colored balls, three books, and an apple. He juggles with the colored balls, puts them back on the desk, and goes out again. The man enters once more with a laptop in a case, sits, opens the case, and takes out the device. He opens it up and works on it, then picks up, one by one, each of the three books on a desk situated on the right side of the screen, reads something in it, then puts it down on the left side of the screen. He works for a while with the laptop, then closes it and moves it to the left. Then, the man puts his hand into his pocket and takes out a small torch, which he points towards the viewer. He turns it on for a few seconds, turns it off, then puts it back into his pocket. He takes the apple from the desk, rubs it on his shoulder, and bites it. He chews and bites the apple repeatedly for a while. He leaves the apple core behind the laptop, to the left of the screen. The man swallows the rest of the apple and wipes his mouth with his hand. Then he makes a happy face, a sad face, and a disgusted face, runs his hand over his face, and makes a happy face again. The man stands up and leaves the room.

Stimuli were presented on a high-definition (HD) 42-inch light-emitting diode (LED) display (TH42PZ70EA, Panasonic Corporation, Osaka, Japan) using Paradigm Stimulus Presentation software (Perception Research System Incorporated, Laurence, KS, USA).

2.3. Data Acquisition

Subjects participated in sessions (~15 min) of active viewing. All participants watched all the stimuli. The presentation of the stimuli was randomized over all possible combinations. The stimuli were presented on a stage that we designed to make participants feel comfortable while watching the media content. We asked participants to watch the stimuli without further requirements, having told them that they would be asked some questions after the visualization. At the end of the session, participants filled out a distracting questionnaire.

Observers' eye blinks were detected following a dual protocol: using electroencephalographic/electromyographic (EEG/EMG) recordings and a HD video recording system. Participants' EEG/EMG was recorded using a wireless device (Enobio®, Neuroelectrics, Barcelona, Spain) with 20 electrodes placed according to the 10–20 International System. Eye blinks were detected by the prefrontal Fp1 and Fp2 electrodes and electrooculographic electrodes. For comparison, participants' faces were also recorded in a close-up shot with an HD camera (HDR-GW55VE, Sony Corporation, Tokyo, Japan) at 25 frames/s.

2.4. Data Analysis

We analyzed eye blinks following two procedures. Firstly, we filtered EEG/EMG data to 0.5–3 Hz and applied Brainstorm's eye-blink detectors (Brainstorm, University of Southern California, Los Angeles, CA, USA) in electrooculographic (EOG), Fp1 and Fp2 channels, running on MATLAB R2013a (The Mathworks Inc., Natick, MA,). In a second step, we manually checked eye blinks in the videos of participants' faces recorded with the HD camera. Using those two methods, we obtained a matrix with a final list of each participant's eye blinks. To assess changes in blink rate with time, each video was divided into 40 blocks of 4.95 s, and the blink number was converted into blinks/min for each block. The blink rate analysis was performed by repeated-measures analysis of variance (ANOVA) designed with two factors: time and style of editing. The time factor corresponds with each of the blocks. Using the blinks within each block, we computed a two-way ANOVA with blocks that showed increases or decreases, and the rest of them, with type of block and style of editing as factors. We used SigmaPlot 11.0 (Systat Software Inc., San Jose, CA, USA) for the statistical analysis.

3. Results

We detected a total of 1721 blinks in the one-shot movie, 1688 blinks in the classical-style movie, and 1560 blinks in the chaotic-style movie. We distributed all the eye blinks into 40 bins of 4.95 s each for presentation as a histogram for further comparisons and analyses (Figure 1). We observed that the evolution of the eye blinks through those bins was very similar, regardless of the style of editing presented to participants. This result made us suspect that movie content would be more relevant than style in the distribution of eye blinks across time. The blink rate analysis revealed a significant main effect of Time ($F_{(39,3041)} = 5.199$, $p < 0.001$) and a significant Time × Style interaction ($F_{(78,3041)} = 2.004$, $p < 0.001$). No significant main effect of Style was found ($F_{(2,3041)} = 2.982$, $p = 0.057$).

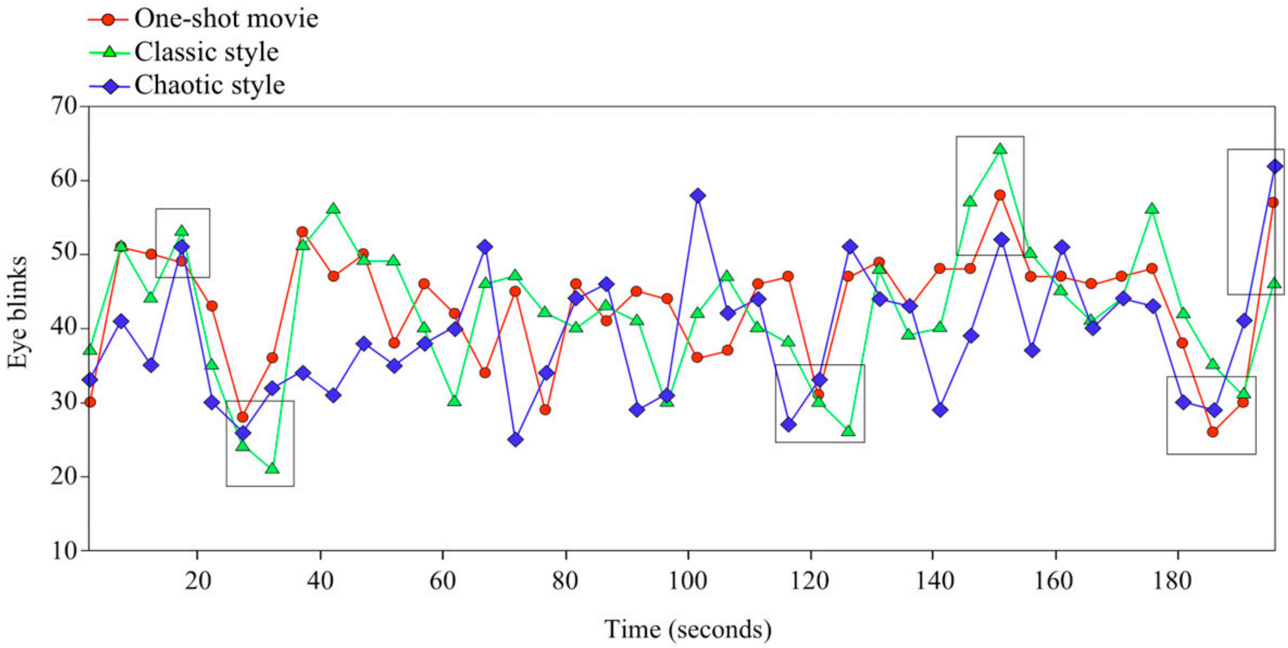

Figure 1. Timeline of the video, showing histograms of eye blinks from all participants ($N = 40$) while watching the movie with each style. Red circles indicate blinks during the one-shot movie; green triangles those during the continuous movie, edited with a classical style; and blue squares those during the movie with discontinuous and chaotic style. The distribution is into 40 bins of 4.95 s each. The boxes indicate the moments and actions when viewers' eye blinks coincide among the different styles of editing.

According to these results, there were six actions in the narrative content when special coincidence between the participants' eye blinks was observed for all three stimuli presented: three corresponding to increased and the others to decreased eye blinks (Figure 1). Since these coincidences were found even when the style of the video was different, we looked at the narrative occurring at these precise moments. The actions with increased eye blinks were the following (Figure 2A): when the actor disappeared from the scene (at around second 20), when the actor finished eating the apple (at around second 150), and at the end of the video, when the actor left the scene again (at around second 192). At the moments where the viewers' eye blinks decreased, we found the following actions (Figure 2B): the actor is juggling (at seconds 20–30), the actor puts his hand into his pocket (at around second 120), and the actor is making happy, sad, and disgusted faces (at seconds 180–190).

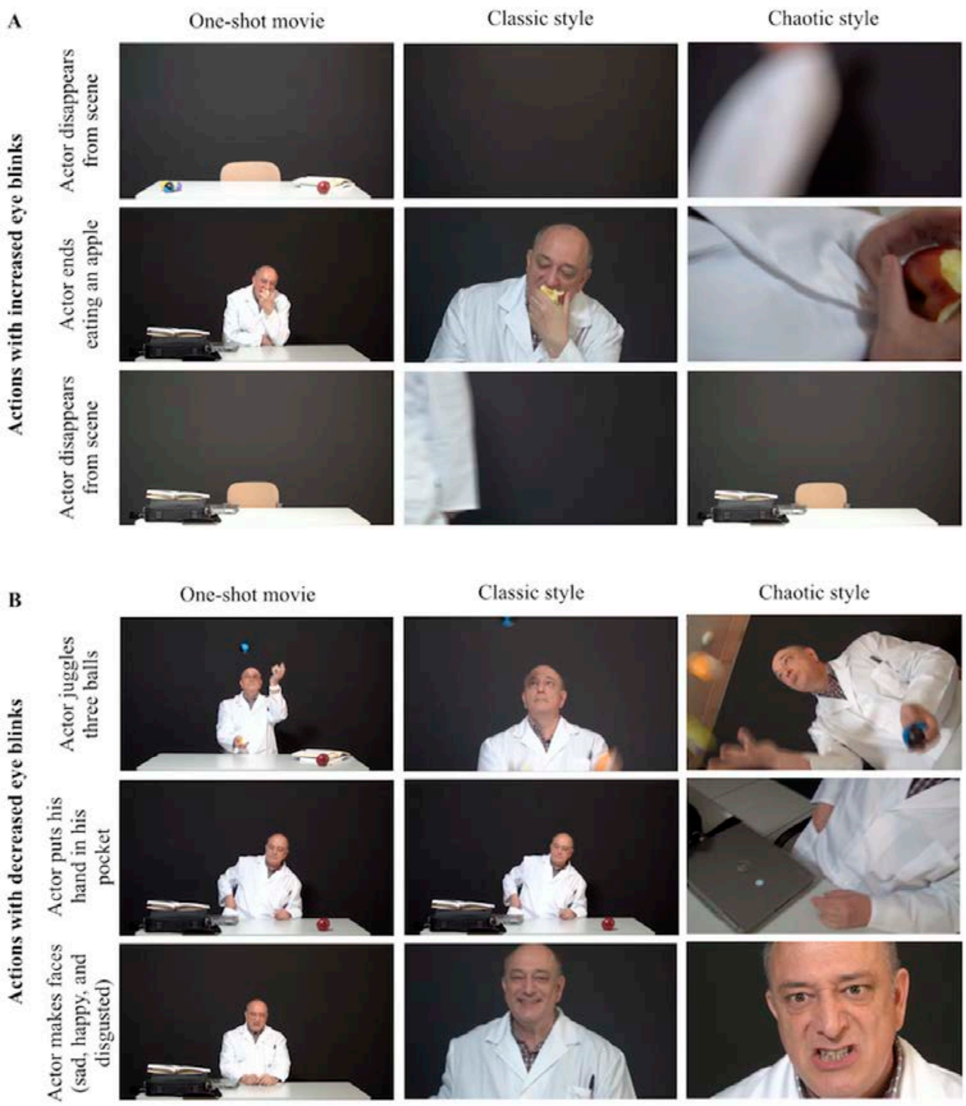

Figure 2. Moments with increased and decreased eye blinks while watching the same narrative with three different styles of editing. (**A**) The three moments when increased eye blinks were observed regardless of the style of editing (from top to bottom): when the actor disappears from the scene near the beginning of the movie, when the actor finishes eating the apple, and when the actor disappears from the scene at the end of the movie. (**B**) The three moments when decreased eye blinks were observed regardless of the style of editing (from top to bottom): when the actor juggles three balls, when the actor puts his hand in his pocket, and when the actor makes faces (sad, happy, and disgusted). The person appearing in Figure 2 is co-author Miguel Ángel Martín-Pascual. Dr. Martín-Pascual consents to the appearance of his image in this publication.

The mean (±SEM) number of eye blinks in the blocks with an increase corresponding to the mentioned actions was 55.89 (±2.18), compared with 29.14 (±1.72) for the bins with a decrease, while for the rest of the bins without an increase or decrease it was 42.03 (±0.67). We compared the mean number of eye blinks during the moments (or blocks) where there was a coincident increase, a coincident decrease, and the rest, also considering the style of editing. A descriptive analysis based on the style of editing showed that the mean (±SEM) number of blinks in the blocks with an increase was 54.67 (±3.78) for the one-shot movie, 58 (±3.78) for the movie with the classical, continuous style of editing, and 55 (±3.78) for the movie with a chaotic style of editing. For the bins with decreased eye blinks, the mean was 28.75 (±3.28) for the one-shot movie, 29.66 (±2.67) for the movie with the continuous style of editing, and 29 (±2.93) for that with a chaotic style of editing. For the rest of the bins, the mean was 43.76 (±1.14) for the one-shot movie, 43.16 (±1.18) for the movie with a continuous style of editing, and 39.16 (±1.16) for that with a chaotic style of editing. A two-way ANOVA showed that the moments (Time) affected viewers' eye blinks significantly ($F_{(2,119)} = 47.963$, $p < 0.001$). There was not a statistically significant interaction between Style and Time ($F_{(4,119)} = 0.472$, $p = 0.76$). We then carried out post hoc multiple-comparison procedures (Holm–Šídák method), with an overall significance level of $p < 0.05$. We found that, while the style of editing was significant within blocks showing no increase or decrease ($p < 0.05$), it was not significant within the blocks showing an increase ($p > 0.05$) or decrease ($p > 0.05$) of viewers' eye blinks. These results confirm that the style of editing [17] is not the only thing that governs the increase or decrease of participants' eye blinks while watching media content.

4. Discussion

We had previously found that the style of editing affects viewers' eye-blink rate, especially the chaotic style [24]. Here, we found that synchronization between increased and decreased viewers' eye blinks occurred at some specific moments of the timeline while they watched a movie, regardless of the style of editing of the movie but linked to its content. This agrees with the idea that, when watching media content, blinks are generated, in part, because of cognitive processing related to the narrative [23]. This study suggests that content can be used as a specific procedure to manage viewers' attention independently of the style of editing. Previous studies had already proven that different techniques can relax the audience's attention depending on the content, such as those used by magicians to perform their tricks [18]. However, no study had compared how different styles of editing would affect viewers' attention to the same content. According to our results, the coincidence of viewers' attention is more related to the content and narrative than to the style.

Two of the three moments when participants increased their eye blinks occurred in the absence of the actor. This is coincident with the findings of a previous study [23]. There was a third moment when increased eye blinks occurred with the actor still in the scene. At this third moment, the actor had been performing the same action (eating an apple) for 20–30 s. These results are in accordance with a previous investigation that found synchronization in viewers' eye blinks during repetition of the same scene [23]. In accordance with those findings, we propose that such increases of eye blinks may be related to the prediction ability of viewers. They have been seeing the same action for a long while and can easily predict what is going to happen since the action has not changed much. If something is predictable, it needs less attention. This would relate to Hawkins' theory of the memory–prediction framework. According to Hawkins, prediction is a tool that is commonly used when knowledge of past events can be applied to new situations that are similar to the past [44]. Our results suggest that this may be the reason why viewers increased their eye blinks: to take advantage of the opportunity to blink when they already know what is happening in the scene.

It is of interest to point out that, although repetition of an action or substantial knowledge of what is going to happen during media content has been linked to increased eye blinks and thus a probable decrease of attention, musical videoclips that are continually replayed on video-sharing platforms become phenomena that capture audiences' attention. On the other hand, we have previously found that media professionals (who are used to constantly watching audiovisuals and thus expected to have greater expertise and ability to predict audiovisual content) exhibit significantly decreased eye-blink rates compared with people who are not media professionals while watching audiovisual content [45]. Further investigations should explain these apparent contradictions.

The three moments with decreased eye blinks have in common the need for alertness to what might happen next. First, in the juggling part, it is understood that viewers do not want to miss information of where the balls are at each moment. That action entails the risk that the balls will fall at any time. Second, in the pocket part, the viewers seem to need to pay attention to what the actor might take out. Again, there is a risk of the unknown: "what could be revealed?" Third, in the faces part, viewers might decrease their eye-blink rate to avoid loss of information and to identify the actor's emotions [46]. Such decreases of eye blinks at moments when the action seems to be unpredictable may be an unconscious strategy to avoid loss of important visual information.

5. Conclusions

A previous study reported that cuts significantly inhibit viewers' eye blinks [36]. However, according to the present results, viewer's eye blinks are more related to content than to style when watching movies. Spontaneous nonconscious eye blinks have been linked to the default mode network [47], which is known to counteract the dorsal attention network and which is involved in introspection [48,49]. Our results suggest that content can be used to increase or decrease spontaneous eye blinks. Thus, we suggest that, in the context of managing viewers' attention, content overrules style. Media creators can use this finding to enhance viewers' attentiveness. The interesting output of this investigation is that it seems possible to create patterns (such as the increase of viewers' eye-blink rate during the disappearance of the main actor from the scene) that would be useful for script writers and media producers. Further research should assess common actions and situations in audiovisual content to identify more patterns in viewers' attention.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/brainsci11040422/s1, Table S1: Distribution of eye blinks/min in 40 blocks of 4.95 s each.

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frontiers in Systems Neuroscience

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The Effect of Media Professionalization on Cognitive Neurodynamics During Audiovisual Cuts

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Experts apply their experience to the proper development of their routine activities. Their acquired expertise or professionalization is expected to help in the development of those recurring tasks. Media professionals spend their daily work watching narrative contents on screens, so learning how they manage visual perception of those contents could be of interest in an increasingly audiovisual society. Media works require not only the understanding of the storytelling, but also the decoding of the formal rules and presentations. We recorded electroencephalographic (EEG) signals from 36 participants (18 media professionals and 18 non-media professionals) while they were watching audiovisual contents, and compared their eyeblink rate and their brain activity and connectivity. We found that media professionals decreased their blink rate after the cuts, suggesting that they can better manage the loss of visual information that blinks entail by sparing them when new visual information is being presented. Cuts triggered similar activation of basic brain processing in the visual cortex of the two groups, but different processing in medial and frontal cortical areas, where media professionals showed a lower activity. Effective brain connectivity occurred in a more organized way in media professionals–possibly due to a better communication between cortical areas that are coordinated for decoding new visual content after cuts.

Keywords: neurocinematics, professionalization, expertise, connectivity, visual perception, film cuts

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INTRODUCTION

Professionalization in anything requires expertise along with a long-time training. As a result, experts have acquired, through experience, the perceptual skills to make fine discriminations (Klein and Hoffman, 1993). Professional athletes have extraordinary skills for learning complex visual scenes (Faubert, 2013). It has been previously proven that professionalization has an impact on cognitive neurodynamics in many brain areas. Event-related desynchronization (ERD) in alpha and beta frequency bands during action observation is sensitive to expertise in contemporary dance. In addition, looking at dance movements evokes desynchronization effects in professional dancers, but not in non-dancers (Orgs et al., 2008). The influence of motor expertise on action observation has also been proven with expert dancers (Calvo-Merino et al., 2005). Expert baseball players show differential activity in their post-task resting state consistent with motor learning, and functional differences found between expert and non-expert baseball players suggest variability in subcortical white-matter pathways (Muraskin et al., 2016). Taxi drivers show navigation-related structural changes in their hippocampi (Maguire et al., 2000, 2006). Expertise in aesthetics modulates cognitive processing and the response in reward-related brain areas (Kirk et al., 2008). The case of musicians may be one of the most studied. For example, it has been found that brain structures, including primary motor and somatosensory areas, differ between musicians and non-musicians (Gaser and Schlaug, 2003). Professional violinists exhibit higher activity in the primary auditory cortex during the execution of a musical piece compared with amateurs, suggesting an increased functional strength in the audio-motor associative connectivity (Lotze et al., 2003). Finally, musical expertise is related to altered functional connectivity during audiovisual integration (Paraskevopoulos et al., 2015).

Regarding audiovisual expertise, we have previously found that media professionalization has an impact in visual perception (Andreu-Sánchez et al., 2017b). Media professionals are watching screens steadily over time (taking concomitant decisions with a high level of attention), and decrease their eyeblink rate not only when watching media works, but also when looking at live events (Andreu-Sánchez et al., 2017a). Media professionals are constantly paying attention to cuts since those are one of the most common tools for audio-visual editors. Cuts segment narrative content, playing a critical role in the proper understanding of observed visual material (Zacks et al., 2010). Their use has been increasing in cinema in the last few decades, reducing the average length of shots (Cutting et al., 2011). Cuts interrupt the visual information that a movie is presenting to viewers, who are nevertheless not conscious of them, provoking a phenomenon called edit blindness (Smith and Henderson, 2008). Both the attentional level and the awareness of cuts depend on the edit construction. A chaotic and non-organized style of edition, plenty of cuts, decreases viewers' eyeblinks compared with a classical edition having fewer and more-organized cuts, and even more compared with a one-shot style without cuts (Andreu-Sánchez et al., 2017b). Since eyeblinks can be understood as attentional markers when watching movies (Nakano et al., 2009), it is important to note that cuts can have a big impact on the management of viewers' attention. Also, memory is better for information presented after related cuts compared with unrelated cuts between two unrelated scenes (Lang et al., 1993). But this event segmentation is linked not only to the style, but also to the meaningful changes in narrative situations (Zacks et al., 2010). In fact, movie viewers move their eyes based on the presented content (for example, to the current speaker in a depicted conversation), suggesting that despite the changes that cuts make in a visual scene, viewers tend to adapt their visual behavior to the content (Germeys and D'Ydewalle, 2007).

Event-related potentials (ERPs) after the cut are coherent with studies on early discrimination of visual stimuli (Thorpe et al., 1996). Activity flows from the primary visual zones to somatosensory and prefrontal areas (Andreu-Sánchez et al., 2018). Besides, the style of edition in which cuts are inserted affects viewers' perception. While cuts in chaotic and fast audiovisuals increase brain activity in the visual cortex, suggesting an increase of attentional scope, cuts in organized and continuous movies increase brain activity in the prefrontal cortex (Andreu-Sánchez et al., 2018), where higher processing areas are located. Interestingly, a study on a very concrete editing rule–the 180° rule, which says that two edited shots of the same event or action should not be filmed from different angles that violate spatial continuity–showed that differences in perception were not linked to visual attention but to sensorimotor activity (Heimann et al., 2016).

To detect the effect of media professionalization on the viewing of audiovisual cuts, here we have investigated differences in brain activity after the cut between media and non-media professionals. We addressed this goal by analyzing and comparing in the two groups the spontaneous eyeblink rate (SBR), the EEG brain activity, and brain connectivity.

MATERIALS AND METHODS

Subjects

Thirty-six participants (30 males and 6 females) took part in this experiment. Eighteen were media professionals (mean age: 43.89 ± 8.79; 15 males and 3 females), and the rest were non-media professionals (mean age: 44.06 ± 7.53; 15 males and 3 females). All had normal or corrected-to-normal vision. For being part of the media professional group, subjects had to have a job related to video edition, including taking decisions related to media editing. Media professional participants were producers, assistant producers, cameramen, image controllers, documentalists, graphic designers, post-production editors, sports commentators, and video editors. Media professionals were mostly recruited from the Spanish Public Television (RTVE) installations in Barcelona. Non-media professionals were carefully chosen outside this criterion. They were individuals who did not make decisions related to media editing and audio-visual cuts in their work. Non-media professional participants were journalists with no media editing responsibilities, computer specialists, administrative and management assistants, telecommunication engineers, electronics technicians, stylists, specialists in prevention of occupational risks, and executive producers with no artistic profile. Subjects did not receive any economic compensation for participating in this investigation.

Ethics Statement

After a detailed explanation of the study, written informed consent was signed by all participants. Experiments were carried out following guidelines, procedures, and regulations for human research of the University Autònoma de Barcelona and approved by its Ethics Commission for Research with Animals and Humans (CEEAH; file number 2003). All experimental sessions were performed at the Neuro-Com Laboratory located at the Spanish Public Television Institute (IRTVE) in Sant Cugat del Vallès, Barcelona, Spain.

Stimuli and Experimental Design

For the experimental sessions, we created four visual stimuli with the same duration (198 s) and narrative content, but with different formats. All stimuli had the same visual content with different style of edition. The action consisted of a man who entered a room with a black background, sat at a desk, juggled with three balls, opened a laptop, looked up some information in books, wrote something in the laptop, closed it, ate an apple, looked directly into camera, and left the room. Stimulus 1 was a one-shot movie; stimulus 2 was a movie edited according to classical Hollywood rules (Bordwell et al., 1985); stimulus 3 was a movie edited according to MTV style (Bordwell, 2002); and stimulus 4 was a live performance. All stimuli were randomly presented to all participants [see Andreu-Sánchez et al. (2017b) for details]. The order of presentation of the four stimuli was randomized with the 24 possible combinations to avoid the impact of sensory adaption and effect of fatigue. The presentation of each stimulus was preceded of 30 s of a black screen. Stimulus 2 presented 33 cuts and stimulus 3 presented 79 cuts. Since the interest of this study was to analyze differences in media professionals compared with non-media professionals while viewing audiovisual cuts, for the present paper we just analyzed data collected during the presentation of stimuli 2 and 3. A total of 4,032 potential cuts (112 cuts per participant) form the sample used in this investigation, before discarding bad data. The task for participants consisted in just watching the visual stimuli.

Video stimuli were presented on a 42-inch HD LED display (Panasonic TH-42PZ70EA, Panasonic Industry Iberia, Madrid, Spain), and participants were placed 150 cm in front of the screen. Stimuli were presented and synchronized with the Paradigm Stimulus Presentation (Perception Research System Incorporated) and the NIC Offline software (Neuroelectrics, Barcelona, Spain).

Data Acquisition

Continuous EEGs were recorded using a wireless system (Enobio®, Neuroelectrics), with 20 electrodes placed according to the International 10–20 system [O1, O2, P7, P3, Pz, P4, P8, T7, C3, Cz, C4, T8, F7, F3, Fz, F4, F8, Fp1, Fp2, and an external electrode used for electrooculogram (EOG) recording] referenced to electronically linked mastoid electrodes [see Martín-Pascual et al. (2018) for details]. The EOG electrode was positioned vertically at the infraorbital ridge and the lower outer canthus of the left eye and was used to monitor eyeblinks. Data were sampled at 500 Hz. In order to have a good quality of EEG signal, participants were asked to wash their hair before attending the session and to avoid any chemical product (such as a hair spray or similar) on it. An HD-video camera (Sony HDR-GW55VE, Sony Corporation España, Barcelona, Spain) recorded at 25 frames/s participants' faces with a close-up for contrasting their eye movements and eyeblinks during the analysis of the eyeblink rate.

Data Analysis

Spontaneous Eyeblink Rate

For analyzing the SBR of each participant, we processed original data with Brainstorm open-source version 3 running on MATLAB R2013a (The Mathworks Inc., Natick, MA, USA) under a MacOS version 10.9.5 (Apple Inc., Cupertino, CA, USA). We filtered the signal from 0.5 to 3 Hz, applied Brainstorm's eyeblink detector, and manually checked the collected results (Tadel et al., 2015). We analyzed original data from Fp1, Fp2, and EOG electrodes. Following Nakano and Kitazawa (Nakano and Kitazawa, 2010), we also checked the results collected with the HD-video camera of participants' faces. To do so and using UNIX Time for synchronization purposes, we manually played the HD-video frame by frame while looking at the time of each eyeblink detected by the Brainstorm's detector and checking that it was in fact an eyeblink. We did not find differences with the other recording procedures. We quantified the rate of SBR/min. We compared two different variables: group (SBR of media vs. non-media professionals) and cut (SBR 1 s after the cut vs. SBR within the rest of the stimuli) through Whitney Rank Sum Tests and *t*-tests. To determine normality of data we carried out a Shapiro-Will test. The statistical analysis was carried out with Sigmaplot 11.0 (Systat Software Inc., San Jose, CA, USA).

Event-Related Potentials, Event-Related Spectrum Perturbances, and Power Spectrum

We first analyzed EEG data to obtain ERPs, event-related spectrum perturbances (ERSPs), and power spectrum. We created a study in EEGLAB (Delorme and Makeig, 2004) open-source version 2019_1, running on MATLAB_R2020a (The Mathworks Inc.) under a MacOS High Sierra version 10.13.6 for comparisons and statistical analysis. Previously, for pre-processing the data, we had used EEGLAB 15.3 on MATLAB R2013a under a MacOS version 10.9.5. We used a spherical BESA® template for channel location. We band-passed data with 0.5 and 40 Hz. We processed the data in 1,500 ms windows (from 500 ms before each cut to 1,000 ms after it). For rejecting artifacts, bad channels, and wrong data, we used visual inspection and the ADJUST plug-in (Mognon et al., 2010) for EEGLAB, after applying independent component analysis. To locate dipoles, we used the DIPFIT plug-in (Oostenveld and Oostendorp, 2002). We analyzed ERP signatures for different periods of the 1,500-ms epochs (−500 to 1,000 ms) through a three-way analysis of variance (ANOVA) taking as factors the following: (1) professionalization (media professionals, non-media professionals); (2) scalp area, with three scalp areas (frontal area with F7, F3, Fz, F4, and F8 electrodes; central area with C3, Cz, and C4 electrodes; and parieto-occipital area with P7, P3, Pz, P4, P8, O1, and O2 electrodes); and (3) latency, with three time windows (400–600 ms after the cut, 600–800 ms after the cut, and 800–1,000 ms after the cut). We approached ERSPs in somatosensory area through an unpaired *t*-test between the electrodes of this specific scalp area. For power spectra analysis, we analyzed the alpha band (8–12 Hz) for the same three scalp areas through Mann-Whitney Rank Sum tests. Analyses were done to contrast differences between media professionals and non-media professionals. Before approaching tests, we checked normality of data with Shapiro-Will normality test. Statistical analysis was carried out with EEGLAB Statistics Toolbox and Sigmaplot 11.0 (Systat Software Inc.).

Brain Connectivity

We approached brain connectivity from functional and effective connectivity analysis. We used clean datasets resulting from the described filtering and used the MATLAB toolbox HERMES (Niso et al., 2013) for brain connectivity analysis.

Functional connectivity can be defined as the temporal correlation of a neurophysiological index measured in different brain areas (Friston et al., 1993). It implies a temporal dependency of neuronal activation patterns of anatomically separated brain regions (van den Heuvel and Hulshoff Pol, 2010). For analyzing functional connectivity, we used the method of phase-locking value (PLV), which detects synchrony in a precise frequency range between two recording sites (Lachaux et al., 1999). PLV uses responses to a repeated stimulus (in this case, cuts) and looks for latencies at which the phase difference between the signals varies little across trials (phase-locking). Given two series of signals (x and y), and a frequency of interest (f), the PLV method computes a measure of phase-locking between the components of x and y at frequency f, for each latency (Lachaux et al., 1999). So, PLV makes use only of the relative phase difference and is defined (Niso et al., 2013) as:

$$PLV = \left|\left\langle e^{i\Delta\phi}rel^{(t)}\right\rangle\right| = \left|\frac{1}{N}\sum_{n-1}^{N} e^{i\Delta\phi}rel^{(t_n)}\right| = \sqrt{\left\langle cos\Delta\phi_{rel}(t)\right\rangle^2 + \left\langle sin\Delta\phi_{rel}(t)\right\rangle^2} \quad (1)$$

where <.> indicates time average. $\Delta\phi_{rel} = \phi_x - \phi_y$, where ϕ is the phase calculated from the Hilbert transform of x and y signals.

We computed the averaged connectivity of PLV in the 18 non-media professional participants and in the 18 media professional participants, with 100 surrogates of the original data, and compared functional connectivity between the two groups in theta (4–8 Hz), alpha (8–12 Hz), low beta (12–20 Hz), high beta (20–28 Hz), and low gamma (28–40 Hz). For the statistical analysis, we applied a *t*-test with multiple comparisons with false discovery rate Type 1 ($q = 0.1$) to the data with 100 surrogates. We looked for significant differences ($p < 0.05$) between groups.

Effective connectivity can be understood as the simplest experimental time-dependent circuit that replicates the timing relationships between the recorded sources (Aertsen and Preißl, 1991). It studies the influence that one neural system exerts over another (Friston, 1994). For analyzing effective connectivity here, we used classical linear Granger Causality (GC) (Granger, 1969). The concept behind GC is that for two simultaneously measured signals x(t) and y(t), if one can predict the first signal better by incorporating the past information from the second signal than by using only information from the first one, then the second signal can be called causal to the first (Wiener, 1956; Granger, 1969; Niso et al., 2013). The argument is that when x influences y, then if you add past values of x(t) to the regression of y(t), an improvement on the prediction will be obtained. GC from y to x (predicting x from y) can be defined (Niso et al., 2013) as:

$$GC_{y\to x} = ln\left(\frac{V_{\ x|\bar{x}}}{V_{\ x|\bar{x},\ \bar{y}}}\right) \quad (2)$$

We computed the average connectivity of GC in the 18 non-media professional participants and in the 18 media professional participants after the cut (0–1,000 ms), with a baseline (−500 to 0 ms). We did 100 surrogates, with a false discovery rate correction (FDR) of Type 1 ($q = 0.1$), MaxDistance 1.5. We did a *t*-test to reveal significant differences ($p < 0.05$) between groups and plotted them.

For both types of connectivity analysis, we obtained binary outcomes for connectivity relations. Non-significant and significant relations ($p < 0.05$) were obtained based on this binary approximation among all pairs of electrodes.

More information about the implementation of these indices in HERMES is available elsewhere (Niso et al., 2013).

RESULTS

Spontaneous Eyeblink Rate

We identified substantial differences in the SBR related to media professionalization. Firstly, we obtained the mean SBR in the first second following the cut. While, among all participants, the mean SBR after the cut was 11.07 ± 7.66 min^{-1}, in non-media professionals the mean SBR after the cut was 14.94 ± 8.43 min^{-1}, and in media professionals it was 7.21 ± 4.25 min^{-1}. The statistical comparison showed significant differences between the two groups after the cut (Mann-Whitney U Statistic = 60.5, T = 434.5, $n = 18$, $p = 0.001$, Mann-Whitney Rank Sum Test). Then, we obtained the mean SBR for the rest of the stimuli. For all participants, the mean SBR was 12.33 ± 7.61 min^{-1}. In non-media professionals, the mean SBR was 15.79 ± 8.72 min^{-1}, and in media professionals 8.87 ± 4.23 min^{-1}. We also found, as expected, statistically significant differences between groups for the rest of the stimuli (Mann-Whitney U Statistic = 79.5, T = 415.5, $n = 18$, $p = 0.009$, Mann-Whitney Rank Sum Test). In a previous study (Andreu-Sánchez et al., 2018), we found that a cut decreases eyeblink rate in viewers during the second following it. Here, we wondered if those differences would be different depending on media professionalization. We found that they are. In media professionals, cuts have a greater impact with a decrease of SBR [$t_{(17)} = -2.99$, $p = 0.008$, paired *t*-test], while cuts seem not to have such an impact in non-media professionals [$t_{(17)} = -1.14$, $p = 0.269$, paired *t*-test]. These results suggest that, in line with previous studies (Andreu-Sánchez et al., 2017a), there is a media professionalization effect in visual perception of media contents (**Figure 1**).

Event-Related Potentials and Event-Related Spectrum Perturbances

We found an effect of media professionalization in ERPs during the viewing of audiovisual cuts. As previously reported (Andreu-Sánchez et al., 2018), we found significant effects related to scalp area [$F_{(2, 306)} = 32.367$; $p < 0.001$] and scalp area x latency [$F_{(4, 306)} = 3.647$; $p = 0.006$]. Interestingly, here we also found an effect of professionalization and scalp area [$F_{(2, 306)} = 4.822$; $p = 0.009$]. With a Holm-Sidak method for *post-hoc* pairwise multiple comparisons, we found significant differences between groups in

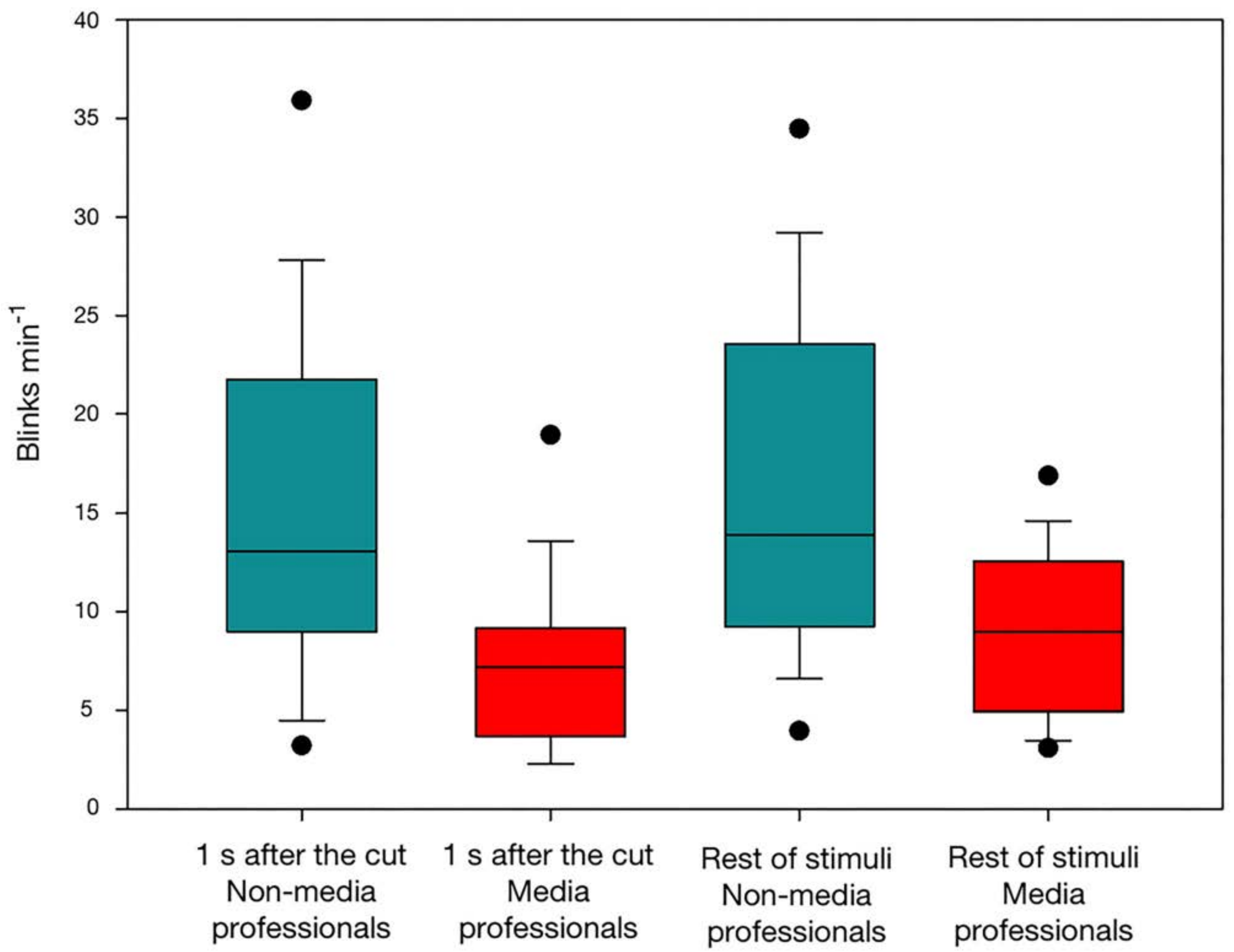

FIGURE 1 | SBRs in non-media (red) and media (turquoise) professionals, during the first second after a cut and during the rest of video stimuli without cuts.

frontal [$t_{(0.264)} = 2.034$, $p = 0.043$] and central [$t_{(0.724)} = 5.587$, $p < 0.001$], but not occipital areas (**Figure 2**).

Based on previous studies linked to somatosensory area differences related to expertise (Gaser and Schlaug, 2003; Orgs et al., 2008), we looked at ERSPs in that specific area, and found that there were differences in C3 (**Figure 3**). Media professionals showed greater activity between 7 and 11 Hz just after the cut, and a lower activity at those frequencies between 200 and 300 ms after the cut. This may be linked to a mu rhythm desynchronization, understood as the attenuation of power in the alpha band recorded over central scalp locations as a reflection of a motor cortex activity (Pfurtscheller, 1977; Pfurtscheller and Lopes da Silva, 1999; Debnath et al., 2019). Differences found here could depend on the media professionalization expertise. No such differences were found in Cz or C4, but this would be coincident with non-symmetric and contralateral sensorimotor activity (McFarland et al., 2000).

Alpha Band

It has been reported that cuts provoke an increase of alpha power in parieto-occipital electrodes (Andreu-Sánchez et al., 2018). However, here we did not find statistically significant differences in the alpha band (8–12 Hz) between media and non-media professionals in any of the studied areas either before or after the cut: frontal area, before the cut (Mann-Whitney U = 131, T = 364, $n = 18$, $p = 0.335$, Mann-Whitney Rank Sum Test); frontal area, after the cut (Mann-Whitney U = 156, T = 339, $n = 18$, $p = 0.862$, Mann-Whitney Rank Sum Test); somatomotor area, before the cut (Mann-Whitney U = 158, T = 329, $n = 18$, $p = 0.912$, Mann-Whitney Rank Sum Test); somatomotor area, after the cut (Mann-Whitney U = 145, T = 316, $n = 18$, $p = 0.602$, Mann-Whitney Rank Sum Test); parieto-occipital area, before the cut (Mann-Whitney U = 132, T = 363, $n = 18$, $p = 0.351$, Mann-Whitney Rank Sum Test); and parieto-occipital area, after the cut (Mann-Whitney U = 126, T = 369, $n = 18$, $p = 0.261$, Mann-Whitney Rank Sum Test).

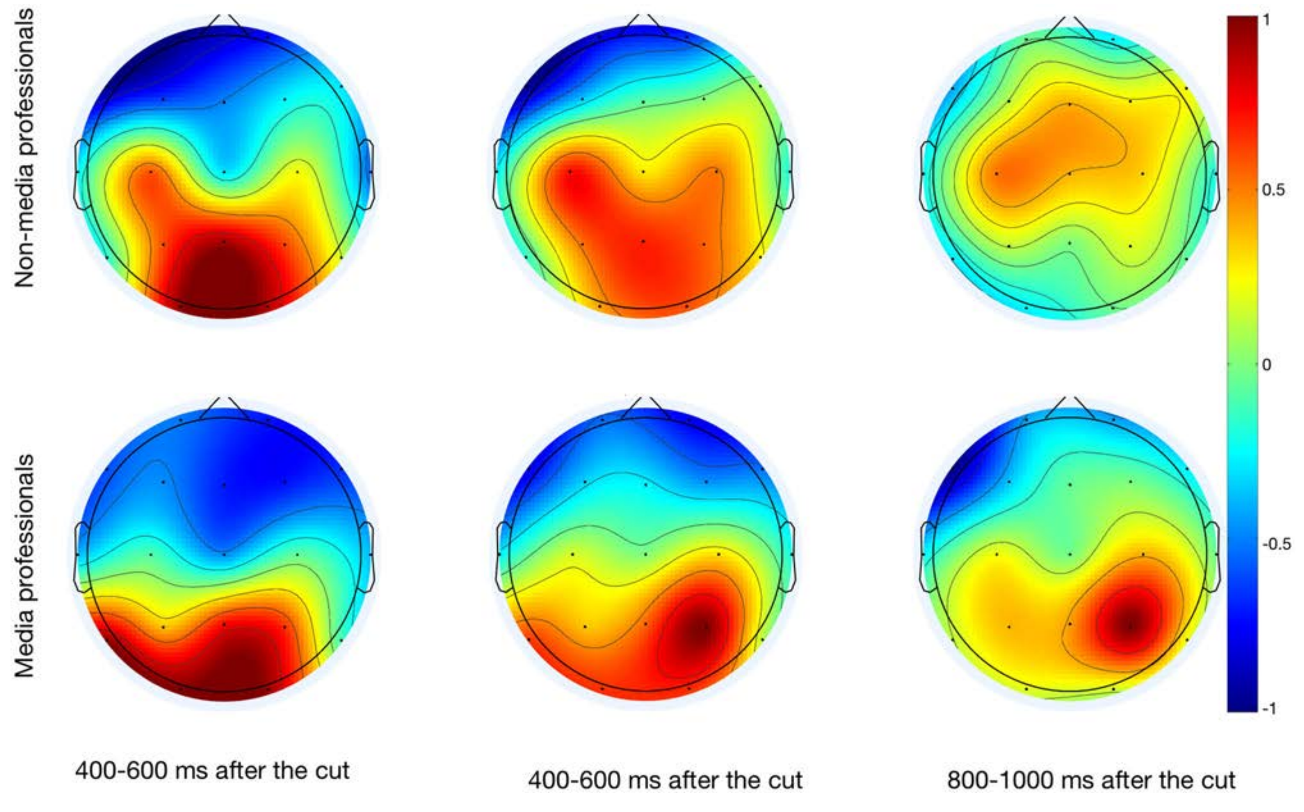

FIGURE 2 | Scalp map after the cuts of the three analyzed time windows (400–600, 600–800, and 800–100 ms) of media and non-media professionals.

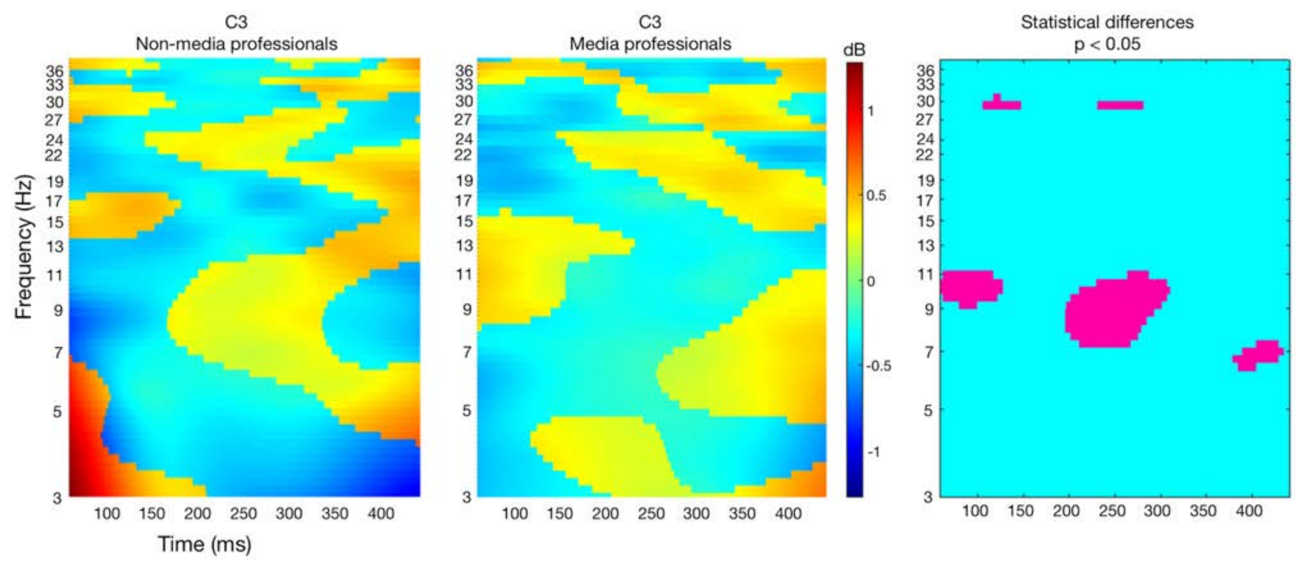

FIGURE 3 | ERSPs in non-media (left) and media (middle) professionals, in electrode C3. The right image shows in pink the statistically significant differences between the two groups (unpaired *t*-test with no correction method for multiple comparison, $p < 0.05$).

Brain Connectivity

Phase-Locking Value

We found some significant differences between the two groups in functional connectivity in all the studied bands after the cut (**Figure 4**). In the theta band (4–8 Hz), we found some minor greater connectivity in non-media professionals in P7-P3 and Pz-O2, and in media professionals between Cz and F7. This suggests a higher functional connectivity in the theta band in parieto-occipital areas for non-media professionals and in prefrontal area for media professionals. In the alpha band (8–12 Hz), we also found a higher functional connectivity in occipital area in non-media professionals, while media professionals showed greater connectivity in central-frontal areas connection (Cz-Fz) and left parietal-frontal connection (P7–F7). We analyzed the beta band for low-beta (12–20 Hz) and high-beta (20–28 Hz) components. We found that in both cases, media professionals presented a higher functional connectivity between crossed sources (P3–F8), while non-media professionals did not show a higher PLV index at any point. In low gamma (28–40 Hz), we found that media professionals had a higher functional connectivity, mostly in frontal areas (F3, Fz, Cz-Fp2, F4-Fp1, F4-Fp2, F8-Fp2), and, again, a crossed flow (P3-F8). Non-media professionals did not show a higher PLV index at any source in low gamma.

Granger Causality

With the aim of comparing effective connectivity between media and non-media professionals after the cut, we analyzed Granger causality. We obtained some significant differences in connectivity between groups (**Figure 5**). According to our results, non-media professionals show a more dispersed GC index in their brain activity, while media professionals' GC connectivity is much more concise since it is mostly concentrated in visual cortex, somatomotor, and frontal areas. And there is statistically significant higher activity in media professionals than in non-professionals in all three of those areas: occipital, medial and frontal.

DISCUSSION

In videos and movies, cuts provoke an artificial interruption of the narrative content. They are constantly used to present different visual information through different shots and visual compositions. A film is a stream of edited moving images consisting of hundreds or thousands of individual camera shots patched together (Heimann et al., 2016). But regardless of the several times per minute that cuts are present in a film, viewers are rarely aware of them, due to the so-called edit blindness (Smith and Henderson, 2008). Previous studies showed that cuts inhibit viewers' eyeblink rate (Andreu-Sánchez et al., 2017b, 2018). However, here we found that this happens with a clearer impact on media professionals, suggesting that this group is more sensitive to cuts. The rate of blinking has been proven to decrease when a cognitive operation is performed (Holland and Tarlow, 1975; Wong et al., 2002). Some studies have shown that watching a film reduces viewers' eyeblink rate (Patel et al., 1991; Andreu-Sánchez et al., 2017a), and it has been proposed that this decrease may be a strategy to minimize the loss of visual information (Nakano et al., 2009). The constant presentation of new visual information by cuts may be related to the decreased blink rate in viewers. And the fact that media professionals decrease their eyeblink rate after cuts significantly more than do non-media professionals may be related to the idea that experts can see what is not there and gain the ability to visualize how a situation has developed and to imagine how it is going to turn out (Klein and Hoffman, 1993). Maybe media professionals can better manage the fact that cuts are going to be followed by new visual information that needs to be decoded, and thereby avoid the loss of information that blinks entail, while non-media professionals are not so aware of cuts, showing a greater edit-blindness.

The context in which a cut is inserted and the situation to which a viewer pays attention affect visual perception (Zacks et al., 2010; Heimann et al., 2016). It is logical to think that cuts trigger an increase of activity in visual cortex that flows toward medial and frontal areas (Andreu-Sánchez et al., 2018) as other visual stimuli do (Thorpe et al., 1996). But since top-down directionality has been recently reinforced (Cheron et al., 2014; Halgren et al., 2019) it is important to keep researching about neuronal flows when watching audiovisual works. To date, using EEG signals for estimating the directionality of the neuronal flows is debated (Nolte et al., 2008) so further research should be done to complete this work. Here, we found that there are differences between media and non-media professionals in frontal and medial areas, while not in the visual cortex. In those frontal and medial zones non-experts presented a higher activity consistent with previous studies (Hill and Schneider, 2006). Apparently, cuts start the same (or a very similar) activation of basic brain processing of the new visual information presented, but how that visual content is managed by the two groups differs afterwards. In most cases, non-media professionals require a higher level of activity to process the visual information. One of the most interesting differences was found in the somatosensory area in C3. Media professionals showed a greater decrease of electrical activity at around 200–300 ms after the cut in C3, and this may be related to mu rhythm suppression during the observation of actions performed by other persons (Gastaut and Bert, 1954; Muthukumaraswamy et al., 2004); but in this case mu rhythm would also be affected by the expertise of the observer. Since previous studies revealed that mu suppression is sensitive to degree of familiarity (Oberman et al., 2008), it could be thought that media professionalization would bring a greater familiarity with media editing. Moreover, it is interesting to note that according to our results, the cut–and maybe other formal characteristics of the stimuli–could also affect mu rhythm suppression during the watching of videos. Our results invite us to keep researching on event-related synchronization (ERS) and desynchronization (ERD) in mu rhythm not only when watching motor activities in videos (Rayson et al., 2016) but also when approaching the language of film (Heimann et al., 2014). This is something that should be further investigated with aimed works for better understanding.

The alpha band has been linked with changes in attention (Reeves et al., 1985; Klimesch et al., 1998; Aftanas and Golocheikine, 2001; Sauseng et al., 2005). Following on from the difference of eyeblink rate found here between groups, and since eyeblinks are understood as markers of the attentional state of subjects (Ponder and Kennedy, 1927; York et al., 1971), we were interested in looking for differences in alpha frequencies. However, we did not observe significant differences in alpha band in any of the studied areas. It has been found that alpha frequencies influence whether a visual stimulus reaches awareness (Mathewson et al., 2009). Since we did not ask

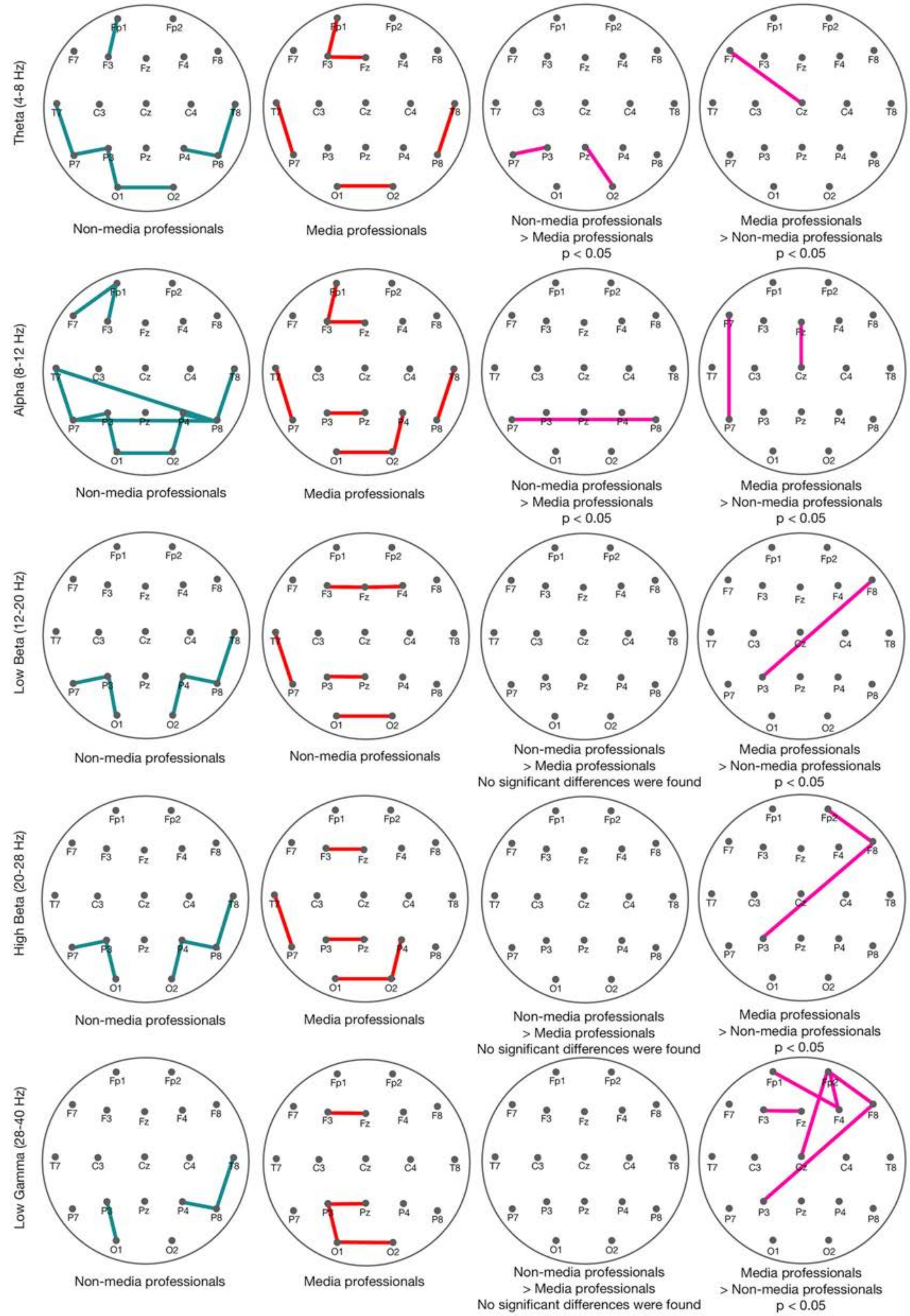

FIGURE 4 | PLVs in non-media (turquoise) and media (red) professionals in different spectral bands: theta (4–8 Hz), alpha (8–12 Hz), low beta (12–20 Hz), high beta (20–28 Hz), and low gamma (28–40 Hz).

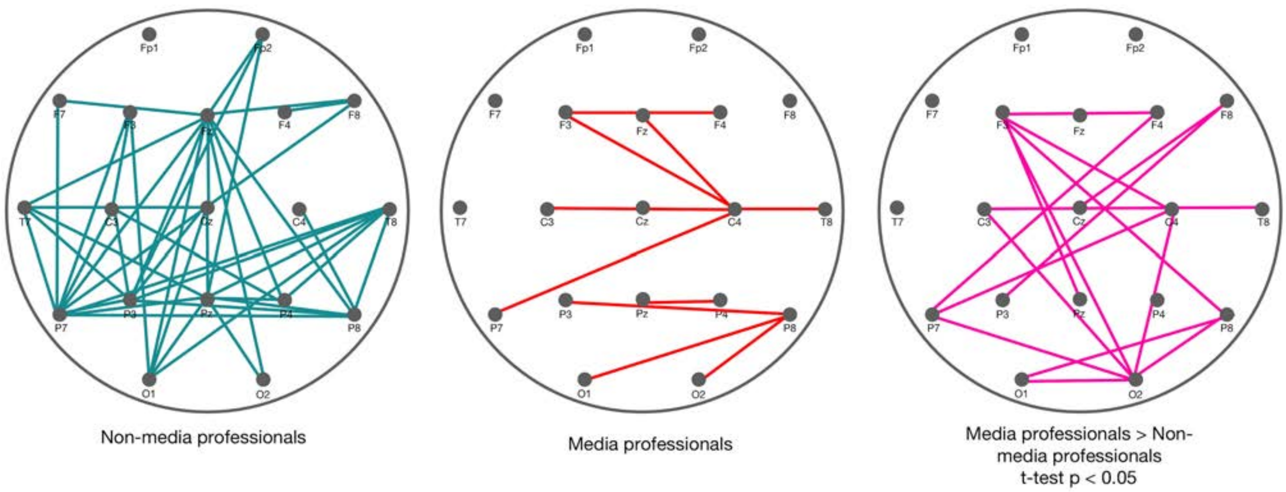

FIGURE 5 | Granger causality in non-media (left) and media (middle) professionals, after the cut (0–1,000 ms, with a baseline of −500 ms before the cut), with significance level based on 100 surrogates. On the right, in pink, the statistically significant differences between the two groups (*t*-test, $p < 0.05$). Those results correspond to the higher GC indices in media professionals compared with the non-media group. No higher GC indices in non-media professionals were found.

participants if they were aware or not of cuts, this connection should be further studied. While the role of beta oscillations in visual processing and attention is less clear (McCusker et al., 2020) further studies could approach if beta band in media professionals could be linked with the attention to visual stimuli (Michalareas et al., 2016). Since it has been hypothesized that beta oscillations may be stronger if the maintenance of the status quo is predicted than if a change is expected (Engel and Fries, 2010), it would be interesting learning about expectance to change while watching audiovisual works by the group of media professionals.

Despite the problem of the volume conduction for stablishing true synchrony (Lachaux et al., 1999) or coherency (Nolte et al., 2004) through biological tissue toward measurement sensors (scalp electrodes in this study), here dynamic measurements of functional and effective connectivity were approached through the PLV and the GC index, respectively. PLV is, of the many phase synchronization measurements available in the literature, one of the most used (Lachaux et al., 1999). It evaluates functional connectivity through the instantaneous phase difference of the signals under the hypothesis that connected areas generate signals whose instantaneous phases evolve together (Bruña et al., 2018). Cuts cause a synchronization effect (Andreu-Sánchez et al., 2018), but results reported here suggest that media and non-media professionals show different functional connectivity when watching cuts. Although those differences are discrete in most of the analyzed frequency bands (theta, alpha, and low and high beta), the general trend found here is a higher synchronization flow between posterior and frontal areas in media professionals. This suggests differences in functional connectivity related to the expertise in media. Apparently, media professionals would increase this kind of connectivity after viewing cuts, compared with non-professionals. This could be related to higher or faster conscious processing of the visual information after the cuts, or to a possibly lower edit blindness (Smith and Henderson, 2008) in this group. Our results suggest that media professionals would increase the connectivity between primary perceptive areas (such as the visual cortex) and more-cognitive processing areas (such as the prefrontal area). But the most-significant differences found between the two groups were in the low gamma band (28–40 Hz). According to our results, media professionals showed greater functional connectivity related to the frontal area in this frequency band. This may reflect differences in a participant's current state of attention or expectation (Hanslmayr et al., 2007) and could be related to the tendency of gamma to increase during novel stimuli (von Stein et al., 2000).

As already explained, we approached differences in effective connectivity between groups through GC. It is presented as a framework to quantify the asymmetric causal interactions between regions of the cortex and brain states (Sánchez-Campusano et al., 2011; Courellis et al., 2017). This measurement is fundamental for describing observed data in terms of directed functional interactions (Seth et al., 2015). Here, we found differences in effective connectivity between the two groups in occipital, parietal, medial, and frontal areas. Overall, media professionals showed high GC indices in three independent areas: occipital, medial, and frontal. It has been possible to distinguish GC in the activity within those areas. However, in non-media professionals, the GC found was much less organized and the connectivity was mostly within all different scalp areas (see **Figure 5**). This suggests that effective connectivity may occur in a more organized way in media professionals due to a better connectivity within areas that are coordinated for decoding new visual information after cuts. We found that the connectivity originating in those three areas (corresponding with visual cortex, somatomotor area, and frontal area) was stronger in media professionals. This is coincident with previous studies that attributed stronger connectivity in professionals compared with control groups to the learning undertaken because of their expertise (Sreenivasan et al., 2017), and that suggested an increased neural efficiency in the brain of highly skilled individuals (Bernardi et al., 2013). The fact that that higher connectivity in media professionals occurs in visual cortex could be related to the importance of that area for visual processing in their daily work. Something similar would occur in the frontal area, where higher cognitive processing of the visual information may be happening. Nevertheless, further studies would be needed to determine whether relevant differences between the two groups in somatosensory cortex could shed more light on this specific brain area, so many times connected to mu rhythm desynchronization and its possible relation to the mirror neuron system (Muthukumaraswamy et al., 2004; Pfurtscheller et al., 2006).

There are dozens of experiments tracking learning or expert performance. Patterns are beginning to emerge showing that learning and skilled performance produce changes in brain activation depending on the brain structure and the nature of the skill being learned (Hill and Schneider, 2006). The present study extends other studies of expertise showing that expertise and professionalization impact on cognitive neurodynamics (Bilalić, 2017). Learning how media professionals approach the perception of audiovisual works' may be useful in those areas that use screened content for training specific capabilities, such as aeronautics, some professional sports, or even basic education, among others.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Commission for Research with Animals and Humans (CEEAH). Universitat Autònoma de Barcelona. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CA-S, MÁM-P, AG, and JMD-G experimental design and wrote the article. CA-S and MÁM-P carried out experiments and data analysis. All authors contributed to the article and approved the submitted version.

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Brain Symmetry in Alpha Band When Watching Cuts in Movies

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Abstract: The purpose of this study is to determine if there is asymmetry in the brain activity between both hemispheres while watching cuts in movies. We presented videos with cuts to 36 participants, registered electrical brain activity through electroencephalography (EEG) and analyzed asymmetry in frontal, somatomotor, temporal, parietal and occipital areas. EEG power and alpha (8–13 Hz) asymmetry were analyzed based on 4032 epochs (112 epochs from videos × 36 participants) in each hemisphere. On average, we found negative asymmetry, indicating a greater alpha power in the left hemisphere and a greater activity in the right hemisphere in frontal, temporal and occipital areas. The opposite was found in somatomotor and temporal areas. However, with a high inter-subjects variability, these asymmetries did not seem to be significant. Our results suggest that cuts in audiovisuals do not provoke any specific asymmetrical brain activity in the alpha band in viewers. We conclude that brain asymmetry when decoding audiovisual content may be more related with narrative content than with formal style.

Keywords: neurocinematics; visual perception; audiovisual cuts; cognitive neuroscience; asymmetry

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1. Introduction

1.1. Neural Processing of Visual Content

Visual perception is one of the most studied topics in neuroscience [1–3]. Learning how the brain processes visual content has been of interest for decades. Visual processing is considered in a hierarchical network [4] with different stages [5]. However, after several experimental approaches, it is not convincingly clear what happens in the brain after a visual stimulus is presented. It is believed that the processing of visual content is a very rapid processing with a large number of stages involved, presumably based on feed-forward mechanisms [6]. Currently, there are, at least, two plausible frameworks of how perception occurs: the outside-in and the inside-out [7]. While in the former the stimulus reaches the eyes with a response of the brain that causes neurons to fire, in the latter we understand the external world by taking actions to learn about an object [7]. On the other hand, the memory–prediction framework matches sensory inputs with stored memory patterns to perceive thanks to elaborate predictions based on previous memories [8]. Based on evidence, what seems more plausible is that different brain areas (or systems) are in charge of perceiving (or processing) different physical characteristics of visual stimuli [9].

1.2. Neural Processing of Audiovisual Cuts

Films present plenty of cuts. They organize the visual content for viewers [10] and, while they present new visual content that needs to be decoded, viewers hardly notice them [11]. According to previous studies, cuts inhibit viewers' eye-blink rate [12] and the higher number of cuts an audiovisual has, the lower the eye-blink rate of viewers [13]. Since eye-blinks are attentional markers [14,15] (the higher the eye-blink rate, the lower the attention), this relationship suggest that cuts affect viewers' perception. Probably due to the new visual content following cuts, they also trigger an increase of occipital brain activity (in the visual cortex) that flows towards frontal areas [12]. Moreover, the brain activity and brain connectivity (functional and effective) when watching cuts depends on the audiovisual background and expertise of the viewer, with higher activation of occipital areas in media professionals and higher activity of medial and frontal areas in non-media professionals [16].

1.3. Brain Asymmetry in Visual Perception

A great part of the world is symmetrical. In part, we process symmetry with an automatic response [17], but how symmetrically our brain works is yet to be solved. Frontal alpha asymmetry has been studied in correlation with behavior and emotion [18,19]. It has also been approached while viewing videos with different engagement levels [20], showing higher right frontal brain activity when viewing videos of interest compared with not-interesting videos. Asymmetry during emotionally evocative films and its relation to positive and negative affectivity has also been studied [21], finding that subjects with positive affectivity exhibit more left-sided activation while watching happy films. Moreover, resting alpha power asymmetry in the frontal area predicts self-reported negative affect in response to videos [22], with a strong relation between frontal asymmetry and fear responses to films. In the area of advertising, this relation between the brain asymmetry and the emotions has also been found when watching ads [23].

While many researchers have approached the perception of cuts in media [24–27] and, as seen, there are some studies about brain asymmetry when watching films, to our knowledge, nobody has studied brain asymmetry in viewers while watching audiovisual cuts, regardless of the emotional content and the emotional feelings that their subsequent content can provoke.

In this study we wondered about the brain asymmetry of viewers when watching the brand-new visual content that follows cuts in movies. To investigate this, in this work we compared brain activity in both hemispheres of viewers watching cuts. The aim was to check whether there was asymmetry of the brain activity in specific areas of the brain.

2. Materials and Methods

2.1. Participants

Thirty-six participants with normal or corrected-to-normal vision were recruited for this experiment. Participants were aged 28–56 (43.97 $\pm$ 8.07). Six were females. Half of participants were media professionals with 6 years or more of expertise. They did not receive any economic compensation for participating in this study. We followed relevant guidelines and regulations for human research and procedures were approved by the Ethics Commission for Research with Animals and Humans (CEEAH) of the University Autònoma de Barcelona, Spain. All participants gave prior written informed consent to participate in the study.

2.2. Stimuli

We created three video stimuli with the same narrative content and duration (198 s), but different styles and a different number of cuts. The videos were randomly presented to all participants. The narrative of the three video stimuli consisted of a man who entered a room with a black background, sat at a desk, juggled with three balls, opened a laptop, looked up some information in books, wrote something in the laptop, closed it, ate an apple, looked directly into camera, and left the room. One stimulus was a one-shot movie with a single shot and no cuts. The second video presented a classical and organized style of edition, with a total of 33 shots and an average shot length (ASL) of 5.9 s. The third stimulus presented a chaotic and disorganized style of edition, with a total of 79 shots and an ASL of 2.4 s. Since here we are interested in analyzing asymmetry when watching audiovisual cuts, we only use data from stimuli two and three, since the first video did not have any cuts.

Stimuli were presented on a high-definition (HD) 42-inch light-emitting diode (LED) display (TH42PZ70EA, Panasonic Corporation, Osaka, Japan) using Paradigm Stimulus Presentation software v1.5 (Perception Research System Inc., Lawrence, KS, USA).

2.3. Data Acquisition

Continuous EEG was recorded from participants using an Enobio® system (Neuroelectrics, Barcelona, Spain) equipped with 20 electrodes [O1, O2, P7, P3, Pz, P4, P8, T7, C3, Cz, C4, T8, F7, F3, Fz, F4, F8, Fp1, Fp2, and an additional electrode used for electrooculogram (EOG) recordings] placed according to the International 10–20 system [28], referenced to electronically linked mastoid electrodes. Data were sampled at 500 Hz. In order to have a good quality of the signal, we asked participants to avoid chemical products (such as hair spray or similar) in their hair before coming to the experimental session. Data acquisition was synchronized with the data presentation system through a TCP/IP system.

2.4. Data Analysis

Data processing was carried out using EEGLAB [29] open-source software (version 2022.0), running on MATLAB 2020a (The MathWorks Inc., Natick, MA, USA) under a MacOS High Sierra (version 10.13.6) (Apple Inc., Cupertino, CA, USA). We used a spherical BESA® template for channel location. We computed average reference, and high-pass filtered the data at 0.5 Hz and low-pass filtered it at 40 Hz. We divided the data into 1500-ms epochs (500 ms before the cut and 1000 ms after the cut), removing the baseline. For rejecting artifacts, bad channels, and wrong data, we used visual inspection and the ADJUST plug-in [30] for EEGLAB, after applying independent component analysis (ICA). To locate dipoles, we used DIPFIT plugin. Estimates of EEG power were based on 4032 epochs (112 epochs from videos $\times$ 36 participants) in each hemisphere. All statistical analyses were performed with Sigmaplot 11.0 (Systat Software Inc., San Jose, CA, USA) and with GraphPad Prism version 9.4.1 for Mac (GraphPad Software, San Diego, CA, USA).

We selected data from different brain areas in the left hemisphere and their correspondent in the right hemisphere. We divided the brain in five sections: frontal, somatomotor, temporal, parietal and occipital. Then we selected the available electrodes for each area (see Table 1). In each brain area, we computed the asymmetry in alpha band (8–13 Hz).

Table 1. Selected sections of the brain for data analysis.

Brain Area	Left Hemisphere	Right Hemisphere
Frontal	Fp1 F3 F7	Fp2 F4 F8
Somatomotor	C3	C4
Temporal	T7	T8
Parietal	P3 P7	P4 P8
Occipital	O1	O2

To compute asymmetry, the measures of the five mentioned regional areas were calculated separately by subtracting natural-log transformed regional EEG power in the left hemisphere from natural-log transformed power at homologous site in the right hemisphere [ln(right) power − ln(left)power] [31]. Positive values of asymmetry reflect greater alpha power in the right hemisphere, indicating greater activity in the left hemisphere, while negative values reflect greater alpha power in the left hemisphere, showing greater activity in the right hemisphere [32]. Then we computed descriptive statistical analysis of all participants and statistical analysis between the group of media and the group of non-media professionals. The Shapiro–Wilk test was used as normality test ($p < 0.05$).

3. Results

We obtained mean values of alpha power and alpha asymmetry in the brain areas selected: frontal, somatomotor, temporal, parietal and occipital (Table S1).

3.1. Alpha Power

Mean (SD) alpha power (in µV) in frontal areas was 3.006 (3.936) in left hemisphere and 2.557 (2.004) in right hemisphere. In somatomotor areas, it was 0.545 (0.462) in left hemisphere and 0.577 (0.534) in right hemisphere. The temporal area showed 0.696 (0.603) in left hemisphere and 0.658 (0.527) in right hemisphere. The parietal showed 1.029 (0.944) in left hemisphere and 0.988 (0.865) in right hemisphere. Finally, the occipital showed 0.742 (0.688) in left hemisphere and 0.712 (0.691) in right hemisphere.

We computed Wilcoxon signed rank tests between alpha power in each hemisphere for each brain area in order to study each specific brain area separately. We obtained no significant differences between hemispheres in none of the cases: frontal area [$Z = -0.456$, $p = 0.654$]; somatomotor area [$Z = 0.833$, $p = 0.409$]; temporal area [$Z = -1.037$, $p = 0.303$]; parietal area [$Z = -0.896$, $p = 0.375$]; and occipital area [$Z = -0.503$, $p = 0.621$].

To check relations among the different brain areas × hemispheres, we computed a Friedman repeated measures ANOVA on ranks with the alpha power. We obtained significant differences [X^2 (9, N = 36) = 155.254, $p = < 0.001$]. We used a Dunn test as multiple comparison procedure in all pairwise, taking as significant differences those with $p < 0.05$. We obtained the result that alpha power in the frontal left area differed from all the rest of the studied areas, except for frontal right: somatomotor left and right, temporal left and right, parietal left and right and occipital left and right. We also obtained the result that frontal right activity differed again from all the studied areas, except for frontal left. Moreover, we found some other significant differences between parietal left and somatomotor left and right, and thetemporal right, and also between parietal right and somatomotor left and right (see Table 2).

Differences found in alpha power among different brain areas and hemispheres (Table 2) could suggest some crossed asymmetry; however, looking at the data in detail whenever a significant difference is found between areas × hemispheres (e.g., frontal left vs. somatomotor right), it also happens just between areas in the same hemisphere (e.g., frontal left vs. somatomotor left). The only case where differences are found between hemispheres is parietal left vs. temporal right.

Table 2. Multiple comparison results of alpha power with $p < 0.05$ using Dunn test for Friedman repeated measures ANOVA on ranks.

Pairwise Comparison	Rank Sum Diff.	Significant?	*p*-Value
Frontal left vs. frontal right	3.000	No	>0.9999
Frontal left vs. somatomotor left	213.500	Yes	<0.0001
Frontal left vs. somatomotor right	204.500	Yes	<0.0001
Frontal left vs. temporal left	165.000	Yes	<0.0001
Frontal left vs. temporal right	180.000	Yes	<0.0001
Frontal left vs. parietal left	95.000	Yes	0.0098
Frontal left vs. parietal right	115.000	Yes	0.0003
Frontal left vs. occipital left	146.000	Yes	<0.0001
Frontal left vs. occipital right	148.000	Yes	<0.0001
Frontal right vs. somatomotor left	210.500	Yes	<0.0001
Frontal right vs. somatomotor right	201.500	Yes	<0.0001

Table 2. *Cont.*

Pairwise Comparison	**Rank Sum Diff.**	**Significant?**	***p*-Value**
Frontal right vs. temporal left	162.000	Yes	<0.0001
Frontal right vs. temporal right	177.000	Yes	<0.0001
Frontal right vs. parietal left	92.000	Yes	0.0154
Frontal right vs. parietal right	112.000	Yes	0.0006
Frontal right vs. occipital left	143.000	Yes	<0.0001
Frontal right vs. occipital right	145.000	Yes	<0.0001
Somatomotor left vs. somatomotor right	−9.000	No	>0.9999
Somatomotor left vs. temporal left	−48.500	No	>0.9999
Somatomotor left vs. temporal right	−33.500	No	>0.9999
Somatomotor left vs. parietal left	−118.500	Yes	0.0002
Somatomotor left vs. parietal right	−98.500	Yes	0.0057
Somatomotor left vs. occipital left	−67.500	No	0.3871
Somatomotor left vs. occipital right	−65.500	No	0.4853
Somatomotor right vs. temporal left	−39.500	No	>0.9999
Somatomotor right vs. temporal right	−24.500	No	>0.9999
Somatomotor right vs. parietal left	−109.500	Yes	0.0009
Somatomotor right vs. parietal right	−89.500	Yes	0.0222
Somatomotor right vs. occipital left	−58.500	No	>0.9999
Somatomotor right vs. occipital right	−56.500	No	>0.9999
Temporal left vs. temporal right	15.000	No	>0.9999
Temporal left vs. parietal left	−70.000	No	0.2896
Temporal left vs. parietal right	−50.000	No	>0.9999
Temporal left vs. occipital left	−19.000	No	>0.9999
Temporal left vs. occipital right	−17.000	No	>0.9999
Temporal right vs. parietal left	−85.000	Yes	0.0422
Temporal right vs. parietal right	−65.000	No	0.5131
Temporal right vs. occipital left	−34.000	No	>0.9999
Temporal right vs. occipital right	−32.000	No	>0.9999
Parietal left vs. parietal right	20.000	No	>0.9999
Parietal left vs. occipital left	51.000	No	>0.9999
Parietal left vs. occipital right	53.000	No	>0.9999
Parietal right vs. occipital left	31.000	No	>0.9999
Parietal right vs. occipital right	33.000	No	>0.9999
Occipital left vs. occipital right	2.000	No	>0.9999

3.2. Alpha Asymmetry

Mean (SD) asymmetry in the analyzed areas was negative in frontal [−0.0822 (0.822)], temporal [−0.0826 (0.504)] and occipital [−0.0826 (0.504)] areas, indicating a greater alpha power in the left hemisphere that would correspond with a greater activity in the right hemisphere of these areas. Asymmetry was found positive in somatomotor [0.0383 (0.422)] and temporal [0.0474 (0.610)] areas indicating a greater alpha power in the right hemisphere and greater activity in the left one (see Table 3). The high deviations indicate a high variability among subjects (Figure 1).

Table 3. Alpha power and asymmetry in frontal, somatomotor, temporal, parietal and occipital areas, in left and right hemispheres.

Brain Area	Left Hemisphere	Right Hemisphere	Asymmetry (SD)
Frontal	3.006 (3.936)	2.557 (2.004)	−0.0822 (0.822)
Somatomotor	0.545 (0.462)	0.577 (0.534)	0.0383 (0.422)
Temporal	0.696 (0.603)	0.658 (0.527)	0.0474 (0.610)
Parietal	1.029 (0.944)	0.988 (0.865)	−0.0826 (0.504)
Occipital	0.742 (0.688)	0.712 (0.691)	−0.0826 (0.504)

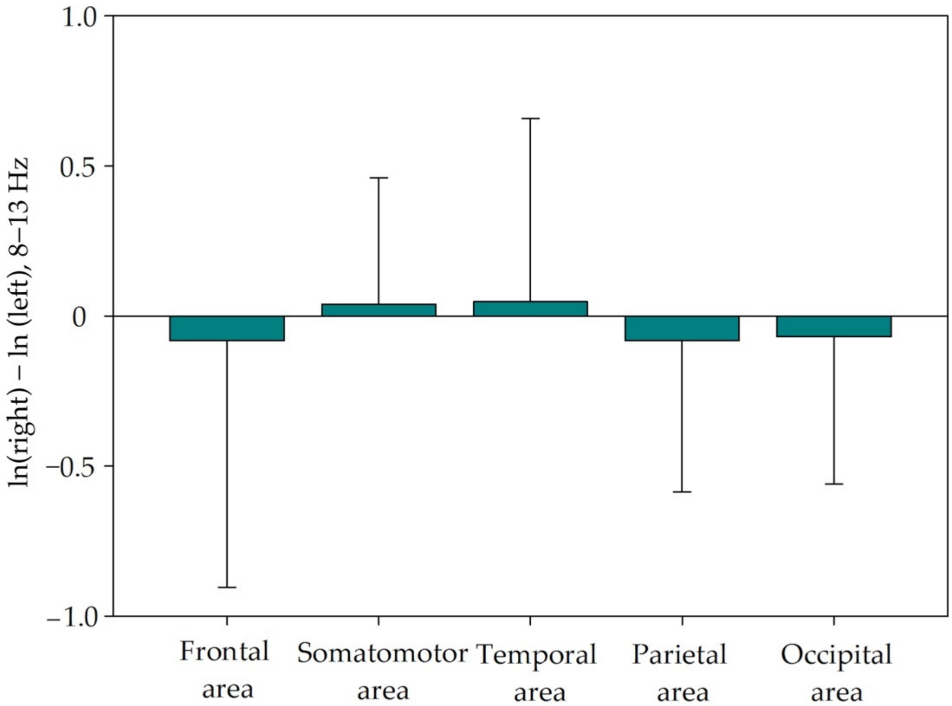

Figure 1. Mean (SD) alpha asymmetry in frontal, somatomotor, temporal, parietal and occipital areas. High SD indicates great variability inter subjects.

We observed that the asymmetry positive or negative trend was not standard among all the participants in each brain area (see Figure 2). In the frontal area, half of participants showed positive asymmetry, and half showed negative. In the somatomotor area, it was 22 (61.1%) positive versus 14 negative. In the temporal area, it was 15 (41.7%) positive versus 21 negative. In the parietal area, it was the same, 15 (41.7%) positive versus 21 negative. And, in the occipital area, we found 16 (44.4%) participants with positive asymmetry and 20 with negative asymmetry.

We computed a Friedman repeated measures ANOVA on ranks with asymmetry of the five studied areas and found no significant difference [X^2 (4, N = 36) = 3.044, $p = 0.55$].

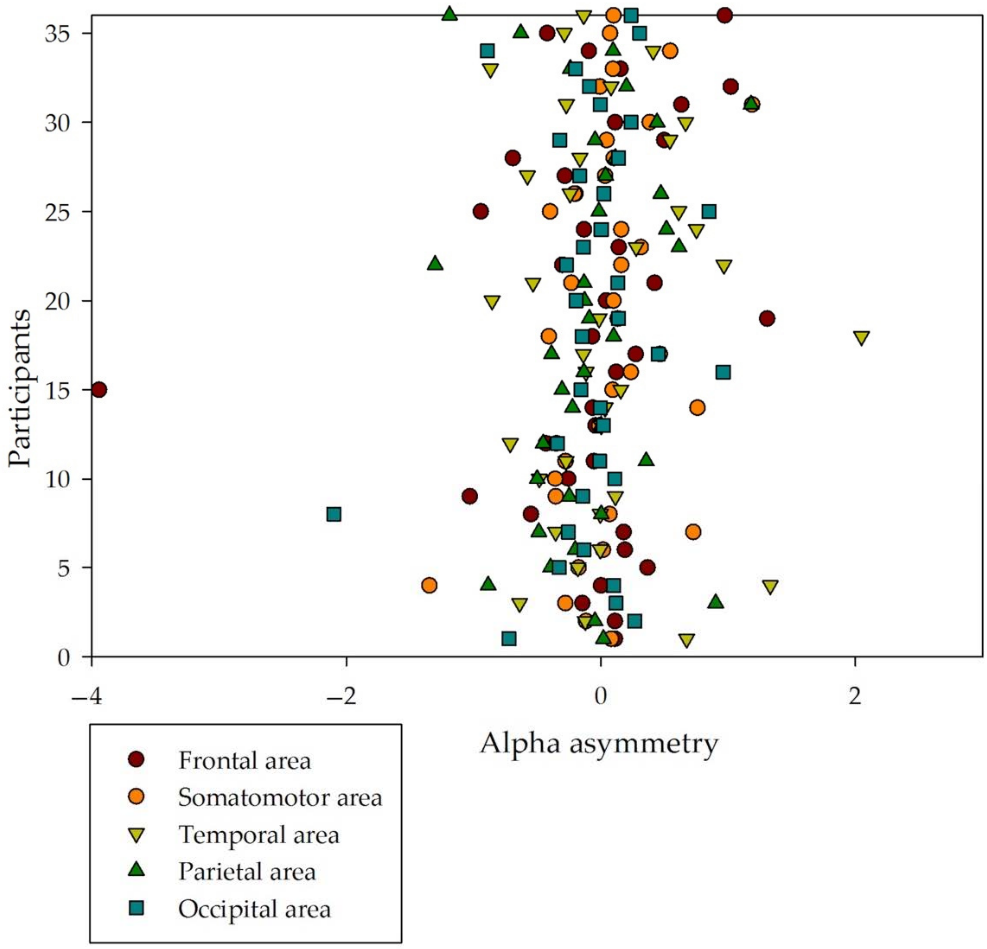

Figure 2. Alpha asymmetry from all participants. Data from all participants in this study, distributed in relation to the five areas of this study: frontal, somatomotor, temporal, parietal and occipital.

3.3. Alpha Asymmetry and Media Expertise

As explained, half of the participants were media professionals. We computed unpaired *t*-tests (or the non-parametrical Mann–Whitney rank sum test for non-normally distributed data) in each area with both groups. We found no significant statistical differences between media and non-media professionals in any area: frontal [Mann–Whitney U Statistic = 131.000, T = 302.000, n = 18, p = 0.335; rank sum test, Mann–Whitney rank sum test]; somatomotor [Mann–Whitney U Statistic = 102.000, T = 273.000, n = 18, p = 0.06; rank sum test, Mann–Whitney rank sum test]; temporal [Mann–Whitney U Statistic = 160.000, T = 335.000, n = 18, p = 0.962; rank sum test, Mann–Whitney rank sum test]; parietal [$t_{(34)} = -0.919$, p = 0.365, unpaired *t*-test]; and occipital [Mann–Whitney U Statistic = 142.000, T = 313.000, n = 18, p = 0.537; rank sum test, Mann–Whitney rank sum test].

4. Discussion and Conclusions

In this manuscript, we wondered whether there would be brain asymmetry in alpha power when watching cuts in movies, dividing the analysis into five brain areas: frontal, somatomotor, temporal, parietal and occipital. On average, we found positive asymmetry in the somatomotor and the temporal area, as a result of a higher right hemisphere alpha power that corresponds with a higher left hemisphere activity. We also found negative asymmetry in frontal, parietal and occipital areas, suggesting the contrary. However, we found great variability among participants and, when computing the statistics, these asymmetries did not seem to be significant. These results suggest that cuts in audiovisuals do not evoke any specific asymmetrical brain activity in the alpha band in viewers. Note that previous studies analyzing brain asymmetry when watching videos paid attention to the narrative content and the emotions that those contents could elicit in viewers [22,23]. Here, we did not draw attention to the content but rather to the cut as a specific formal characteristic of videos. These results suggest that brain asymmetry when decoding audiovisual content may be more related with narrative content than with formal style.

We found some differences in alpha power between the non-corresponding brain areas and hemispheres. This could be related to the differences in the rate of flow of brain activity [6]. We found a significant difference in alpha power in left parietal and right temporal areas. Although it suggests an interesting relation between both hemispheres and areas, further studies should be made to confirm this.

We also looked for differences between media and non-media professionals. Based on previous studies, these two groups perceive audiovisual content differently [16,33]. Different brain connectivity (functional and effective) has been found between them. Also, there is quite a lot of literature regarding the effect of professional specialization or expertise on the brain (such as in drivers [34,35], in musicians [36], in surgeons [15], in athletes [37], among others). Here we found that there is no significant difference between media and non-media professionals in terms of alpha asymmetry when watching audiovisual cuts.

To our knowledge no study had looked before at brain asymmetry in relation with media professional expertise. Since brain connectivity differences between media and non-media groups were found significant [16], while brain asymmetry was not, we believe further studies connecting these two different manners of approaching brain activity could be of interest for a better understanding of brain processing of local field potentials when watching movies. Furthermore, in the future, a temporal dimension could be added to find possible correlations of brain asymmetry in relation with the narrative content. Moreover, this type of study could be replicated with attention tests [38,39] in order to look for correlations between asymmetry and attention. Finally, it would be interesting to study correspondences between asymmetry and eye-gaze behaviors when watching audiovisual content.

This study has several limitations: we did not ask participants about their right or left handedness, so this information could not be added to the analysis. Another limitation was the data acquisition approach: a higher number of electrodes (we used a 20-electrode system) could have given a higher volume of conduction of the signal, and an individual MRI could have provided much more specific information for each one of the participants.

In conclusion, cuts in audiovisuals do not evoke asymmetrical brain activities in the alpha band in viewers, suggesting that brain asymmetry, when decoding audiovisual content, may be more related with narrative content than with formal style.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/sym14101980/s1, Table S1: Alpha power and asymmetry of all participants.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Universitat Autònoma de Barcelona (protocol code CEEAH 2003).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available in Table S1.

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