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Article title: Neurocinematics

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Abstract
Neurocinematics, an approach at the intersection of neuroscience, media psychology, and film, uses neuroimaging methods to elucidate the reception and processing of movies. This article provides a brief introduction to methods and an overview of current research.

Keywords
Neurocinematics, neuroscience, audience analysis, neuroimaging, fMRI, EEG, MEG, inter-subject correlation, movies

Main text
Movies strongly influence audiences, despite being mere representations of real life. They make us jump, cry, laugh, and scream. They educate and even inspire the formation of large social communities. What are the mechanisms that bring about these strong effects? For decades, many disciplines have been tackling these questions including philosophy, film studies, psychology, and communication. However, advances in measurement and analysis of human brain activity enable the empirical study how movies affect the brains of audiences. This article provides an overview of this approach and discuss how it can help address longstanding questions in film studies and media psychology.

[A] Why neurocinematics?

Movies capitalize on fundamental principles of human brain function (Dudai, 2012; Shimamura, 2013). For example, cinematographers often exploit bottom-up attentional processes like the eye's natural attraction to human faces, and they make strategic use of lighting, composition, and close-ups to guide the audience's attention through a scene. Furthermore, they carefully introduce information and manipulate its saliency in order to elicit specific cognitive or emotional responses such as expectations, inferences, hopes, and fears. Beyond the ability to steer viewers' natural psychological responses in a planned fashion, movies can even overcome the limits of reality with regard to time and space (e.g., montage).

To illustrate, consider a scene of a man in a room. If the director relied on long or medium shots of this man standing, then the audience's eyes might wander around. By contrast, if the director chooses a close-up of the man's sweating brow with an illuminating shot of a gun hidden under his coat, then this leads viewers to infer that the man might intend to harm someone, which in turn raises tension regarding what will happen next. In this way, skilled cinematographers exploit basic mechanisms related to perception, cognition, and emotion that are almost universally shared among humans.

Filmmakers have amassed a powerful set of methods to elicit strong, predictable audience reactions. In less than 25 years after the Lumiere brothers' premiered their short films in 1885, there were schools dedicated to the theory and craft of cinema. Together with information coming from cognitive science and social psychology, the body of knowledge now includes montage techniques, methods for character and plot development, and more. Some of this knowledge is formally provided in textbooks, some of it seems to have evolved through trial and error (e.g., the increase in pace, Cutting et al., 2011), and a good deal is simply informed by valid folk-psychological intuitions and expert creativity. What is missing, however, is a clear and coherent scientific explanation of the causal sequence that starts with eyes and ears converting information into neural impulses and ends with the relationship between these neural responses and psychological phenomena like attention, emotion, and even associated bodily responses like accelerated heart rate and sweaty palms.

Accordingly, a neurocinematic approach uses movies and examines their effects on the brain, the biological organ of the mind. This creates several mutually beneficial research opportunities across many disciplines. For neuroscientists, movies provide novel stimuli to study phenomena related to high-level cognitive (e.g., prediction, anticipation, social cognition) and emotional processes in a more realistic and engaging way than afforded by classical laboratory experiments. For media psychologists, a neurocinematic approach provides new data to continuously assess viewer responses that are difficult to report with verbal language and uneffected by overt questioning or social desirability concerns (e.g., emotional arousal during violent or erotic content). For filmmakers and practitioners, the approach provides new means for objective audience response measurement. Although neurocinematics is still a rather basic science and it is not yet market-ready, it seems plausible that its methods could be used to provide feedback and guide the creation process.

[A] Methods for assessing brain activity

Prominent methods for human neuroimaging are functional magnetic resonance imaging (fMRI) and electro- and magnetoencephalography (EEG/MEG). For a longer description of these methods and important considerations for how to use them, please see this encyclopedia's entry on Psychophysiology (IEMP0013). In brief, fMRI detects changes in relative cerebral blood flow in small sections of the brain. For each of these sections, called voxels (volumetric pixels), the machine derives a signal that indexes activity of that area of the brain. At each time point, the collection of these voxels forms a 3D volume of highly spatially-resolved brain activity. In contrast to fMRI, EEG and MEG capture electrical or magnetic brain signals at a high temporal resolution but with lower spatial resolution. Thus, the two methods complement each other in that one excels in spatial precision (fMRI) and the other in temporal (EEG) precision. The strength of each method, however, lies in their ability to track objective audience responses to content as it varies over time without interruption.

Historically, the neuroimaging community relied on very simplistic and reduced stimuli because movies and other naturalistic stimuli were considered too complex and uncontrolled. Of note, although it may come as a surprise that movies are seen as naturalistic because they are carefully crafted products, the label naturalistic here refers to the notion that movies provide continuous stimulation that resembles real-world perception. Since roughly 2004, however, there has been consistent ongoing adoption of many forms of media in neuroscientific studies, such as books, podcasts, PSAs, speech recordings, etc. Not only does this allow neuroscientists to study brain function in response to stimuli that more accurately represent real life, but it allows media psychologists and film scholars to use brain imaging data to study movies and messages.

[A] Approaches for linking movies and brain activity

The following is an introduction to three different approaches that scholars can apply to study the relationship between movies, individual brain activity, and audience-wide responses. The first approach, termed movie-to-brain, focuses on how specific movie variables relate to the brain activity they elicit. The second approach, termed brain-to-movie, runs in the opposite direction and uses recorded brain activity to identify parts of the movie that evoke this activity. Lastly, the third approach, termed brain-to-brain, exposes how movies collectively engage audiences and evoke similar brain responses across viewers.

[B] Movie to Brain

It is clear that certain movie features will evoke specific brain responses. For example, time-varying changes in brightness over the course of a movie should evoke activity in brain regions or systems that process this feature such as the visual cortex in the occipital lobe. A similar argument can be made for any visual or auditory feature, such as the presence of faces, motion of objects, presence of sounds, or human language. The goal of the movie-to-brain approach is thus to quantify such features in the movie timeline and then identify the corresponding changes in recorded brain activity. This approach is similar to most classical neuroimaging studies, which typically use carefully manipulated stimuli, such as a set of 500 images that vary in level of brightness, in order to reveal brain regions or networks that are responsive to this manipulation of brightness. The main difference of the neurocinematics approach is that instead of creating 500 images varying in brightness, researchers would use the natural variations in brightness that are inherent to the movie.

This approach is ideal for grounding hypothetical constructs in observable brain responses and identifying how media-psychological variables - either experimentally manipulated or naturally occuring within a movie - impact brain activity. For instance, Huth and colleagues (2016) presented a group of viewers with movie footage for which they had carefully annotated the semantic content (e.g., faces, body parts, animals, and letters) to study the brain regions associated with specific content variables. Additionally, Magliano and Zacks (2011) instructed participants to segment a commercial film into meaningful events to characterize the behavioral and brain response associated with different methods of continuity editing. In sum, the movie-to-brain approach establishes a knowledge base of how the sensory, perceptual, and psychological ingredients of movies elicit specific responses in the viewers' brains. Weber, Mangus, and Huskey (2015) and Weber et al., (2015) provide a more thorough introduction to the research questions that a movie-to-brain approach can answer and important considerations for integrating neuroscience and media psychology.

[B] Brain to Movie

The brain-to-movie approach essentially reverses the direction of the movie-to-brain approach. Rather than quantifying aspects of the movie and examining how they relate to brain activity, a researcher taking a brain-to-movie approach would identify salient features in the brain activity and 'go backwards' to ask which part of the movie elicited that activity. This method has a highly successful history in visual neurophysiology and is sometimes known as reverse correlation (Ringach & Shapley, 2004).

To perform a reverse correlation, one would begin with a brain region of interest and inspect the time series in that region to identify the moments where this region exhibits maxima and minima, or when the region is the most and least active. For instance, Grall and Schmaelzle (2018) identified the five highest peaks and lowest troughs of the temporoparietal junction (TPJ), a region often implicated in processing social information, while viewers watched a short movie. These peaks and troughs were then connected back to the content on screen associated with this activity, resulting in short trailers representing the moments that maximally or minimally drove the activation of that brain region.

Analysis of the trailers showed that the high TPJ activity trailer was filled with conversation and perceived as more social compared to the low TPJ activity trailer. This approach provides a novel, data-driven technique to investigate and even create content that is tied to regional brain function. Although reverse correlation analysis has not been widely adopted as of 2019, media psychologists trained in communication theory and neuroimaging methods are ideally situated to leverage this method for theoretical contributions.

[B] Brain to Brain

A third approach to neurocinematics research focuses on the relationship between the brain activity of different viewers - hence the title brain-to-brain. This approach is discussed in greater detail because it is currently among the most promising methods for insights at the intersection of movies and brains, and it was this approach that lead to the popularization of the term neurocinematics.

In 2008, an interdisciplinary team demonstrated a novel technique for studying brain responses to movie stimuli (Hasson et al., 2008). In the study, participants watched several movies including *The Good, the Bad, and the Ugly (Sergio Leone), City Lights (Charlie Chaplin),* and unedited video of a concert in a park while their brain activity was monitored with fMRI. Using an analysis called intersubject correlation (ISC), the researchers demonstrated that when participants watched the same movie, there was a notable degree of similarity between the regional brain activity of individuals. In fact, beyond revealing correlated responses in the visual and auditory regions of viewers' brains, many regions involved in higher-order cognitive, social, and emotional processing also exhibited significantly correlated brain responses when participants watched the movies. Importantly, these correlations were especially strong for the carefully-crafted movie clip, such as the one directed by Sergio Leone. Additionally, there was no similarity in brain activity across individuals when they watched a black screen.

To foster an intuition for what this means, consider a conductor with an orchestra. The conductor continuously directs the many sections of musicians who follow the detailed time-locked cues: grow louder, more energy from the violins, play with more staccato. Despite all instruments managing distinct parts, the conductor coordinates this activity to create the emergent sound of a symphony. Now, imagine two unique orchestras following one conductor. The more each section of musicians is dedicated to following the conductor, and the more skilled the conductor, the more in unison the music will sound. This is what Hasson and colleagues demonstrated; movies act like a conductor and each brain is like one orchestra. Movies evoke specific responses in individual brains, and these responses are similar across different brains exposed to the same movie. Despite brain regions managing different functions, the information provided by the unfolding movie coordinates regional brain activities and thus promotes the emergent experience of watching a film. The more each brain region is recruited to process the film, and the more well-crafted the film to guide that processing, the more two unique brains will respond similarly when watching the same film. In fact, ISC can act as an index of how strongly a movie collectively engages an audience by capturing their attention and eliciting shared cognitive and emotional responses.

Mathematically, intersubject correlation (ISC) analysis represents the degree of similarity in the brain activity of an audience in response to some complex stimuli. It involves correlating the time series data from one brain region from one audience member with the average time series of that same brain region from all other audience members (for more information see Nastase, Gazzola, Hasson, & Keysers, 2019). This is repeated for all participants and, after averaging those correlations together, the final correlation coefficient represents the extent to which that brain region fluctuated similarly across all participants watching the same film. This procedure is repeated for all regions, which results in a brain map of the more or less correlated regions of the audience responses to that film. Although here we discuss ISC as conducted on fMRI data, this analysis can also be applied to EEG data (Dmochowski, Sajda, Dias, & Parra, 2012), which benefits from a less resource-intensive data collection process with better temporal resolution.

The utility of ISC for neurocinematics research comes from the following logic. As an audience watches a movie, their eyes and ears convert the continuous stream of sights and sounds into brain activity. These brain signals propagate through the brain, starting from regions dedicated to processing vision and audition, to networks that enable the perception of objects or faces, and then on to the more complex systems that generate meaning from the actions on screen. Based on the high degree of similarity in the evolved, modular structure of brains at a coarse scale, it makes sense that there is similarity in brain function when processing sensory or perceptual stimuli. In other words, we should clearly see aligned activity in the auditory cortex of all audience brains when there is a loud explosion compared to moments of silence. Additionally, the regions specialized for language comprehension will fluctuate similarly when processing conversations compared to lyricless music. Of note, this is not to say that there are no individual differences - quite the opposite. However, viewing the same movie undeniably evokes a host of obligatory auditory and visual processes, which are similarly implemented in the brain of all humans. Furthermore, regions involved in higher-order functioning like attention, emotion, or social information processing also become more or less correlated depending on the movie content quality and construction.

Mounting evidence suggests that the degree to which a movie synchronizes the brain activity of an audience (as indexed by ISC) is an indication of how well a movie, or a particular characteristic of a movie, collectively engages an audience. As previously mentioned, there are widespread ISCs when a film has been crafted to guide and grip audience attention compared to when the content lets audience minds wander (Hasson et al., 2004; Hasson et al., 2008). This is evidenced by ISCs in frontal and parietal regions of audience brains when watching carefully edited scenes from *The Good, The Bad, and the Ugly* or *Alfred Hitchcock Presents*, but minimal ISCs when watching an unedited clip of a park or a black screen. ISCs depend on whether or not the audience can comprehend the story, as indicated by the lack of ISCs in brain regions involved in story processing when listening to a story spoken in another language (Honey, Thompson, Lerner, & Hasson, 2012). The rhetorical strength of a speech drives increased ISCs in regions like the medial prefrontal cortex, a region heavily implicated in social cognition, compared to weaker speeches (Schmalzle et al., 2015). Furthermore, there is stronger similarity in brain function within groups that share a particular interpretation of an ambiguous story (Yeshurun et al., 2017). It is worthy to note that this collection of studies serve as evidence that it movie content and quality drive ISC, not the structural features of particular stimuli. Overall, correlated activity across brain regions can indicate whether the audience attended to the movie, comprehended the content, and even had some shared cognitive or emotional response. For more information on the utility of ISC for communication research, please see Schmälzle and Grall (in press).

The first publication of this line of research in 2004 spread the notion that movies are useful for neuroscientists to study the brain (Hasson, Nir, Levy, Fuhrmann, & Malach, 2004), but the extension of this work in 2008 set the stage for a nuanced adoption of brain imaging data to inform questions important to film studies and content creators. Are particular cinematographic strategies more effective at capturing attention for specific genres? How do elicitors of suspense affect audiences and lead to expectations about what comes next in a film? Obviously, such questions cannot only be answered from theorists and philosophers alone, but require a principled way to experimentally study *how* specific manipulations affect audience brain responses. This is what neurocinematic studies aim to achieve.

[A] A brief demonstration of a neurocinematics approach with suspense

The phenomenon of suspense easily lends itself to a neurocinematics approach, especially because it has garnered interest from a variety of fields including philosophy, communication, psychology, and neuroscience. Across this body of work, there are many definitions of suspense and how it captivates audiences through activating a unique blend of cognitive and affective processes like a rise in anticipation and prediction of story outcomes. What remains lacking across conceptualizations, however, is a characterization of the role of the brain in this process which logically must begin with movie content, move to processing within audience brains, and result in experiences of suspense. One recent study speaks to this missing piece by investigating the relationship between the similarity in audience brain responses to a suspenseful film indexed by ISC and collective ratings of perceived suspensefulness recorded with continuous response measurement (Schmälzle & Grall, 2019). Results revealed a positive relationship between perceptions of suspense and brain similarity such that when suspense is at its highest (a movie's climax), this is when an audience's brain responses are most aligned. Notably, this relationship is particularly strong in regions associated with working memory and salience processing such as the dorsolateral prefrontal cortex and anterior cingulate, respectively. This contributes to our understanding of the brain function that is common across an audience viewing a suspenseful film and how that shared function relates to an audience's experience.

[A] Important considerations for neurocinematics research

As in all science, the promise of neurocinematics comes with several critical disclaimers. There is a long history of cognitive approaches to movies that must be acknowledged (see Shimamura, 2013 for recent updates to this work), and there are fields dedicated to empirically testing theory on the processing and effects of media messages (i.e., media psychology). The novelty of a neurocinematics approach comes solely from the integration of brain imaging data, which should be considered one piece of the larger picture of the biological component of the movie-viewing process (see IEMP0013 for other psychophysiological tools). One major strength of this approach is its assumption that it is imperative to integrate methods that offer unique forms of data, and we can maximally benefit our research questions when synthesizing neuroimaging data with content analytic techniques, surveys, and behavioral methods like eye-tracking. This is because, like all forms of measurement, neuroimaging has many limitations that constrain the conclusions one can draw. Any variation in brain function in response to a movie cannot, in and of itself, be taken as evidence of a viewer's experience. This would be what is known as reverse inference (Poldrack, 2006), which is a common mistake in neuroimaging often stemming from a misunderstanding of the relationship between biological data and psychological theory. The conductor and orchestra analogy above, although a useful aid, belies the extreme complexity of brain structure and function, which cannot be underestimated. Furthermore, although a neurocinematics approach might help explain how the developed techniques of filmmakers can achieve some goal in an audience, it cannot replace the creativity of filmmakers or somehow account for the aesthetic or cultural impact of a film.

As movies, and messages broadly, continue to educate, persuade, and entertain, a neurocinematics approach provides a unique source of data for understanding the effects of movies. Neuroimaging research is resource intensive in both monetary and time costs, and thorough training on biological and psychological methods is necessary. However, the increased use of movie stimuli in neuroscience with the increased efforts to share datasets means that there is more publicly available neuroimaging data with movies than ever before. New tools continue to be developed and shared, making neurocinematics a promising approach to help capture the communication process holistically from content to brain to behavior, which is necessary to advance our understanding of the power of movies.

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Figure captions

Further Reading/Resources

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