KREA-TECH

Innovative learning and teaching practices for implementing new technology in the creative media processes

WP: WP2. Needs Analysis on how psychophysiology and data-driven insights can be used in Media.

TASK: T2.3. Develop framework to enable data-driven decision making

DELIVERABLE: D2.6. Framework report for data-driven communication

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DATE: 04/07/2025

UPDATE: 21/07/2025

1. Index

2. Introduction

This deliverable is aimed to suggest a data-driven decision-making framework to enable professionals, outside the field of neuroscience to make informed decisions based on data gathered in content testing. The framework has to be intended as a theoretical but data-driven approach, through which, with a conscious use of terms, concepts and tools, a film industry professional can be able to employ an innovative data-based neuroscientific model to obtain information on how to best plan and design their content to improve final users' experience. The deliverable will provide a detailed overview of preliminary concepts, data collection procedures, analysis and visualization tools, in order to provide insights into production processes and audience engagement. The framework will be developed based on the needs assessment and communication framework carried on in T2.1 and T2.2.

3. Working with Physiological Data

3.1. Principles of Mind-Body Interaction

The concept of mind-body interaction represents a profound scientific frontier that challenges traditional boundaries between psychological and physiological domains. At its core, this principle argues that mental processes are not isolated abstract phenomena, but dynamic, measurable biological events with tangible physiological correlates.

Historical perspectives on mind-body interactions have evolved dramatically. Early philosophical approaches, such as Cartesian dualism, viewed mind and body as separate entities. Contemporary neuroscience, however, demonstrates their intricate, inseparable relationship. Every cognitive event—whether it's a fleeting emotion, a complex decision, or a subtle perception—generates immediate and measurable changes in bodily systems.

For instance, when a person experiences stress, the following physiological cascade occurs:

1. The hypothalamus activates the sympathetic nervous system
2. Adrenal glands release cortisol and adrenaline
3. Heart rate increases
4. Skin conductance changes
5. Brain wave patterns shift

These interconnected responses illustrate how mental states are not merely metaphorical but represent complex, quantifiable neurophysiological processes.

3.2. Data Sources

Physiological data sources can be categorized into three primary domains, each offering unique insights into human cognitive and emotional experiences:

Neurological Signals

Understanding the functioning of the brain is at the heart of neurometrics. While the autonomic nervous system (ANS) reflects *how the body reacts* to internal and external stimuli, neurological signals provide direct insights into *what the brain is doing*—that is, how it processes, perceives, and evaluates a stimulus in real time. In this context, technologies such as Electroencephalography (EEG) and functional Near-Infrared Spectroscopy (fNIRS) have become essential tools in assessing neural dynamics in applied contexts such as film production, advertising, and user experience design.

[...]

Autonomic Nervous System Indicators

The Autonomic Nervous System (ANS) plays a central role in regulating unconscious physiological functions such as heart rate, respiration, perspiration, and pupil dilation. These processes are tightly linked to emotional and cognitive states, making the ANS an essential target in neurometric research. By analyzing ANS-related signals, researchers can non-invasively infer levels of stress, arousal, engagement, and emotional valence—states that are highly relevant in the context of audience response to cinematic content.

The ANS consists of two main branches: the sympathetic nervous system (SNS), which is activated in response to stress, danger, or high arousal situations—commonly known as the "fight or flight" response. The parasympathetic nervous system (PNS), which promotes relaxation and recovery—the "rest and digest" response.

[...]

Ocular Metrics

While neurological and autonomic signals offer insights into internal cognitive and emotional states, ocular metrics provide a direct window into visual attention and mental processing. The eyes are not only the organ of vision, but also an *external indicator* of what the brain is focusing on, how it processes information, and how engaged it is. In neurometrics, eye tracking has become a foundational tool for evaluating user experience, attention, and affective responses to visual stimuli—especially in film, advertising, gaming, and immersive media.

Ocular metrics offer several advantages: they are non-invasive, highly precise, and often intuitive to interpret. In the context of film production, they allow creators to understand *what viewers look at*, *for how long*, and *in what sequence*—providing critical feedback on visual saliency, narrative design, and emotional pacing.

[...]

Conclusions on data sources

The different data sources here listed have not to be considered as alternative, on the contrary their insightfulness will be enhanced by their combined use, in what is known as multimodal approach.

For instance, with respect to attention, it's essential to distinguish between visual attention (what the eyes look at) and cognitive attention (what the brain processes deeply). Eye-tracking provides observable evidence of attention, while EEG or fNIRS measure its internal processing counterpart. For example: a viewer may look at an actor's face (eye tracking), but EEG may show low engagement—suggesting automatic viewing without emotional or cognitive investment. Conversely, sustained dwell time and pupil dilation combined with theta EEG activity may indicate deep narrative immersion. This highlights the benefit of combining ocular metrics with neural or autonomic signals for a comprehensive understanding of audience experience.

3.3.Data Collection

Effective data collection is a meticulous process requiring sophisticated technological infrastructure and rigorous methodological considerations. The collection of physiological data in neurometric research is far more than a technical task—it is a methodological foundation that determines the reliability and interpretability of all subsequent analysis. In film production environments or creative UX research, where stimuli are rich and dynamic, high-quality data acquisition demands sophisticated instrumentation, carefully controlled conditions, and deep respect for participants' well-being.

Technological Requirements

The foundation of any neurometric investigation lies in the reliability and precision of the technological ecosystem used to collect physiological data. Whether measuring neural activity through EEG or fNIRS, eye movements via eye tracking, or emotional arousal through GSR or heart rate, the instrumentation must meet rigorous standards of accuracy, temporal resolution, and real-world applicability. In experimental contexts like film production, where participants are exposed to continuous, immersive stimuli, devices must not only capture high-fidelity signals but also operate unobtrusively, preserving the ecological validity of the experience. Achieving this balance between technological sophistication and participant comfort is essential for obtaining usable, interpretable data. Additionally, the system's ability to process signals in real time, filter out noise, and adapt to diverse experimental setups is what transforms raw data collection into a scientifically grounded and ethically sound research practice. Effective neurometric setups must integrate hardware and software systems that fulfill key scientific demands while maintaining usability in real-world or semi-naturalistic environments:

[...]

Experimental Design Considerations

While advanced technology enables the collection of high-resolution physiological data, the scientific value of that data ultimately depends on the quality of the experimental design. This is particularly true in neurometric research applied to film and media, where the stimuli are complex, multimodal, and emotionally engaging. Designing an effective experiment means carefully managing the conditions under which data is recorded—ensuring that signals are clean, participant responses are authentic, and the research environment reflects the intended context of use. Key considerations include minimizing noise and artifacts, maximizing participant comfort, and aligning measurement protocols with both scientific rigor and creative realities.

[...]

Participant Comfort and Ecological Validity

In neurometric research—particularly when applied to creative domains like cinema or immersive media—the participant experience is not just a background concern, but a central variable that can shape both the quality and authenticity of the data collected. Physiological signals are highly sensitive to discomfort, distraction, and artificial constraints; even slight increases in muscular tension or reduced engagement can introduce noise or mask meaningful responses. Ensuring participant comfort is therefore not a matter of convenience, but a prerequisite for scientific integrity. At the same time, achieving ecological validity—the degree to which the experimental setup mirrors real-world experiences—is essential for making neurometric findings relevant and applicable outside the lab. This means designing protocols that preserve the natural flow of the viewing experience, minimize sensor intrusiveness, and respect the spontaneity of human emotional and cognitive responses. The challenge lies in balancing technological control with the freedom of natural behavior, a task that requires thoughtful integration of engineering, psychology, and design principles.

[...]

Ethical and Methodological Standards

As neurometrics increasingly enters applied domains—from filmmaking to user experience and media testing—its ethical implications become more than a formal requirement; they become a core aspect of responsible scientific practice. The collection of physiological and neurocognitive data involves deeply personal dimensions of human experience, often occurring outside of participants' conscious awareness. For this reason, clear and transparent informed consent, rigorous data anonymization, and strict adherence to ethical research guidelines are indispensable. Moreover, methodological integrity—ensuring the reproducibility, validity, and transparency of experimental procedures—must accompany every stage of the research process, from data acquisition to publication. In creative and commercial contexts, where neurometrics may influence design, storytelling, or audience targeting, these principles help safeguard participants' rights, foster public trust, and preserve the scientific credibility of the field. Ethical and methodological standards, far from being constraints, are in fact the framework that enables innovation to remain meaningful, respectful, and socially grounded.

- **Informed consent**: Participants must be told what data is being collected, how it will be processed, and their right to withdraw (Faden et al., 1986).
- **Anonymization**: All data must be stored in coded form and stripped of identifying information before analysis.
- **Ethical compliance**: Studies should conform to institutional review boards (IRBs), the Declaration of Helsinki, and—where applicable—the General Data Protection Regulation (GDPR) (Hansson, 2009).

3.4.Data Processing

Raw biosignals—whether from EEG, fNIRS, GSR, or eye tracking—are complex, high-dimensional, and filled with noise. Data processing transforms these signals into analyzable and meaningful metrics that reflect the cognitive or affective states under investigation. This transformation process demands a rigorous pipeline consisting of signal cleaning, normalization, and feature extraction.

Signal Preprocessing Stages

Raw physiological signals—whether from EEG, fNIRS, GSR, or eye tracking—are inherently noisy, multidimensional, and sensitive to a multitude of internal and external factors. Before any meaningful interpretation can occur, these signals must undergo a meticulous preprocessing phase, in which noise is reduced, distortions are corrected, and the data is prepared for analysis. This phase serves as a crucial filter between the chaotic complexity of the real world and the structured clarity required for scientific insight. Effective preprocessing ensures that what remains in the data reflects true cognitive or emotional processes, rather than muscular artifacts, environmental interference, or sensor misalignment. The process typically includes artifact detection and removal, baseline correction, and normalization, all guided by physiological knowledge and statistical rigor. In this sense, preprocessing is not merely a technical step—it is a form of signal curation, where scientific judgement and computational precision converge to isolate the meaningful from the meaningless. Here below the main steps are listed:

[...]

3.5.Analysis, Evaluation, and Visualization

Once physiological signals have been cleaned, normalized, and transformed into interpretable features, the true challenge of neurometrics begins: extracting meaningful insight from complex, multidimensional data. This phase—where analysis meets interpretation—is where physiological measures become cognitively and emotionally intelligible. In applied contexts such as film production, interactive media, or immersive storytelling, the stakes are high: researchers must not only detect patterns, but also translate them into actionable knowledge for creatives, designers, or human-centered systems. This requires sophisticated analytical strategies—often combining classical statistics with machine learning—as well as a deep understanding of human variability and the non-linear nature of mental states. Equally important is the role of visualization: how data is represented shapes how it is understood. Whether through dynamic dashboards, time-aligned overlays, or gaze heatmaps, effective visualization allows both scientists and storytellers to see the invisible—to observe how attention, emotion, and cognition unfold across time and narrative. In this way, analysis and visualization become not just tools, but a language for understanding human experience through data. Data analysis in neurometrics is both computationally rigorous and visually communicative. It involves discovering interpretable patterns within high-dimensional physiological data and presenting these insights in ways that inform creative or operational decision-making.

Analytical Approaches

[...]

Visualization Strategies

In neurometrics, how data is visualized is as important as how it is analyzed. Translating complex physiological signals into intuitive visual formats allows both researchers and non-expert stakeholders—such as filmmakers, designers, or producers—to access and interpret findings in a meaningful and immediate way. Visualization serves as the final interface between raw data and human understanding; it gives form to the invisible dynamics of attention, emotion, and cognitive load. Whether it involves plotting EEG-derived engagement curves across film scenes, rendering gaze distributions through heatmaps, or creating real-time dashboards of multimodal responses, the goal is always the same: to reveal patterns, temporal structures, and relationships that might otherwise remain hidden. Moreover, well-designed visualizations enable comparative evaluation between stimuli, subjects, or narrative conditions, making them powerful tools for both scientific discovery and creative decision-making. In this sense, visualization is not just about communication—it is a cognitive tool in itself, one that allows us to see how people experience a story, a space, or a sequence, frame by frame, layer by layer.

- **Time-aligned plots**: Overlay physiological metrics with stimulus timelines (e.g., film scenes, dialogue).
- **Heatmaps and gaze maps**: For eye-tracking data, indicating visual focus areas.
- **Engagement curves**: Plotting emotional or attentional metrics over time to reveal narrative arcs.
- **Interactive dashboards**: Built in tools like MATLAB, Python Dash, or Tableau, allowing dynamic exploration of multimodal data.

4. Introduction to Neurometrics

4.1.What are Biometric and Neurometric Data?

Biometric Data refers to measurable physiological and behavioral characteristics that can be used to identify or analyze individuals. Neurometric Data specifically focuses on quantifiable neurophysiological signals that provide insights into cognitive and emotional processes.

Neurometrics transform complex biological signals into interpretable, scientifically rigorous measurements of mental states, cognitive load, emotional responses, and perceptual experiences.

4.2.How Can Neurometrics Be Measured?

Measuring neurometrics means capturing quantifiable, objective indicators of cognitive and emotional processes by observing how the brain and body respond to stimuli—typically without relying on conscious self-report. Unlike behavioral responses, which are often filtered through introspection or cultural bias, neurometric signals are physiological expressions of mental states: real-time traces of attention, effort, arousal, emotion, and preference. These measurements rely on a suite of biosensing technologies, each suited to specific dimensions of experience and experimental contexts.

[...]

Ultimately, neurometric measurement is not about replacing traditional evaluation methods, but about enriching them. By giving researchers and creators access to the physiological substrate of experience, neurometrics offers a deeper, data-driven understanding of how users process stories, visuals, and interfaces—moment by moment, beneath the surface of conscious awareness.

4.3.Main Neurometrics and Practical Examples

Several neurometrics of different mental and emotional states have been developed and validated by scientific community, even if very often there is not a common agreement, rather each research team propose its own "version". However, they all lay on common physiological evidences. In cinema applications, seven key cognitive and emotional states can be of interest to be measured, because of a direct impact on audience engagement and narrative comprehension. Each neurometric provides unique insights into how viewers process and respond to audiovisual content, offering filmmakers objective data to optimize storytelling effectiveness.

[...]

4.4.Analysis Principles

Each neurometric requires specific analytical approaches that ensure reliable measurement and meaningful interpretation of physiological signals in cinematic contexts. The complexity of neurophysiological data necessitates systematic processing pipelines that transform raw biological signals into actionable insights for filmmakers and researchers, as previously introduced and here below discussed with more details.

[...]

5. Examples & State of the Art

Neurometrics find applications across diverse domains, demonstrating their maturity as scientific tools and their potential for transformative impact in the entertainment industry. The successful implementation of neurophysiological measures in safety-critical and commercial applications provides compelling evidence for their reliability and practical value in cinematic contexts.

[...]

6. From Signals to Stories — Toward a Neurometric Framework for Creative Decision-Making

Over the course of this document, we have explored how neurometrics—through the measurement of neural and physiological signals—offer a powerful lens through which to interpret the cognitive and emotional states of human audiences. We examined the theoretical basis of the mind-body connection, described the core technologies and data processing steps necessary to extract reliable metrics, and detailed specific indicators such as attention, workload, emotion, and visual engagement. These components form the backbone of an emerging scientific toolkit that can revolutionize the way audiovisual content is designed, tested, and optimized.

But the true value of neurometrics lies not only in measurement—it lies in actionable insight. The methodologies presented here can be translated into a data-driven decision-making framework that empowers creative professionals to make informed, empirically grounded choices in storytelling, editing, sound design, and beyond. Crucially, such a framework does not require filmmakers to become neuroscientists. Rather, it provides them with a structured, replicable process for evaluating how viewers actually experience their work—on a physiological and emotional level that goes beyond traditional focus groups or surveys.

6.1. Building a Creative Decision-Making Framework

A practical neurometric workflow for film production might include the following steps:

1. **Define the creative question**: What aspect of the viewer experience do you want to optimize? (e.g., sustained attention in a key scene, emotional resonance of the climax, clarity of a narrative twist)

2. **Select appropriate metrics**: Choose the neurometrics that best reflect the target experience—EEG for attention, GSR and HRV for emotional arousal, eye tracking for visual focus.

3. **Design a minimally intrusive experimental protocol**: Ensure ecological validity by testing scenes in realistic viewing conditions with lightweight wearable sensors.

4. **Collect multimodal data from a sample audience**: Gather physiological data alongside subjective feedback (e.g., Likert-scale ratings or open responses).

5. **Analyze and visualize the data**: Use statistical and machine learning tools to identify where engagement drops, where cognitive load spikes, or where scenes elicit strong affective responses.

6. **Translate findings into creative decisions**: Iterate on the audiovisual content—trim a slow-paced segment, re-score a scene to enhance emotion, or restructure a narrative to improve clarity.

By integrating neurometric insight into the creative process, filmmakers gain access to a non-verbal, real-time diagnostic system that reflects how their audience *truly* experiences their work—not just what they say afterward.

6.2.A Practical Case Study: Emotional Impact of Alternate Endings

Imagine a director testing two alternate endings to a film—one tragic, one hopeful. A group of 15 participants views each version while wearing EEG headbands, GSR sensors, and eye-tracking glasses in a controlled theatre-like environment.

- The **EEG data** shows a stronger frontal theta response in the tragic version, indicating deeper cognitive processing.
- **GSR peaks** suggest a stronger emotional arousal during the hopeful version's resolution.
- **Eye tracking** shows greater fixation duration on character faces during the tragic ending, signalling enhanced empathy.

Combined with subjective reports, these data provide a nuanced picture: while the tragic ending provokes more reflection, the hopeful one delivers a more intense emotional closure. The director might then decide based on which outcome aligns better with the intended tone of the film—or choose to combine elements of both endings for a richer narrative balance.

6.3.Conclusions

As creative industries navigate a rapidly changing media landscape, where attention is scarce and audience expectations evolve, neurometrics offers a frontier of opportunity. It enables filmmakers to ground their artistic vision in empirical evidence, without compromising creativity or authenticity. The challenge ahead lies not in replacing intuition with data, but in enhancing intuition with deeper understanding. By bridging neuroscience and storytelling, we gain the ability to create films that do more than entertain—they resonate, they captivate, they move. And in doing so, we bring viewers not just to the edge of their seats—but to the heart of the experience.

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