Psychophysiological Methods: Options, Uses, and Validity

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The field of media psychology, born from classic media effects research, prioritizes a mechanistic approach to investigating the processes underlying the effects we observe in response to media messages. The field has pioneered content analytic methods and developed many self-report techniques to study these processes. However, no mechanistic explanation of media psychological phenomena can be achieved without integrating the biological processes that give rise to those effects we can observe. The role of psychophysiology in media psychology is to provide theories and measures for physiological processes that underlie or result from psychological phenomena.

Why should we engage in psychophysiological research? Psychophysiological methods are tools for capturing and untangling the mind–body interactions that are the causes and effects of the phenomena that media psychology strives to explain. For example, what we commonly call "surprise" involves cognitive activity, such as noticing an unexpected event, and physiological and behavioral effects, such as widening pupils, a change in heart rate, or a startling of the body. Obviously, in order to be surprised, the senses must first notice something, such as the unanticipated loud sound of a gunshot in a movie. This information then prompts cognitive processing in the central nervous system that subsequently orchestrates a cascade of physiological, subjective psychological, and behavioral effects. As for surprise, similar arguments can be made for most psychological phenomena associated with media: Suspense, horror, inspiration, and various other cognitive–emotional constructs all consist of complex, interwoven interactions between central and peripheral nervous system reactions that constitute psychological processes. A comprehensive scientific explanation of these phenomena therefore cannot be achieved via self-report measures alone, but requires an integrative strategy that captures data from physiological, subjective, and behavioral channels. A psychophysiological approach is thus indispensable for assessing and analyzing these processes, and the methods have never been more readily adaptable to advance media theory and research.

Although physiological psychology has a longer history, the field called psychophysiology became formally established in the 1960s. Since then, advances in biology, measurement technology, and computing enabled multichannel measurements of various peripheral responses. Within media psychology, well-known work by Zillmann and colleagues relied on psychophysiological measures of heart rate and skin conductance (Zillmann, Johnson, & Day, 1974), and psychophysiology is prominently featured

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in the information processing approach to media, such as the limited capacity model of motivated mediated message processing (LC4MP) and other frameworks (Kempter & Bente, 2004; Lang, 2000; Ravaja, 2004). These established examples of leveraging peripheral nervous system measures for media psychology serve as a springboard for more widespread adoption. Furthermore, the recent expansion of measurement of brain activity itself, sometimes called central psychophysiology, allows us to study the brain as the vital organ for any communication process (Cacioppo, Tassinary, & Berntson, 2007). Relevant measurement modalities include electroencephalography and magnetoencephalography (EEG/MEG), functional magnetic resonance imaging (fMRI), and, more recently, functional near infrared spectroscopy (fNIRS). These technologies create the bridge to study not only the physiological antecedents or consequences of mental events (e.g., sweaty palms and a racing heart while watching a horror scene), but the neural basis of the mind itself (Gazzaniga, Ivry, & Mangun, 2013). Hidden cognitive reactions that were previously inaccessible are now readily measurable, such as the P300 component shown in event-related brain potential (ERP) studies to consistently precede overt responding when someone is surprised (Donchin, 1981). Additionally, we can spatially map out the brain regions involved in these covert processes through fMRI. Overall, by combining psychophysiological approaches with their established expertise in measuring media content and audience responses, media psychologists can achieve more complete explanations of the rich effects produced by media (Potter & Bolls, 2011).

Psychophysiological measures afford a host of benefits, even in consideration of the trade-offs they present. They provide unique data that align well with the media-related processes of interest. Namely, psychophysiological measurement is inherently processed-based and recorded on a moment-to-moment basis, which closely matches how media stimuli unfold over time. This is a strong advantage over relying on summative ratings taken at the end of message to represent the entirety of some media consumption process. Moreover, these methods are not plagued by the limitations of self-report, such as the undue influence of question wording, social desirability bias, or the challenge to report verbally about implicit processes that are detached from the language system. Researchers wishing to embrace these methods must be aware that they require greater logistical efforts than other approaches and demand additional training in biosignal analysis. However, this added complexity should not be considered an insurmountable hurdle but a necessary step to understand the hidden factors between message features and their effects on recipients.

Which psychophysiological methods exist and what do they measure? The following list is divided along common conceptions of the peripheral (e.g., heart activity, muscle, sweat glands, etc.) and central nervous system (brain and spinal cord).

Peripheral psychophysiological measures

Heart and pulse signals

Electrocardiography measures the electrical activity of the heart using electrodes placed at the surface of the body. Another option for measuring heart-/pulse-related activity is the photoplethysmogram (PPG), which measures changes in light absorption from sensors that are typically placed on the fingertips, or the earlobes. Various metrics can be derived from such measures, such as the heart rate, its variability, or the pulse volume amplitude. Although the primary function of the heart is to maintain a constant blood supply to the body, several psychological factors can modulate the heart's activity. For instance, a well-known psychophysiological effect is the defense cascade of the heart rate, consisting of an initial slowing and a subsequent acceleration in response to a threatening event (Lang & Davis, 2006). This can occur in response to encountering a wild animal, or even the first-person simulation of such an encounter on TV or in virtual reality (VR).

Electromyography (EMG)

When the many individual fibers of a muscle contract, an electrical signal can be measured using sensors placed on the skin above the muscle. Such electromyographic signals can, in principle, be recorded for all muscles, but the most relevant applications lie in facial electromyography. Facial expressions can be recorded at sites such as the musculus zygomaticus major or the corrugator supercilii, which are the muscles involved in smiling and frowning respectively. EMG of the orbicularis oculi, often used to measure the startle reflex, shows the emotional modulation of this reflex. Specifically, it is enhanced when a viewer is in an aversive emotional state, like watching a scene in which a person is walking across a cemetery at night, and it is inhibited when in an appetitive state (Lang, Bradley, & Cuthbert, 1990). Facial EMG is also used to measure activity of the zygomaticus major, the muscle that pulls the corners of one's mouth up during laughter.

Electrodermal activity

Psychologically relevant events, such as the bursting of a balloon or an opening door, evoke a strong phasic change in the conductivity of the skin, the so-called psychogalvanic reflex. Measures of electrodermal activity (EDA) may be referred to as SCR and SCL (skin conductance response and skin conductance level, focusing on phasic versus tonic components respectively). Generally, EDA is related to sympathetic autonomous activity that manifests as a change in skin conductivity due to sweat gland activity, detectable from the palm or fingertips. Phasic (i.e., rapid) skin conductance responses have been shown to covary with highly emotional images (Lang, Greenwald, Bradley, & Hamm, 1993), and tonic (i.e., prolonged) skin conductance measurements have been used to explore various stress-related phenomena.

Additional psychophysiological measures include plethysmographic measures, measures of respiration, and various humoral measures like cortisol level in saliva, electrogastrography, and so forth (Cacioppo et al., 2007). Eye-tracking methods, which lie somewhere in between psychophysiology and unobtrusive behavioral measures, are described in a separate article in this volume (EYE TRACKING).

Central psychophysiological measures: neuroimaging methods

The methodological arsenal for measuring brain activity is constantly expanding and both measurement techniques and analytic approaches will continue to grow markedly over the next decade. Here we focus on EEG and fMRI, which are currently the most widely used approaches. EEG and fMRI have complementary strengths: EEG has an excellent temporal resolution on the order of milliseconds, and fMRI offers high spatial precision on the order of millimeters.

Electroencephalography (EEG)

The human electroencephalogram can be recorded noninvasively by placing sensors on the head. The electrical voltage picked up at these sensors is generated by the summed activity of thousands of synchronously active neurons. Of note, the voltage changes that EEG measures are tiny, only a few millivolts or microvolts, and signals that are generated at various locations inside the brain become superimposed as they propagate to the scalp surface. Therefore, it is hard to infer where in the brain the signal is generated. EEG systems come in various sizes and price ranges, from low-cost devices with just a few sensors to high-density systems that can record from as many as 256 sensors. Continuous EEG recordings can be broken down into several frequency bands, which have been coarsely associated with psychological states (e.g., alpha oscillations between 8 and 12 Hz have been associated with relaxation and they increase when eyes are closed).

One prominent method, called event-related potential (ERP) technique, consists of presenting several images or sounds and computing the average activity associated with these events. ERP research can reveal cortical information processing with exquisite timing precision and has thus been termed the reaction time of the 21st century. For example, one can present series of highly arousing and neutral images to participants and compute ERPs for each class to gain insight into how the brain differentiates arousing from neutral images before participants can provide overt responses (Schupp, Schmälzle, & Flaisch, 2014). Several cognitively relevant ERP components have been identified, which are characterized by their polarity (positive or negative), latency, amplitude, and scalp topography (e.g., the P1, N1, N170, P300). An overview of relevant research on attention, comprehension, memory, and emotion is provided in Luck and Kappenman (2013).

One disadvantage of past ERP research was that the paradigms were quite artificial and required discrete events (e.g., isolated images or words). This has limited the technique's applicability to complex media stimuli (e.g., movies or stories). However, recent advances hold great promise for studying dynamic media stimuli with continuous EEG. Together with similar developments in fMRI research, these advances make neuroimaging relevant and feasible for widespread adoption to research in media psychology.

Functional magnetic resonance imaging (fMRI)

fMRI measures the changes in the relative availability of oxygenated blood in individual brain regions, which are tightly correlated with neural activity (Huettel, Song, & McCarthy, 2008). Thus, similar to ERP research, one can expose a participant to images and record regional brain responses. By comparing the brain response to various classes of images (e.g., arousing versus neutral images), one can uncover brain regions that respond differentially to psychological manipulations. Although the jargon and physics of fMRI (and EEG) technology can be intimidating, the basics of fMRI are actually quite simple: fMRI measures regional brain activity to find meaningful patterns of brain function in response to a task. The BOLD fMRI signal (blood-oxygenation level dependent) is recorded from individual voxels (volumetric pixels) throughout the brain. Each voxel has a resolution of a few millimeters, and one entire 3D image of the brain (one volume) consists of about 50–100 000 voxels. The time taken to record one volume lies in the order of seconds or less.

fMRI is suited to reveal the brain systems involved in specific mental functions. Typically, a psychological variable is manipulated, and the effect of this manipulation on brain activity is assessed. For example, by comparing the strength of the BOLD responses in each voxel across conditions (e.g., arousing versus neutral images), statistical maps can be created that show regions in which responses differ. Recent extensions of this traditional analytic approach focus not only on the amplitude of responses in individual regions, but also on distributed patterns and interactions between brain activity from different regions (Huskey, Wilcox, & Weber, 2018).

Another variant of fMRI that is gaining popularity for media effects studies is inter-subject correlation analysis (ISC; Schmälzle & Grall, in press). This approach captures the concordance of responses across multiple recipients exposed to the same stimulus. For example, by correlating the brain activity time series from one region (e.g., the visual cortex) in a given viewer with the corresponding regional time series in the brain of another viewer, one can expose brain regions that respond similarly to the same content across the audience. Variations of this ISC approach can be used to study engagement or convergent and divergent responses to an identical message. This approach is ideally suited for audience response measurement and related media psychological studies (Imhof, Schmälzle, Renner, & Schupp, 2017).

In the previous examples, the physiological response typically served as the dependent variable to test how variations in media content affect physiological responses. The brain-as-predictor approach, by contrast, uses the brain as the independent variable. For example, brain responses to individual health messages can be used to predict the effects of the messages on subsequent behaviors (e.g., smoking reduction or decreased sedentary behaviors; Falk, Cascio, & Coronel, 2015). Of note, the brain-as-predictor approach is, in principle, applicable to any physiological measure (physiology as predictor).

Beyond EEG and fMRI, other neuroimaging measures relevant for media psychophysiology include: MEG, the magnetic counterpart of EEG; fNIRS (functional near-infrared spectroscopy), a more portable and less costly technique that uses optical measurement to gauge signals similar to those detected by fMRI; structural MRI, which can be used to study long-term predictors or effects of media use (e.g., changes in cortical thickness in motor cortex as a result of intense gaming); diffusion MRI, which measures anatomical connectivity between brain regions, similarly linkable to various media-related variables. Notably, there are also methods that can *causally* manipulate regional brain activity (e.g., turn on or off, or at least interfere). Noninvasive methods that achieve this include transcranial magnetic stimulation (TMS) and transcranial direct-current stimulation (TDCS). Invasive methods are beyond the scope of this entry.

Validity and related theoretical aspects of psychophysiological measures

But what do we know about the validity of psychophysiological measures? The integration of psychophysiological measures into media psychology research demands a nuanced understanding of the relationship between biological measures and psychological constructs in the context of one's research goals. The answer to the validity question is more complex than it seems on the surface. Validity, at its core and stripped from philosophical and measurement jargon, requires "measuring the thing you intended to measure." Put simply, this requires that (i) the thing exists, and (ii) that the measure measures it (Borsboom, Mellenbergh, & van Heerden, 2004). Historically, perhaps due to the preponderance of introspective methods and theories solely based on such approaches, researchers with limited biological background often expect to see direct relationships between psychological constructs and physiological measures (Cacioppo et al., 2007). Some typical examples illustrating this line of thinking are: "Does activity of the musculus zygomaticus measure enjoyment?" or more recently "Does activity in the amygdala indicate fear?" These questions presuppose a simple mapping between psychological states and biological data. In reality, however, complex biological processes are at work to bring about these phenomena.

The misunderstanding that there could be a direct relationship between psychological constructs and physiological measures is perhaps partly rooted in the emphasis on latent variables in psychological theory and their assumed construct validity. Enjoyment, fear, and other constructs are more complex than they seem given their folk-psychological labels. For example, for a researcher studying food cravings, the most practical method may indeed be simply asking individuals what food they crave for. However, for a researcher interested in what craving *is* and how *it* is affected by media cues, asking what an individual craves for says little about the mechanism that produces the phenomenon. Physiological processes must be taken into account in order to move beyond a purely mentalistic perspective. Such a perspective is clearly incomplete because craving involves a complex sequence of subconscious neural responses as well as bodily reactions that, if ignored, will mischaracterize the phenomenon. The same applies for most other psychological phenomena, but particularly for all emotional and motivational constructs. The data for these phenomena, as Lang puts it, need to be threefold: verbal report, behavior, physiology (Lang & Davis, 2006).

For the most part, a direct one-to-one relationship between physiological measures and psychological constructs is not plausible. Although it is tempting to attribute a rise in a viewer's heart rate to the psychological construct of "fear," heart rate may rise and fall due to intense joy, cognitive effort, or simply digesting caffeine. Thus, there is a many-to-one relationship. Despite this, a media researcher examining responses to horror is well advised to measure heart rate because the cardiovascular system can be assumed to react to the content. Even though heart rate may not be a pure indicator, cardiovascular responses are a key component of aversive responses to horror and hence necessary to measure. Indeed, it is argued that a study on emotion in response to horror movies that relies exclusively on self-reports of feelings will miss key parts of the phenomenon it claims to investigate.

The complex relationship between physiological processes and mental constructs also influences interpretations of brain activity. fMRI may reveal an increase in amygdala activity during a horror movie and, again, it is tempting to attribute this increase to fear. However, amygdala activity is related to anxiety, saliency, the viewing of faces, and a host of other processes. In the neuroimaging literature, further information on this important issue can be found under the label "reverse inference."

Ultimately, physiological methods are valid in the sense that we know what and how they are measuring. Heart rate is the number of contractions of the heart muscle measured via the ECG, and the fMRI signal in the amygdala indexes activity in that region measured via BOLD-imaging technology. Responses in the cardiac system and amygdala are components of emotional responses, but they do not exclusively represent "the emotion." In order to further uncover the generative mechanisms that give rise to mental processes, an integrative measurement strategy must be pursued, without prioritizing either self-report or physiology. The beauty and potential lies in capturing all relevant data streams to reveal the fascinating mechanisms and powerful effects of media in full clarity.

SEE ALSO: Big Data, Analysis of; Excitation Transfer Theory; Eye Tracking; Limited Capacity Model of Motivated Mediated Message Processing; Psychophysiological Effects of Media Use; Unobtrusive Measures for Media Research

References

Borsboom, D., Mellenbergh, G. J., & van Heerden, J. (2004). The concept of validity. *Psychological Review, 111*, 1061–1071.

Cacioppo, J. T., Tassinary, L. G., & Berntson, G. (2007). *Handbook of psychophysiology*. New York, NY: Cambridge University Press.

Donchin, E. (1981). Surprise!? Surprise? *Psychophysiology, 18*, 493–513.

Falk, E. B., Cascio, C. N., & Coronel, J. C. (2015). Neural prediction of communication-relevant outcomes. *Communication Methods and Measures, 9*, 30–54.

Gazzaniga, M. S., Ivry, R., & Mangun, G. R. (2013). *Cognitive neuroscience: The biology of the mind*. New York, NY: Norton.

Huettel, S. A., Song, A. W., & McCarthy, G. (2008). *Functional magnetic resonance imaging* (2nd ed.). Sunderland, MA: Sinauer Associates.

Huskey, R., Wilcox, S., & Weber, R. (2018). Network neuroscience reveals distinct neuromarkers of flow during media use. *Journal of Communication, 68*, 872–895.

Imhof, M. A., Schmälzle, R., Renner, B., & Schupp, H. T. (2017). How real-life health messages engage our brains: Shared processing of effective anti-alcohol videos. *Social Cognitive and Affective Neuroscience, 12*(7), 1188–1196. doi:10.1093/scan/nsx044

Kempter, G., & Bente, G. (2004). Psychophysiologische Wirkungsforschung: Grundlagen und Anwendungen. In R. Mangold, P. Vorderer, & G. Bente (Eds.), *Lehrbuch der Medienpsychologie* (1st ed.). Göttingen: Hogrefe.

Lang, A. (2000). The limited capacity model of mediated message processing. *Journal of Communication, 50*, 46–70.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological Review, 97*, 377–395.

Lang, P. J., & Davis, M. (2006). Emotion, motivation, and the brain: Reflex foundations in animal and human research. *Progress in Brain Research*, *156*, 3–29. doi:10.1016/s0079-6123(06)56001-7

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30*, 261–273.

Luck, S. J., & Kappenman, E. S. (2013). *The Oxford handbook of event-related potential components*. Oxford: Oxford University Press.

Potter, R. F., & Bolls, P. (2011). *Psychophysiological measurement and meaning: Cognitive and emotional processing of media*. New York, NY: Routledge.

Ravaja, N. (2004). Contributions of psychophysiology to media research: Review and recommendations. *Media Psychology, 6*, 193–235.

Schmälzle, R., & Grall, C. (in press). Mediated messages and synchronized brains. In K. Floyd & R. Weber (Eds.), *The handbook of communication science and biology*. New York, NY: Routledge.

Schupp, H. T., Schmälzle, R., & Flaisch, T. (2014). Explicit semantic stimulus categorization interferes with implicit emotion processing. *Social Cognitive and Affective Neuroscience, 9*, 1738–1745.

Zillmann, D., Johnson, R. C., & Day, K. D. (1974). Attribution of apparent arousal and proficiency of recovery from sympathetic activation affecting excitation transfer to aggressive behavior. *Journal of Experimental Social Psychology, 10*, 503–515.

Further reading

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (1998). *Cognitive neuroscience. The biology of the mind*. New York: Norton.

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