

Psychophysiological Responses to Using Digital Media

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Media researchers have long investigated emotions using a variety of measures. This body of work has mostly focused on affective responses to traditional media such as television and radio. However, new and emerging digital media continue to rapidly evolve, while providing affordances and capabilities that make the technology, audiences, and users seem—and perhaps more importantly feel—ever more present both socially and psychologically. As such, the study of digital media and emotion has become a major focus for communication scientists. However, research employing psychophysiological measures of emotion in the study of digital media effects is currently quite sparse despite being fertile research ground.

This chapter provides an overview of perspectives pertaining to how the “old brain,” which has not evolved as fast as media technology has developed, affectively and physiologically responds to “new” digital media. Next, a summary of the dominant, though not exhaustive, theories of emotion involved in studying psychophysiological responses to media is presented. Peripheral psychophysiological measures as indices of emotional message processing are then discussed including a review of findings from studies examining digital media technologies, platforms, and affordances. This chapter concludes with a discussion of the advantages and limitations that come with the measurement of emotion via psychophysiological measures as applied to the study of digital media, as well as considerations for future research.

When the Old Brain Meets New Digital Media

A dominant perspective held by psychophysiological researchers is that the human brain of the 21st century, specifically the limbic system, does not significantly differ from the brains of our upright-walking ancestors of our

human tribe, Hominini (Darwin, 1859; MacLean, 1990). Hence, our old “reptilian brain” (or *r-complex*; MacLean, 1990) did not evolve to deal with media, old or new (Reeves & Nass, 1996). In theorizing about humans’ interactions with, what was considered at the time, “new media,” Byron Reeves and Cliff Nass (1996) argued in their book *The Media Equation* that humans respond to computers, television, and new media as if they are real people and places. Reeves and Nass (1996) further posit that people respond to media content (e.g., representations of social reality) that are communicated through those technologies as if those images, texts, and pixels are also real and immediately present. Unsurprisingly, much of their theory has been applied with an evolutionary lens to examine how people interact with and respond to media, in general (Griffin, 2012; Reeves & Nass, 1996). That is, humans do not have a neural or anatomical function to recognize mediated stimuli as not real. This theory postulates that we are here, reading this chapter, because our ancestors fled when a threatening animal approached in the wild. We are here because when food was available our ancestors approached it, gathered or captured it, and consumed it for energy. What our ancestors perceived to be a real person, object, or place was in fact real. And the parts of our 21st-century brains that make such judgments have not evolved beyond theirs. Hence, Reeves and Nass (1996) postulate that our brains emotionally and cognitively respond to media in the same fashion as our ancestors responded to things in their lives, as if what we are encountering (though mediated) is, in fact, real and immediately present.

Indeed, the brain is quite effective (within 1000 milliseconds) when encountering a stimulus—including a mediated stimulus—at deciphering whether it is positive, negative, or neutral, which then automatically motivates approach-or-avoid behaviors (Cacioppo et al., 2012). It is this approach-or-avoid motivational activation that generates higher-order emotional responses (Bradley et al., 2001). Thus, the brain automatically responding to stimuli that were and are motivationally imperative has been a major evolutionary advantage. A wealth of research has indicated that the brain’s automatic response is unconscious and immediate. As such, the time used to consciously decipher “hmm, is what I am seeing real?” would result, historically, in an unfortunate outcome, such as death. Rather, the brain automatically responds as if the stimulus perceived is in fact real and then motivates an adaptive behavior. Anecdotally, one might reflect as to how we physically startle when we watch a scary scene in a horror movie; that is your body’s response to the actions of the phylogenetic structures of the brain. Or you might find yourself saying during the same scene that “this is not real, it’s fake, it’s fake” in order to reduce negative affect. Interesting how we make effortful attempts to convince ourselves

that what we are seeing is fake, right? These examples, albeit anecdotal, line up with the propositions of the media equation (Reeves & Nass, 1996).

Why is the media equation important for studying emotional responses to digital media? As alluded to above, our brains are not equipped to decipher between what is real and what is mediated. That is, mediated content is perceived to be real; therefore, we emotionally respond as if it is real (Reeves & Nass, 1996). This assumption is vitally important to understanding theories of emotion as applied to media and psychophysiological research.

Theories of Emotion and Media: Discrete and Dimensional Perspectives

Philosophers, economists, communicators, psychologists, and neuroscientists, among others, have all sought to understand the human condition as it pertains to the interworking and basis of something called “emotion” (Barrett, 2006). Although there is not a universally accepted definition, most theorists consider emotions as internal mental states that represent evaluative valenced reactions to events, agents, or objects that vary in intensity (Ortony et al., 1990; see Chapter 1 of this volume). Moreover, P. J. Lang (1995) defines emotions as biologically based action dispositions that influence, if not determine, behavior.

Two leading perspectives in the study of emotion, especially in media research, include the discrete view of emotion and the dimensional view of emotion (Bolls, 2010; Nabi, 2010). The discrete or categorical view of emotion postulates that emotions can be identified and classified into categorical states. Each classification has a unique set of underlying cognitive appraisals (i.e., cognitive interpretations of the event or object; Schachter & Singer, 1962) that are causal antecedents of whether the emotion will be felt, which then influences action tendencies or adaptive responses (Frijda, 1986; Lazarus, 1991). That is, there are causal links between specific appraisals and specific emotions (Lazarus, 1991; Nabi, 1999).

The dimensional theory of emotion conceptualizes emotion as an affectively valenced response emerging from basic motivational processes in response to an evaluation of some object or stimulus (Bradley et al., 2001; P. J. Lang, 1995; P. J. Lang & Bradley, 2008; P. J. Lang et al., 1997b). This is the perspective on emotion that is typically applied in psychophysiological investigations of emotional responses to media (Cacioppo et al., 2000; Potter & Bolls, 2012). The dimensional theory of emotion is based on Russell’s (1980) circumplex model of affect, which posits that discrete emotions are highly intercorrelated and therefore can be organized on a two-dimensional

circular space that is separated into four quadrants coordinated around the *arousal* dimension and the *affective-valence*, also termed *pleasure–displeasure*, dimension. For example, “excitement” is located in the pleasant, high-arousal quadrant, whereas “boredom” is located in the unpleasant, low-arousal quadrant. “Distress” is located in the unpleasant, high-arousal quadrant, whereas “relaxation” is located in the pleasant, low-arousal quadrant (Ekkekakis & Petruzzello, 2002; Russell, 1980).

Building on Russell’s (1980) circumplex model of affect is the notion of biological motivation derived from the evaluative space model¹ (ESM; see Cacioppo & Berntson, 1994, 1999; Cacioppo et al., 1997, 1999, 2012). The ESM posits that two independent and evolution-based motivational systems, the appetitive (approach) motivational system and the aversive (avoid) motivational system (Bradley et al., 2001; Cacioppo & Gardner, 1999; Cacioppo et al., 1999; P. J. Lang et al., 1997b), activate when evaluating a stimulus in our environment (i.e., the operations by which organisms discriminate threatening from nurturant environments).

The ESM assumes that positive emotional valence is linked with appetitive motivational activation and negative emotional valence with aversive motivational activation. As such, a highly positive stimulus leads to greater approach motivation and increased positive emotional valence, whereas a highly negative stimulus leads to greater avoidance motivation and increased negative emotional valence (Cacioppo et al., 2012). Thus, activation in one or both motivational systems contributes to emotional valence (i.e., pleasant, unpleasant, ambivalent, neutral), with intensity of emotional valence varying based on the level of activation (i.e., emotional arousal; Bradley et al., 2001; Cacioppo & Berntson, 1994; Cacioppo & Gardner, 1999).

Importantly, Cacioppo and Berntson (1994) and Cacioppo and colleagues (1997, 1999) theorize that two asymmetries in the activation of appetitive and aversive motivational systems have evolved over time to provide adaptive advantages. For example, the human appetitive (approach) motivational system has evolved to be more active in neutral environments than the aversive motivational system. This asymmetry or difference in motivational activation is termed the *positivity offset* (Cacioppo & Berntson, 1994; Cacioppo & Gardner, 1999; Cacioppo et al., 1999). This makes sense from an evolutionary perspective because animals, including humans, must be willing to leave the nest in search of food and mates (i.e., exploration). The human aversive

¹ Communication scholars refer to the ESM and “dual-motivational theory” interchangeably. The ESM and dual-motivational theory offer the same predictions pertaining to appetitive and aversive motivational system activation.

(avoid) motivational system, however, has evolved to provide vigilance and protection from harmful stimuli (Bradley et al., 2001). For example, when a threat is encountered in one's environment the aversive motivational system responds quicker and more vigorously than the appetitive motivational system, the idea being that a threat can attack quickly and that it is biologically imperative to respond quickly and appropriately. This quick, avoid response is the second asymmetry presented in the model and is known as the *negativity bias* (Cacioppo & Berntson, 1994; Cacioppo & Gardner, 1999; Cacioppo et al., 1999). The positivity offset and negativity bias have been observed across a wide range of domains including animal learning (Miller, 1961), human affective judgments (Ito et al., 1998), and attitude and impression formation (Cacioppo & Berntson, 1994).

In theorizing about the nature of motivational activation, Cacioppo and Gardner (1999) propose four possible activation states: (1) inactivity (i.e., a state in which neither system is activated), (2) reciprocal (i.e., activation in the appetitive system increases, and activation of the aversive system decreases or vice versa), (3) uncoupled (i.e., activation of the appetitive system increases, while the aversive system remains unchanged or vice versa), and (4) coactive (i.e., both motivational systems activate at the same time, and therefore both positive and negative emotional valence are experienced) (Clayton, 2022; Clayton, Leshner, Tomko, et al., 2017; Keene & Lang, 2016; Wang et al., 2012). For example, from an evolutionary perspective, animals in the safari might approach an open source of water, which simultaneously exposes them to potential predators (Norris et al., 2010). In this scenario, both motivational systems are activated; and, therefore, both positive and negative valence are experienced at, likely, moderate levels of arousal (Cacioppo & Gardner, 1999). Indeed, Clayton, Leshner, Bolls, et al. (2017) and Clayton, Leshner, Tomko, et al. (2017) theorized that this type of simultaneous approach–avoid response is akin to motivational dissonance, that is, simultaneous rocking toward (approach) the incentivizing stimuli and away (avoid) from the potential threat.

To be clear, the dimensional theory of emotion (Bradley, 1994; Bradley et al., 2001; P. J. Lang et al., 1997b) and the ESM (Cacioppo & Berntson, 1994, 1999; Cacioppo et al., 1997, 1999) posit that humans can learn, over time, via classical conditioning that some objects, though not necessary to our survival, are positive and some are negative. For example, mediated images of junk food have been found to activate the appetitive motivational system (Clayton et al., 2019), and unhealthy eaters subsequently perceive images of junk food more positively than images of healthy foods like fruits and vegetables (Yeghyan & Bailey, 2016; see also Bailey, 2016; Bailey et al., 2022, for a review). Additionally, mediated images of risky behaviors (e.g., handling of snakes or

guns) might be perceived by some individuals, especially those characterized as being high in trait sensation-seeking, as highly positive (A. Lang et al., 2007). To this end, research has shown that motivational reactivity to different types of mediated content largely depends on personality type (Clayton, Lang, et al., 2019; A. Lang & Bailey, 2015; A. Lang et al., 2007). Thus, self-relevant information and learned associations can influence appetitive and aversive motivational activation and therefore generate individual differences in affective responses.

As noted above, researchers who use psychophysiological measures to study emotional processing of media predominantly operate from a dimensional perspective on emotion (Bartholow & Bolls, 2013; Bradley et al., 2001; Cacioppo & Berntson, 1994; Cacioppo & Gardner, 1999; Cacioppo et al., 1999, 2000; Larsen et al., 2009; Potter & Bolls, 2012, 2020). From this perspective, the media effects researcher is positioned to examine emotional valence and intensity as emerging from evolution-driven responses (i.e., appetitive/approach or aversive/avoid) based on stimulus evaluation. Below, measurement of these types of responses to media is discussed in detail.

Peripheral Psychophysiological Measures

Grounded in the understanding that the brain and body generate affective psychophysiological responses to information in our environment via motivational system activation, that these responses can be organized on a two-dimensional space of valence and arousal (Cacioppo & Berntson, 1994; Cacioppo & Gardner, 1999; Cacioppo et al., 1999), and that such responses occur to old and new media as if the content is real and immediately present (Reeves & Nass, 1996), the question of interest now is how, exactly, are such affective responses operationalized? Here, the various peripheral psychophysiological measures as indices of arousal and valence are discussed.

Psychophysiological Measures of Arousal and Valence

Researchers applying psychophysiological measures to the study of human emotion and communication assume that the mind is part of the human body. This assumption is often referred to as the *embodied mind* (Potter & Bolls, 2012). Thus, mental experience does not exist without the ongoing physical activity of the brain. Indeed, information travels from the brain to the periphery via the nervous system but is also received reciprocally from the

periphery (Potter & Bolls, 2012, 2020). Researchers have therefore employed peripheral psychophysiological measures to study psychological constructs and, most specific to this chapter, arousal and valence. Thorough descriptions of the central and peripheral nervous systems and paradigmatic assumptions are outlined elsewhere (see Bartholow & Bolls, 2013; Bolls et al., 2020; Potter & Bolls, 2012, 2020). However, a description of peripheral psychophysiological measures of arousal and valence is provided in detail below.

Physiological Arousal

Physiological arousal, specifically as indexed by electrodermal activity (EDA) and, in older terminology, by galvanic skin response, has an extensive history in communication research (Zillmann, 1971, 1982; Zillmann & Bryant, 1985). EDA is influenced only by the sympathetic nervous system and refers to the ease with which electricity moves across the skin (Potter & Bolls, 2020). The measurement of EDA takes place where eccrine sweat glands are most densely located, specifically the palmar and plantar surfaces (i.e., hands and feet; Dawson et al., 2007); thus, it is recommended that EDA be measured from these locations (Boucsein, 1992). Most often, two electrodes are placed on the palmar skin surface and a small electrical voltage (.5 v) is sent to the electrodes. The more sympathetic nervous system activity, the more sweat that is secreted and fills the ducts, and the greater the electrical conductance between the two electrodes (Potter & Bolls, 2020; Stern et al., 2001).

EDA has been found to increase when people are exposed to novel or motivationally significant stimuli, including mediated stimuli that require attention (A. Lang et al., 1995). The EDA response is often classified as a phasic or tonic response (Potter & Bolls, 2020). The rapid, phasic response occurs within 3 seconds of stimulus onset and is known as a *skin conductance response*. The tonic response, referred to as *skin conductance level*, is a slower response that is aggregated into 1-second increments so that trends can be examined for over-time variation (Dawson et al., 2007; Potter & Bolls, 2020). See Table 3.1 for a review of conceptualization and operationalization of EDA.

Physiological Indicators of Valence

The study of facial expressions and emotions was first investigated by Darwin (1872/1965) in a seminal analysis examining how observable patterns of facial muscle action are associated with different emotional states. Tomkins (1962) revisited this work, finding that facial movement and feedback play an important role in the experience of emotion. That is, expressions of emotion can be communicated non-verbally via facial muscle activity (Cacioppo et al., 1986; Fridlund & Cacioppo, 1986). For instance, raising the corners of

Table 3.1 Conceptualization and Operationalization of Psychophysiological Measures of Arousal and Valence

Measure	Dimension/emotion	Muscle region/reflex	Sensor placement	Impedance/filter settings
Electrodermal activity	Interpreted as an indicator of intensity of motivational activation and therefore the arousal dimension.	Eccrine sweat glands are most densely located on palmar and plantar surfaces.	A bipolar placement of two standard 8-mm Ag/AgCl disposable electrodes to the palmar surface of participant's non-dominant hand or on the medial side of the foot.	An amplifier passes a direct and constant .5-v excitation. Amplifier gain setting of 5 μ O/V and a low-pass filter set at 10 Hz.
Orbicularis oculi	Interpreted as an indicator of appetitive motivational activation and therefore the pleasant dimension of emotion.	Muscular reaction that occurs just beneath the eye socket and at the corner of the eye.	One 4-mm electrode placed 1 cm inferior to the outer commissure of the eye fissure. A second 4-mm electrode should be placed 1 cm medial and slightly inferior to the first electrode.	Inter-electrode impedance at or below 30 k Ω . Amplifier settings typically have a gain setting of 5 k. Low-pass filter set at 500 Hz. High-pass filter set at 10 Hz.
Zygomaticus major	Interpreted as an indicator of appetitive motivational activation and therefore the pleasant dimension of emotion.	Muscular reaction that results in the upward pulling of the corners of the mouth during a smile.	One 4-mm electrode along an imaginary line along the cheek that connects the upper portion of the ear to the corner of the mouth. A second 4-mm electrode should be placed 1 cm inferior and medial to the first electrode following the same line.	Inter-electrode impedance at or below 30 k Ω . Amplifier settings typically have a gain setting of 5 k. Low-pass filter set at 500 Hz. High-pass filter set at 10 Hz.
Duchenne smile	Interpreted as an indicator of appetitive motivational activation and therefore the pleasant dimension of emotion.	Simultaneous activation of the zygomaticus and orbicularis oculi muscle regions.	See sensor placement for zygomaticus and orbicularis oculi.	Inter-electrode impedance at or below 30 k Ω . Amplifier settings typically have a gain setting of 5 k. Low-pass filter set at 500 Hz. High-pass filter set at 10 Hz.

Post-auricular response	Interpreted as an indicator of appetitive motivational activation and therefore the pleasant dimension of emotion.	The reflex pulls the ear upward and back in response to a large and sudden, pre-attentive noise or movement.	Two 4-mm electrodes are placed on the scalp behind each ear on the strip of the skin midway up the pinna.	Acoustic startle stimulus, such as a 50-ms burst of 1000 hz white noise, is programmed in the media content. Inter-electrode impedance should be at or below 5 k Ω .
Corrugator supercilii	Interpreted as an indicator of aversive motivational activation and therefore the unpleasant dimension of emotion.	Muscle reaction that creates a furrowing or knitting of the brow.	One 4-mm electrode directly above the brow following an imaginary vertical line that traverses the eye fissure. A second electrode should be placed 1 cm lateral to and slightly above the first electrode on the border of the eyebrow.	Inter-electrode impedance at or below 30 k Ω . Amplifier settings typically have a gain setting of 5 k. Low-pass filter set at 500 Hz. High-pass filter set at 10 Hz.
Eye-blink startle reflex	Interpreted as an indicator of aversive motivational activation and therefore the unpleasant dimension of emotion.	A largely unconscious defense response to a sudden loud noise, sharp movement, or threatening stimulus.	The same as orbicularis oculi. One 4-mm electrode 1 cm inferior to the outer commissure of the eye fissure. A second 4-mm electrode should be placed 1 cm medial and slightly inferior to the first electrode.	Inter-electrode impedance at or below 30 k Ω . Amplifier settings typically have a gain setting of 5 k. Low-pass filter set at 500 Hz. High-pass filter set at 10 Hz.
Levator labii	Interpreted as an indicator of aversive motivational activation and therefore the unpleasant dimension of emotion.	Muscular reaction that results in a rising of the upper lip and widening of the nostrils.	Electrodes are placed 1 cm lateral to the base of the nostril. A second 4-mm electrode positioned 1 cm above the first electrode	Inter-electrode impedance at or below 30 k Ω . Amplifier settings typically have a gain setting of 5 k. Low-pass filter set at 500 Hz. High-pass filter set at 10 Hz.

Note: For a more exhaustive conceptual and operational review of psychophysiological measures of emotional valence and arousal, please see the *Handbook of Psychophysiology* edited by Cacioppo et al. (2017).

the mouth can indicate positive emotion, whereas furrowing of the brow can communicate negative emotion (Fridlund & Cacioppo, 1986). Hence, it is no surprise that psychophysiological researchers measure emotion via changes in electrical output that are generated from the summation of facial motor unit action potentials (Fridlund & Cacioppo, 1986). These small, covert electrical changes occur at different facial muscle regions during media exposure in evaluating the perceived valence of a stimulus (Hazlett & Hazlett, 1999). It is argued that facial electromyography (EMG) measurement provides more precision relative to human coding of overt facial expressions (Cacioppo et al., 2000; Potter & Bolls, 2012, 2020; Tassinari & Cacioppo, 1992). Indeed, discrete emotions are highly intercorrelated, making them difficult to differentiate (Cacioppo et al., 2000). Thus, an advantage of facial EMG over other measurement tools is the ability to record facial responses even in the absence of an overt expression (Cacioppo et al., 1986).

The facial muscle regions most often examined in media research include the orbicularis oculi, located on the lower eyelid just below the pupil, and the zygomaticus major, located on the cheek in line with the base of the nose and below the outer edge of the eye. When combined, these two facial EMG regions comprise the authentic smile, also known as the *Duchenne smile* (Ekman, 1984, 1992; Fridlund & Cacioppo, 1986). Moreover, the corrugator supercilii, located on the forehead and slightly above the eyebrow and toward the nose, and the levator labii, located at the base of the nostril and slightly above the lip (Potter & Bolls, 2012), are frequently measured as indicators of aversive motivational activation and negative emotional valence (Fridlund & Cacioppo, 1986). Reflexes as indices of emotion are less frequently measured in media studies but include the eye-blink startle reflex (P. J. Lang et al., 1990) and the post-auricular reflex (Potter & Bolls, 2012). Measurement of these five psychophysiological indicators of valence are conceptualized and presented in Table 3.1 following the dimensional and dual-motivation theory of emotion (Bradley et al., 2001; Cacioppo & Gardner, 1999; Cacioppo et al., 1999; P. J. Lang & Bradley, 2008; P. J. Lang et al., 1997b).

Triangulating Psychophysiological and Self-Report Measures

There are many advantages of using psychophysiological indicators of emotional valence and arousal in the study of media technology and content. First, physiological arousal and facial EMG are relatively non-invasive measures emerging during media exposure on a second-by-second basis, and therefore

offer incredible dimensionality to the study of various forms of media content. Moreover, such measures provide real-time data that post hoc (or even in situ) self-report responses generally cannot (Potter & Bolls, 2012). Indeed, Hazlett and Hazlett (1999) were the first to publish work using facial EMG measures as a “way to get beyond the limitations and biases that often plague self-report” (pp. 19–20). That said, it should be noted that researchers who triangulate their physiological data with self-report batteries of emotion may be better equipped to holistically examine emotional responses. For instance, researchers operating from the dimensional perspective often employ one of the most common self-report scales, the Self-Assessment Manikin (SAM), to assess dominance, valence, and arousal following exposure to media (Bradley & Lang, 1994; Lang et al., 1997a). Participants are instructed to rate arousal on a continuum from calm to extremely excited and valence on a continuum from unpleasant to pleasant (Potter & Bolls, 2012). Of course, it is reasonable to also proctor additional scales that measure affective responses beyond the valence and arousal dimensions.

For example, a study investigating emotional responses to self-transcendent media content might observe positive emotional responses as indicated by facial EMG, increased physiological arousal indicated by skin conductance levels, and elevated self-reported pleasantness and arousal as self-reported on the SAM. From a dimensional perspective, these data would align with a highly active appetitive (approach) motivational system. However, what higher-order and specific “positive” emotions might be generated from activation of the appetitive motivational system? With additional self-report batteries, such as the discrete emotion questionnaire (Harmon-Jones et al., 2016) and the Positive and Negative Affect Schedule (Watson et al., 1988), one might find that participants were not only experiencing all relevant signs of appetitive motivation activation, and therefore increased positive affect and arousal, but also increased levels of elevation, in particular (Clayton et al., 2021). With these data, the researcher is positioned to further understand the types of media content that generate specific emotions, how individuals make meaning from their emotional experience, and how specific discrete emotions might influence subsequent behaviors above and beyond an “approach” response. For instance, the Clayton et al. (2021) study found that exposure to the self-transcendent videos versus simply funny (i.e., hedonic) videos generated greater intentions to share the videos as a marker of prosociality, suggesting that appetitive motivation activation and higher-order self-transcendent emotions are capable of broadening our thought–action repertoires. Thus, it is strongly recommended that researchers triangulate psychophysiological and self-report measures when possible.

Psychophysiological Responses to Using Digital Media

The rise of digital media has led scholars to examine how patterns and types of media use influence, and are influenced by, our emotional experiences. However, to date, there appears to be limited research employing psychophysiological measures as indicators of emotional responses to digital media technologies and content. Nevertheless, an overview of digital media studies employing psychophysiological measures of emotion, though limited, is offered below.

Digital Media Technologies

The psychosocial and emotional role of the smartphone in our daily lives has received much attention given how the cell phone has become a ubiquitous part of everyday life. The idea that mobile technologies are capable of being incorporated in the fabric of our social and emotional lives has been termed *mobilization*. Indeed, Harkin (2003) proposes that mobile technology has become such an intimate part of most people's lives that it represents "an extension of our physical selves—an umbilical cord, anchoring the information society's digital infrastructure to our very bodies" (p. 16). This proposition, among others, has led communication researchers to examine the psychological and emotional effects of smartphones (Clayton et al., 2015). For instance, research has examined the effects of smartphone separation on fear of missing out (FOMO; Rosen et al., 2013). Specifically, Rosen and colleagues found self-reported anxiety to be associated with participants not being able to check in on social media sites, among other platforms, on their smartphones. Others have focused on mobile dependence, termed *nomophobia*, which refers to the pathological fear related to being out of touch with technology (King et al., 2013). Most pertinent to this chapter are the studies that have examined how smartphones, as a technological device and extension of our physical and emotional selves, influence affective psychophysiological responses.

In 2015, Clayton and colleagues conducted an experiment to examine how iPhone users physiologically, emotionally, and cognitively respond when separated from their iPhone. The results indicated that participants' blood pressure and heart rate (indicators of a stress response) were significantly greater during iPhone separation compared to when participants' iPhones were in their possession. Participants also reported increased self-reported anxiety, arousal, and unpleasantness during iPhone separation.

However, when the iPhone was returned and in participants' possession, all psychophysiological and self-report signals returned to their lower, baseline levels. Participants also performed better on a word search puzzle when in possession of their iPhone than when separated. Interestingly, participants also reported feeling a lessening of their self (i.e., extended-self theory; Belk, 2013) during iPhone separation. Thus, Clayton et al.'s (2015) study provided compelling evidence that technology, including smartphones, is part of our emotional and physical selves and that, when we are separated from them, indicators of aversive motivational activation and intense negative emotional valence (i.e., unpleasantness and arousal), as well as lessening of one's "self," may occur.

Other studies have focused on how dependence on technology, such as the smartphone, influences physiological responses. In their study, Markowitz et al. (2019) examined how applying self-control to mobile phone use influences psychological and psychophysiological responses via the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP; A. Lang, 2006). Of most relevance here, Markowitz and colleagues found that when users were without their phone (i.e., *no phone* condition), they experienced concentration difficulties and an increase in physiological arousal as measured by EDA beginning at the 3-minute marker of the experimental period. That is, participants without their phone (i.e., *no phone* condition) displayed heightened arousal responses compared to participants who had their phone present but were asked to resist using it (i.e., *phone resist* condition) and to participants who were allowed to use their phone during the experimental period (i.e., *phone use* condition). Thus, the Markowitz et al. (2019) study conceptually replicated Clayton et al.'s (2015) psychological and psychophysiological findings, while also advancing the self-control literature.

Despite growing interest in psychophysiological responses in the study of communication technologies, such as the smartphone, there remain many questions to be investigated. For instance, what affordances of the technology influence affective responses? Is it the device itself or the affordances of the device that influence emotional responses or both? Researchers might also consider conducting ambulatory assessment research, wherein psychophysiological responses and self-report are collected while participants undergo normal activities in their day-to-day environments with their smartphones. Indeed, new wireless wearable systems that record physiological responses make such endeavors possible. Additionally, new and emerging technologies such as the smartwatch (e.g., Apple watch, Fitbit) make studying the emotional effects associated with FOMO, device separation, sleep quality, and conversation quality all worthy of future investigation.

Digital Media Platforms and Affordances

Aside from the technology itself, researchers have examined a wide variety of responses to various social networking sites (SNSs), such as Facebook, Twitter, and YouTube. Initially, researchers were interested in outcomes related to impression management (boyd, 2004) and how and why people bridge online and offline social networks (Ellison et al., 2007). Scholars have since divided SNS research into three broad domains: uses and gratifications, sociopolitical and psychosocial influences, and privacy implications (boyd & Ellison, 2007; Wise et al., 2010). However, there has been limited research examining users' psychophysiological responses as they pertain to these research areas, with a few exceptions discussed below.

In a foundational study, Wise and colleagues (2010) examined users' physiological affective responses while engaging in social browsing and social searching behaviors on Facebook. Social browsing was conceptualized as a passive social information-seeking strategy and social searching as an extractive social information-seeking strategy (Wise et al., 2010). In their study, the authors asked 36 participants in individual laboratory sessions to use Facebook for 5 minutes while skin conductance (i.e., physiological arousal), corrugator activation (i.e., aversive motivational activation and negative emotional valence), and orbicularis oculi activation (i.e., appetitive motivational activation and positive emotional valence) were measured on a second-by-second basis. Screen recording of the participants' behaviors while on Facebook indicated that they spent more of their time allocated to social browsing than social searching. Moreover, the psychophysiological data indicated that skin conductance (i.e., physiological arousal) decreased over time while engaging in both social browsing and social searching. The authors found no differences with corrugator supercilii activation (i.e., negative emotional valence) between social browsing or search searching. However, there was greater orbicularis oculi activation as an indicator of positive emotional valence during social searching versus social browsing.

The Wise et al. (2010) study mirrored self-reported accounts of Facebook activities (Lampe et al., 2006) but also provided initial evidence that emotional responses, as conceptualized from an ESM and dimensional perspective of emotion, can be captured using skin conductance and facial EMG measures during SNS use. Moreover, the authors found novel evidence indicating that social searching appears to elicit greater positive emotional valence than social browsing, as predicted by the positivity offset per the ESM (Cacioppo & Berntson, 1994).

In another study, Alhabash and colleagues (2019) collected psychophysiological responses including heart rate as a measure of cognitive resource allocation, as well as skin conductance, and facial EMG leading up to participants enacting a Facebook behavior including a like, share, comment, and status update. In looking at each Facebook behavior separately, the authors found that the time leading to performing a Facebook like resulted in brief increases in skin conductivity levels, whereas leading to writing a status on Facebook generated a continuous increase in skin conductivity levels (Alhabash et al., 2019). The study found no significant differences across psychophysiological measures in the time leading up to sharing or commenting on Facebook (Alhabash et al., 2019). Overall, the authors concluded that pressing the Facebook like button might reflect an automatic response, whereas writing a post leads to more cognitive engagement, both of which are physiologically arousing (Alhabash et al., 2019).

Although the application of psychophysiological measures to the study of digital media use is limited, the studies overviewed here provide exciting opportunities for future research. While most experimental studies employing psychophysiological measures are tightly controlled, especially in terms of stimuli presentation, the Wise and Alhabash studies allowed for “organic use” during their studies. In each study, the authors’ recorded the participants’ SNS behaviors using screen-recording software or eye-tracking measures. The recordings were then coded, and psychophysiological responses during the coded segments were analyzed and compared. The creativity in their experimental designs and, ultimately, ability to infer some causality while maintaining more realistic media interactions on Facebook (i.e., external validity) provide a novel methodological framework for future research.

A Call for Data-Recording Solutions

As new technologies for data collection emerge, such as wireless recording systems, the ability to examine psychophysiological responses that unfold in real time as people interact with digital media will become ever more attainable. However, one major issue of concern is that of movement artifact. The majority of, if not all, physiological recording systems are extremely sensitive to participant movement (i.e., coughing, moving the wrist or hand, etc.) during stimulus exposure. When this occurs, the data become extremely “noisy,” making data analysis and data interpretation very challenging (Potter & Bolls, 2012). Indeed, it is possible that so few studies to date have applied psychophysiological measures to assess physiological responses to digital media use

for this exact reason. The fact that a cough or sneeze—not to mention typing a Facebook comment or holding a hand-held controller during a video game—can create noise during data collection is methodologically problematic. In fact, a few of the studies reviewed in this chapter alluded to this concern, noting that, despite careful data collection, filtering, and cleaning, there might be potential noise in the data given the instructions provided to participants (e.g., using one's hand and fingers to scroll Facebook with a computer mouse).

One recommendation to counteract this limitation is to collect data from other bodily sites, such as the foot for skin conductance (Potter & Bolls, 2012). However, this assumes the participant is sitting during the study. Thus, solutions as to how to collect peripheral psychophysiological responses wherein movement is required (e.g., virtual reality settings, video-game play, SNS use) are necessary in order to obtain clean and reliable data. Finding solutions for movement artifacts during data collection would allow researchers to apply psychophysiological measures to a broader range of digital media environments.

Conclusion

This chapter provided an overview of theoretical approaches to the study of emotion in the context of digital media with a focus on the application of peripheral psychophysiological measures. Thus, an overview of psychophysiological measures pertaining to arousal and valence was presented. It was also argued that psychophysiological measures of emotional valence and arousal should be triangulated with self-reported discrete emotions in order to obtain a more holistic picture of affective responses to using digital media. The chapter concluded with a presentation of studies applying psychophysiological measures to the study of digital media technologies (i.e., smartphones) and digital media platforms (i.e., SNSs). Despite a few limitations for the recording of psychophysiological responses in digital media studies, the future appears to be wide open in terms of potential research questions, study design, and measurement of psychophysiological responses in the study of emotion and digital media.

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