

**[CT] Inducing and Measuring Emotion and Affect: Tips, Tricks, and Secrets****[CA] Karen S. Quigley, Kristen A. Lindquist and Lisa Feldman Barrett**

Every person (barring those with a brain disorder) knows what it feels like to be moved by something – to feel energized or defeated, anxious or tranquil. Even without labeling these feelings, or being aware of them in an explicit way, such feelings exist as states of mind or can be observed in certain actions. In the Western views of the human mind that ground scientific psychology, such states are referred to as “emotional” or “affective” (as distinguished from “cognitive” or “perceptual”).<sup>1</sup> These two words – “emotion” and “affect” – have caused great confusion in the scientific literature because they are used by some authors to denote two different classes of phenomena, whereas others use these words interchangeably. In English, the word “affect” literally means “to produce a change,” whereas the word “emotion” derives from the French word “to stir up” and the Latin word “to move.” In psychological discourse, “affect” has sometimes been used to refer to free-floating feelings whereas “emotion” has referred to feelings in response to a specific triggering event (e.g., [James, 1890](#)). The word “affect” also has been used to refer to feelings that accompany emotions such as anger, sadness, fear, happiness, and so on, which are defined as physical states (e.g., [Panksepp, 1998](#)). “Affect” has been used as a general term to mean anything emotional (e.g., [Davidson, Scherer, & Goldsmith, 2003](#)), allowing researchers to

talk about emotion in a theory-neutral way. And sometimes “affect” is used to refer to hedonic valence and arousal (e.g., [Barrett & Russell, 1998](#); [Russell, 2003](#)) or to approach or avoidance action tendencies (e.g., [Lang, Bradley, & Cuthbert, 1990](#)) that are common to experiences and perceptions of emotion, as well as to refer to the motivating, engaging core of all mental states covering a range of psychological phenomena, including but not limited to emotion ([Barrett & Bliss-Moreau, 2009b](#)); in such cases, emotions are designated as discrete states of anger, fear, sadness, disgust, and happiness (plus a few others, depending on the theorist) in which affect is meaningfully linked to a situation in some causal way.

In this chapter, we review the typical methods that are used to create and measure the physical states and subjective feelings that researchers refer to as “affect” or “emotion,” keeping in mind the scientific distinction between these two constructions. We refer to “affect” as the properties of any mental state that can be described as pleasant or unpleasant with some degree of arousal ([Barrett & Bliss-Moreau, 2009a](#); [Russell & Barrett, 1999](#)). These properties correspond to brain representations of some change in the core autonomic and hormonal systems of the body (whether or not such changes actually take place). There is no widely accepted operational definition of emotion. Sometimes writers describe emotion as coordinated packets of experiences, physiological changes, and behavior, but this is nonspecific because every waking moment of life there are coordinated changes of this sort. Furthermore, there remains tremendous debate over which mental states count as emotion versus which do not (e.g., [Ortony & Turner, 1990](#)). In this chapter we take a simple approach: an “emotion” is a mental state to which people assign a commonsense name (like anger, sadness,

fear, disgust, happiness, and a handful of others like shame, guilt, pride, and so on); when someone uses an “emotion” label, it implies they have invoked conceptual knowledge about emotion to make sense of or to communicate their internal state. From our perspective, inducing emotion necessarily involves a change in affect (whereas changes in affect are not always transformed into emotions). This means that to make claims about emotion, it is necessary to ensure that findings do not simply reflect changes in valence or arousal. Furthermore, there are times when a scientist’s intention to evoke an affective change in a participant produces an unexpected change in an emotion (e.g., showing a participant an image of a dying person, which evokes a memory of a family member who died recently).

With these considerations in mind, we very generally review the variety of induction methods and measurement techniques that are used most frequently in social and personality psychology. For more detailed treatments, see the *Handbook of Emotion Elicitation and Assessment* (Coan & Allen, 2007) and the *Handbook of Affective Sciences* (Davidson et al., 2003). We highlight novel points related to inducing affect or emotions as *experiences* or *states* and discuss the most serious challenges that researchers face, the most serious being that at times the intent is to measure changes in *emotion* when the measurement tools only permit inferences about *affect*. Currently, there is no strong empirical justification for using any single objective measurement, or profile of measurements (in the face, body, or brain) to indicate when a person is in a state of anger, or fear, or sadness, and so on. People do not always scowl in anger, heart rate does not always go down in sadness, and people do not always freeze or

run in fear. Reviews of the empirical literature have reached this conclusion again and again over the past hundred years (Lindquist, Siegel, Quigley, & Barrett, in 2013). Yet it is possible to have a powerful and robust science of emotion, when induction methods are used judiciously and measurements are interpreted appropriately. This chapter is designed to help interested readers move forward in that direction.

### **A Methods for Inducing Affective Changes, Including Emotions**

We outline thirteen laboratory induction techniques that are the most frequently and successfully used laboratory-based inductions. A brief summary of each method is also presented in Table 10.1, including a description, prototypical references, and advantages and disadvantages of each method. For a more extensive Supplemental Table 10.1, see <http://www.affective-science.org/publications.shtml>. Because emotions are a subset of affective changes more generally, in principle, any stimulus that is used to induce affective changes (varying in hedonic valence and arousal) can also be used to evoke emotions (anger, sadness, fear, etc.) and vice versa, depending on the instructions given to the participant at encoding. Although we summarize methods typically used in the scientific literature for evoking affect more generally, and emotion more specifically, from our point of view it is possible to evoke an emotion whenever a stimulus or the context elicits conceptual knowledge about emotion (or when a perceiver is prompted to categorize a response as emotional either explicitly or implicitly using emotion words; we say more about this latter issue in the section on measuring emotion). Thus an emotion can be evoked, even when

the experimenter's intent is to evoke affect. Conversely, when such conceptualization is prevented, then a stimulus is likely to evoke an affective response (even when the experimenter's intent is to evoke emotion).

## **B**     **Films**

The entertainment industry knows that people will pay a lot of money to see a movie, precisely because movies powerfully influence momentary experience. Several scholarly works have proposed theoretical frameworks for understanding how films evoke affective and emotional changes (e.g., [Allen & Smith, 1997](#); [Tan, 2000](#); see [Table 10.1](#) for references to film clip sets). Films are easy to use. In the typical film-based induction, participants are seated in front of a blank television or computer screen and asked to relax for a 1–3-minute baseline period after which they view a film clip for 2–5 minutes on average. A downside is that participants will vary in their familiarity with the movie clips, which introduces variability as error variance (because familiarity can influence potency). Manipulation checks (after the film) should be performed with caution because presenting adjectives to a participant and having the participant rate his or her state with those words have the potential to transform an affective state into an emotional one, or to change one emotional state to another, over and above the impact of the induction itself. If attempting to induce a change in affect, consider using an affect-based rating scale like the Self-Assessment Manikin (SAM; [Bradley & Lang, 1994](#)) or a two-dimensional affect grid ([Russell, Weiss, & Mendelsohn, 1989](#)) as a manipulation check. With both measures, it is important to clearly define arousal (high vs. low activation), as this property is not identical to the intensity of experience, although the two are often confused (Kuppens,

Tuerlinckx, Russell & Barrett, 2012). Also, keep in mind that any rating has the potential to reduce the intensity of the induced change (e.g., Lieberman, Eisenberger, Crockett, Tom, Pfeifer, & Way, 2007), which in turn has the potential to reduce its subsequent influence on behavior. Even when inducing emotion, it is advisable to plan when and how to conduct a manipulation check. For instance, experiences of anger that are labeled as “anger” by participants have a different physiological response pattern than unlabeled experiences of anger (e.g., Kassam & Mendes, 2013). On the other hand, asking participants to retrospectively report their experience later in the experiment also has costs, because memory-based measures have their own biases (Robinson & Clore, 2002).

## **B Images**

In daily life, people seek out evocative images in magazines, newspapers, museums, or on the Internet. Researchers use images to induce an affective or specific emotional change in participants (see Table 10.1 for examples). Images from the International Affective Pictures System (IAPS; Lang, Bradley, & Cuthbert, 2008) are most frequently used in psychological research. The major benefit of these images as induction stimuli is that they are normed for affect in both younger (e.g., Ito, Cacioppo, & Lang, 1998; Lang et al., 2008) and older adults (Grühn & Scheibe, 2008), and some images have also been normed for discrete emotions (Libkuman, Otani, Kern, Viger, & Novak, 2007; Mikels, Frederickson, Larkin, Lindberg, Maglio, & Reuter-Lorenz, 2005). The images have also more recently been normed for distinctiveness, familiarity, and other

cognitive/perceptual features (Delplanque, N'diaye, [Scherer, & Grandjean, 2007](#); [Libkuman et al., 2007](#)).

In a typical picture induction study, participants are seated in front of a computer screen and shown a series of images, with each one presented for 2–7 seconds followed by an inter-stimulus interval of 50 milliseconds or more. Sometimes participants are shown a class of images in blocks to induce a single, sustained, evocative state (e.g., unpleasant: [Lynn, Zhang, & Barrett, 2012](#)). Other times, participants view IAPS images in random order and responses to each image are recorded. Participants can be asked to rate their own experience while viewing the slides (i.e., self-focused emotion), rate the affective or emotional quality of the slides (i.e., world-focused emotion),<sup>2</sup> or the researcher makes physiological recordings of autonomic nervous system activation and facial muscle movements. Inducing evocative states with visual images is easy and efficient. One major drawback of the IAPS slide set is that they do not sample all portions of affective space equally (there are very few slides to induce low-arousal positive and negative states and high-arousal neutral states). The few IAPS images that appear to be both highly arousing and neutral are only neutral by virtue of their mean ratings across individuals with large standard deviations (meaning that some people experience them as negative and others as positive). A related limitation is that there is considerable idiographic variation across individuals in their affective reactions to the images, although this is not well documented in published research other than by the standard deviations of slide norms. These limitations (uneven distribution of stimuli across the arousal and valence dimensions, and high idiographic variation) are not unique and likely

describe affective stimuli more generally. That being said, the IAPS images suffer from a third problem, namely that slides used to evoke pleasant (positive) changes tend to be less arousing than those evoking unpleasant (negative) changes.

Finally, IAPS images are also unimodal visual stimuli and do not have the multimodal richness of movies. A recent study found that pairing IAPS images with music was a particularly effective affect induction technique (Lynn et al., 2012), suggesting that future work could combine stimuli to increase the potency of inductions.

## **B** Faces

Posed depictions of emotion on the face (scowling faces symbolizing anger, pouting faces symbolizing sadness, etc.) are common in the published literature (see [Table 10.1](#) for references to face sets). Although faces are not routinely used to evoke emotional reactions, they can be used to assess the effect of affect or more specifically emotion on other psychological processes such as visual awareness (e.g., [Anderson, Siegel, & Barrett, 2011](#)). In a typical study, participants view digitized images of faces on a computer screen. Some investigators ask participants to watch the faces passively ([Lange et al., 2003](#); block 1), whereas others ask participants to make either emotional judgments of the face (e.g., [Critchley et al., 2000](#), Study 1) or non-emotional judgments (e.g., gender; [Critchley et al., 2000](#), Study 2). It is presumed that either passive viewing or rendering non-emotional judgments involves implicit processing of emotion, whereas labeling a face as emotional brings “online” explicit knowledge about the emotion. Like IAPS images, faces are easy to use in an experiment, but with the main disadvantage that it is not clear which psychological process they provoke.



For instance, there is evidence that individuals subtly move their own facial muscles when perceiving another person's facial actions (e.g., [Niedenthal, 2007](#); for a review, see Niedenthal, Mermillod, Maringer, & Hess, 2005), and consistent with this facial feedback hypothesis, some studies find evidence that viewing faces influences self-reported feelings ([Dimberg, 1988](#)). Yet it is unclear whether viewing a posed emotional expression induces the same emotion in a perceiver. For example, participants viewing scowling and smiling faces had increased activity in the corrugator supercilii and zygomaticus major facial muscle regions, respectively, but reported experiencing more fear in response to the angry faces and happiness in response to the happy faces ([Dimberg, 1988](#)). There are additional concerns with the use of posed, caricatured facial expressions that should make researchers cautious about using them for emotion induction purposes ([Barrett, 2011b](#); [Barrett, Mesquita, & Gendron, 2011](#)). The faces might be useful for priming emotion knowledge, however. Posed scowls, pouts, and the like are more like cultural symbols of emotions than inborn, reflexive signals of emotion per se ([Barrett, 2011b](#)), suggesting that viewing faces likely activates embodied knowledge about emotion concepts. This claim is supported by evidence that posed facial expressions produce increased activity in brain regions involved in semantic retrieval ([Lieberman et al., 2007](#); Lindquist, [Wager, Kober, Bliss-Moreau, & Barrett, 2012](#)). It is also bolstered by event-related potential (ERP) data showing that early potentials distinguish stimuli differing in valence (i.e., pleasantness and unpleasantness), but that later ERPs (i.e., after 300 msec when semantic information comes "online") distinguish discrete emotion categories ([Eimer & Holmes, 2007](#)).

In some studies faces are followed by a visual mask such that the face is presented very briefly followed by a picture of the same identity posing a neutral face (e.g., [Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike, 1998](#)) or a scrambled face ([Kim, Loucks, Maital, Davis, Oler, Mazzulla, & Whalen, 2010](#)). Such “backward masking” methods are thought to engage subliminal processing of emotional information, although the mask itself seems to influence how the face stimulus is processed (see [Kim et al., 2010](#)). Newer methods for subliminal presentation of faces, such as continuous flash suppression, offer a way of examining the impact of affective changes without the problems associated with backward masking. In continuous flash suppression, two visual images are simultaneously presented via a stereoscope, one image to each eye. One image is static while the other is interleaved in a variety of images that flash and change during brief presentations over the trial. Conscious awareness of the static image is suppressed, and participants only see the flashing images. The unseen image is encoded, however, and has an affective impact that then is misattributed to the affective value of the “seen” image, which is usually objectively neutral ([Anderson, Siegel, White, & Barrett, 2012](#)).

## **B** Sounds/Voices

Both the acoustical properties of a sound (e.g., its pitch and variation) and its representational meaning (e.g., whether it is the sound of bees, an ambulance siren, or a human voice) evoke affective and emotional changes in perceivers. Specific acoustical properties have the capacity to directly affect the nervous system of the perceiver ([Bachorowski & Owren, 2008](#)), whereas other sounds have affective potency because of their conceptual meaning. For example, a

gentle buzzing sound might be soothing with prior experiences of bees in a garden, but terrifying if you have been stung by a swarm of bees. The most frequently used sounds for inducing evocative states are the International Affective Digitized Sounds (IADS; [Bradley & Lang, 2007](#)) that have been rated in terms of their ability to evoke changes in hedonic valence and level of arousal (see [Table 10.1](#)). Participants usually listen to digitized sounds through speakers or headphones. Like other digitized stimuli, sounds are easy to administer. Their major drawback is that, like faces, it is not always clear which psychological processes they provoke (e.g., are they inducing autonomic changes alone, conceptual changes, or both?). Some require conceptual processing for their effects and others do not.

There are even more complex issues to consider with vocal stimuli than with other sounds. Although some researchers hypothesize that emotional content is carried by the prosody of a voice ([Patel, Scherer, Bjorkner, & Sundberg, 2011](#)) or vocal utterances (Simon-Thomas, [Keltner, Sauter, Sinicropi-Yao, & Abramson, 2009](#)), other data suggest that such sounds only carry information about the arousal of the speaker ([Bachorowski & Owren, 2008](#); [Russell, Bachorowski, & Fernandez-Dols, 2003](#)). If true, then such stimuli are useful for studying affect rather than emotion per se. In practice, most vocal stimuli are not used to induce an evocative state but are instead used to study emotion perception (i.e., where participants evaluate the emotional or affective meaning of the stimulus). However, models of primate vocal communication suggest that such vocal stimuli shift the affective state of the perceiver ([Owren & Rendell, 1997](#)), so it is possible that these stimuli induce a change in affective state in perceivers.

The affective or emotional impact of vocal sounds might also vary depending on whether the vocalizations are produced by physiological changes occurring in the speaker, or whether they are volitionally produced even in the absence of changes in affective experience (Owren, Amoss & Rendell, 2011; Scherer, 1995; Scherer, Johnstone & Klasmeyer, 2003), although this distinction remains understudied.

## **B Music**

Music is a specific kind of sound used to induce affect and emotion (Juslin & Laukka, 2003; Juslin & Sloboda, 2001). In some studies, music is used alone (e.g., Tamir & Ford, 2009), but in other studies it is often paired with another type of induction stimulus, such as pictures (e.g., Lynn et al. 2012) or imagery (e.g., Eich & Metcalfe, 1989). The Continuous Music Technique (CMT; Eich, 1995; Eich & Metcalfe, 1989) is a well-known affect induction (see Table 10.1). A major advantage of the CMT is that music continues to play throughout the experiment, which extends the duration of the evocative state (Lindquist & Barrett, 2008) and permits the participant to simultaneously perform another task. The major disadvantage of this technique is that it is relatively ineffective for inducing specific emotions, although it can robustly induce affective states. For example, the CMT does not reliably induce distinctive states of anxiety and anger (both unpleasant, highly aroused states), but it reliably induces an unpleasant, highly aroused state, a pleasant state, and a neutral state (see Lench, Flores, & Bench, 2011, table 4).

## **B Imagery and Recall**

Imagery and recall are not only used in conjunction with music (e.g., Eich & Metcalfe, 1989), but they can also be used on their own as an effective method for

inducing affect and emotion (Lench et al., 2011). Neuroimaging evidence has demonstrated that imagining the future, remembering the past, and creating fictitious imaginings recruit a similar network of brain regions (e.g., Spreng, Mar, & Kim, 2008), suggesting that memory and imagery rely on similar psychological mechanisms that involve retrieval of embodied information from the past. These same brain regions show an increase in activation during the experience of emotion (Kober, Barrett, Joseph, Bliss-Moreau, Lindquist, & Wager, 2008), consistent with our hypothesis that prior experience is important for creating emotional states from simpler affective changes (Barrett, 2006b; Barrett & Bliss-Moreau, 2009b), indicating that imagery and recall are valid ways to induce affect or emotion. For example, the “scenario induction” technique has been successfully used to evoke a variety of emotional experiences during brain-imaging experiments (Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011). Indeed, people frequently engage in “mental time travel” throughout the day, during which they remember emotional events from their past, or imagine emotional events to come in the future, and the resulting affective changes are more potent than those induced by the person’s immediate circumstances (Killingsworth & Gilbert, 2010). One of the major benefits of the mental imagery and recall techniques is their relative ease of use. A potential drawback is that participants differ in the ability to engage in mental imagery (e.g., Marks, 1973).

## **B** Words

Since Osgood’s classic work (e.g., Osgood, Suci, & Tannenbaum, 1957), it has been well known that words have affective connotations, and therefore should have the capacity to produce affective changes in a speaker or a listener. There

are standardized sets of evocative words, including the Affective Norms for English Words (ANEW; [Bradley & Lang, 1999](#); see [Table 10.1](#)). In a typical experiment, words are presented to participants either supraliminally (i.e., for a second or longer) or subliminally (i.e., latencies under 50 msec) on a computer screen to prime affective content without participants' conscious awareness ([Bargh, 2004](#); also see Bargh and Chartrand, Chapter 13 in this volume). Affective primes have been shown to be generally effective, although affective priming scores have only low to moderate reliability, which can lead to inconsistency in effects across studies (for review see De [Houwer, Tegie-Mocigemba, Spruyt, & Moors, 2009](#)). Also, as noted in the meta-analysis by Lench, Flores, and Bench (2011), priming manipulations have relatively small effect sizes. Furthermore, a method like the sentence-unscrambling task, in which participants reconstruct a set of scrambled words into an emotional sentence, does not, in and of itself, alter emotional state ([Innes-Ker & Niedenthal, 2002](#)).

Of all the evocative stimuli used for induction purposes, words are perhaps the easiest to present because they do not require special technology (i.e., even a piece of paper will suffice). It is important to recognize that, like faces and voices, words evoke both changes in representations of the body that are experienced as affective (e.g., [Lewis, Critchley, Rotshtein, & Dolan, 2007](#)) but they also require conceptual processes involved in word recognition and comprehension. Consistent with this view, neuroimaging evidence indicates that words are represented as “embodied” – that is, as reenactments of prior sensory and motor experiences (Kan, [Barsalou, Solomon, Minor, & Thompson-Schill, 2003](#)). Despite these findings, meta-analytic evidence suggests that, on average,

presenting participants with evocative words can induce anxiety, although this might not be sufficient to induce other evocative states (see [Lench et al., 2011](#), table 4). Like faces, words might be better used as primes to activate conceptual knowledge than as a means to induce feelings per se.

## **B** Bodily Movements and Posture

Given the recent emphasis on the role of simulation and embodiment in emotion (e.g., [Niedenthal, 2007](#)), it seems reasonable that bodily movements and posture could be used to evoke affect generally and emotion more specifically. For example, the facial feedback hypothesis states that feedback from contraction of specific facial muscles provides affective information to the central nervous system about the affective state being expressed which is then interpreted (see [McIntosh, 1996](#)). Early studies utilizing facial movements to induce affect were criticized because of the strong demand characteristics of the task, which meant that participants could have used conceptual knowledge rather than the physical aspects of the task to report an emotion state consistent with the face posed (e.g., [Zuckerman, Klorman, Larrance, & Spiegel, 1981](#)). To address this concern, [Strack et al. \(1988\)](#) developed a paradigm that believably altered facial muscle activation without invoking conceptual knowledge about emotion by asking participants to hold a pen in their pursed lips, which covertly prevented muscle activation consistent with a smile, or between their teeth, which activated muscles associated with a smile. For other recent uses of this paradigm, see [Supplemental Table 10.1](#) at <http://www.affective-science.org/publications.shtml>. Beyond moving facial muscles, postural and other gross bodily movements have also been used to induce changes in affective state or, more commonly, to alter affective

judgments of stimuli (i.e., world-focused affect). A smaller number of studies have used overall changes in bodily posture (along with careful cover stories to avoid demand characteristics) to directly alter a participant's emotional state (e.g., [Stepper & Strack, 1993](#)) and in some cases postures changed brain activity consistent with an approach or avoidance motivational state (e.g., [Harmon-Jones & Peterson, 2009](#)). Combining bodily manipulations across multiple body systems (e.g., facial changes with postural changes with imagined or presented evocative stimuli) might further intensify the potency of such manipulations (e.g., [Flack, Laird, & Cavallaro, 1999](#); but see [Price & Harmon-Jones, 2010](#)).

## **B** Physiological Manipulations

The classic work of [Schachter and Singer \(1962\)](#) demonstrated how pharmacological manipulation of physiological arousal (with injections of epinephrine or placebo) altered the experience of anger versus happiness (depending on a confederate's behavior when the arousal symptoms were unexpected), and changed the participant's behavior (e.g., participant agreed/disagreed with the confederate, or engaged in behaviors initiated by the confederate). Although these findings were interpreted as evidence that social affiliation influenced the construction of anger or happiness specifically, the observed changes are also consistent with a simple manipulation of hedonic valence.<sup>3</sup> Other physiological manipulations, such as caffeine, have resulted in weak or no affect-altering effects (and any affective impacts may be attributable to caffeine withdrawal; [James & Rogers, 2005](#)). Exercise provides perhaps the most well-characterized way to manipulate peripheral physiological arousal producing an affective change (e.g., [Ekkekakis, Parfitt, & Petruzzello, 2011](#)). For



example, when exercise intensity reaches the exerciser's own ventilatory threshold (i.e., beyond which exercise becomes increasingly anaerobic instead of aerobic), individuals switch from reporting a positive affective state to a negative one (Ekkekakis et al., 2011). Other work has shown that a brief (i.e., 5-minute) bout of cycling exercise alone did not have an affective impact (Tomaka, Blascovich, Kibler, & Ernst, 1997), perhaps because the physiological arousal induced by exercise must be of longer duration to alter subjective experience of affect, which suggests that endocrine or other bloodborne effects of increased arousal may be critical for a successful induction of this sort.

Although physiological manipulations of affect can be quite potent, they come with the distinct disadvantage that many require considerable expertise to administer and extensive precautions for their safe use, and thus are relatively scarce in the psychological literature. Oxytocin, for example, is administered intranasally in humans, and has recently emerged as a potential way to manipulate affect. It has been shown to decrease arousal ratings of visual images of human, but not animal, threat stimuli (Norman et al., 2011). Much of the research to date has investigated the effects of oxytocin on the perception of affect and emotion (e.g., Gamer, Zurowskis, & Buchels, 2010) rather than on emotion induction, but the work by Norman et al. (2011) suggests it may be a promising affect inducer or modulator, although perhaps only in the presence of social stimuli (for a review, see Norman, Hawkley, Cole, Berntson, & Cacioppo, 2011).

Botulinum neurotoxin-A (i.e., botox), used cosmetically to reduce facial wrinkles, is a peripheral physiological method for changing affect. Most commonly, botox injections into the corrugator supercillii muscle region (i.e.,

“scowl” muscles) have been used to alter affective ratings of evocative videos (Davis, Senghas, Brandt, & Ochsner, 2010) and decrease depression (Finzi & Wasserman, 2006). Botox injections to the corrugator region also decreased activation in the left amygdala when individuals imitated scowling facial expressions, and more generally decreased coupling between the amygdala and dorsal brain stem areas responsible for autonomic efferent activity (Hennenlotter, Dresel, Castrop, Ceballos-Baumann, Wohlschläger, & Haslinger, 2009).

Emerging methodologies for directly manipulating brain activity are expanding the potential to manipulate affect via the central nervous system. For example, “real time functional magnetic resonance imaging” (rtfMRI) allows researchers to detect (with fMRI) and provide feedback to a person about their ongoing brain activity as they experience a mental state (e.g., Weiskopf, Veit, Erb, Mathiak, Grodd, Goebel, & Birbaumer, 2003; Yoo & Jolesz, 2002). With feedback, participants gain the ability to regulate activity in brain regions associated with affect such as the insula (e.g., Caria, Veit, Sitaram, Lotze, Weiskopf, Grodd, & Birbaumer, 2007) or related areas such as the anterior cingulate cortex to modulate the experience of pain (DeCharms et al., 2005). Also, the future will likely bring greater use of transcranial magnetic stimulation (TMS) in which a magnetic pulse is used to temporarily activate or disrupt activity in certain brain areas. Here, researchers measure experiential or behavioral changes when a brain area is temporarily stimulated or taken “offline.” For instance, a study used TMS of the anterior temporal lobe that is thought to support semantic judgments, among other things, to show that participants were significantly slower to complete a task that required them to find a matching

synonym in a set of words than in a control task of similar difficulty (Lambon [Ralph, Pobric, & Jefferies, 2009](#)). To date, TMS has been used to study the perception of facial expressions ([Pitcher, Garrido, Walsh, & Duchaine, 2008](#)), motor cortex excitability during affective picture viewing ([Hajcak, Molnar, George, Bolger, Koola, & Nahas, 2007](#)), and approach-avoidance tendencies (Schutter, de Weijer, Meuwese, Morgan, & van [Honk, 2008](#)).

## **B Confederates**

[Schachter and Singer \(1962\)](#) published arguably the most famous emotion study to utilize confederates, but labs have been using scripted confederates to induce emotion or affect for the past several decades (see [Table 10.1](#); [Cohen, Nisbett, Bowdle, & Schwarz, 1996](#); DeSteno, [Bartlett, Baumann, Williams, & Dickens, 2010](#)). Confederates typically produce impactful changes in induce affect and emotion. Designs using confederates are labor-intensive, however, involving lots of practice to ensure that confederates are convincing and that their behavior is the same across participants. In addition, researchers must attend to such details as controlling the confederate's vocal prosody and nonverbal behaviors, and carefully scripting the confederate's behavior and words. Use of additional lab equipment (videotape or microphone) helps a researcher ensure that every administration is as similar as possible.

## **B Motivated Performance Tasks**

In a motivated performance task, participants give an impromptu speech in front of an audience (Trier Social Stress Test or TSST; [Kirschbaum, Pirke, & Hellhammer, 1993](#)) or complete serial subtraction problems in the presence of an evaluative experimenter (e.g., [Quigley, Barrett, & Weinstein, 2002](#)) to produce

high arousal affective states and alter autonomic nervous system activity. (See [Table 10.1](#) for variations on these methods.) The advantage of motivated performance tasks is that they are ecologically valid and both subjectively and physiologically evocative. The robust nature of motivated performance tasks can also be a disadvantage because certain participants (particularly those with social anxiety or low self-esteem) might find them excessively distressing and may even disengage from the task altogether. Researchers must therefore take precautions at screening and also use methods for detecting when an individual has disengaged and is no longer performing the task.

## **B Virtual Reality**

In virtual reality, participants (or players) are presented with digital (and sometimes photorealistic) images of what looks like real-world people, objects, scenes, and events, which are combined with tracking of the player's movements to allow her or him to become immersed in and interact with this artificial world as if it were real. Virtual reality allows a person to immerse themselves in a social situation or a scene in a first-person way (as opposed to viewing the scene in a third-person way) – a distinction that appears to have specific neural correlates (e.g., [Ochsner, Knierim, Ludlow, Hanelin, Ramachandran, Glover, & Mackey, 2004](#); [Ruby & Decety, 2004](#)). Although virtual reality has great potential as an affect and emotion induction method, this method is, thus far, used rarely. A notable exception is Project EMMA (Engaging Media for Mental Health Applications) in Spain that examines how emotion contributes to “presence” (feeling part of, or immersed in) of a virtual environment. Here, a virtual urban park with multisensory features (e.g., sounds, sights, different kinds of affective

stimuli) is used to induce changes such as anxious, relaxed, or neutral affective states (Riva et al., 2007). For details and a use of these methods for another application, psychotherapy, see Table 10.1. Computer-based virtual reality, other immersive technologies like augmented reality in which photorealistic objects are combined with computer-simulated environments and/or objects, and other related technologies, like gaming, are likely to radically change affect and emotion research (for an excellent and accessible look at this revolution, see Blascovich & Bailenson, 2011). Blascovich et al. (2002) enumerated the methodological advantages of virtual-reality-based studies for social psychological research including research in emotion and affect (see Table 10.1). These methods are likely to provide a potent way to induce affect or emotion because the human brain is wired to “travel” to virtual worlds (using the “default” network) in the form of remembering the past, imagining the future, and mind wandering beyond one’s current circumstances (Andrews-Hanna, Reidler, Huang, & Buckner, 2010). In some ways, imagination is a low tech type of “virtual reality” that appears to rely on the same brain circuitry.

## **B Real-World Stimuli**

Researchers have used spiders, snakes, participation in extreme sports, foods or other substances, pain stimuli, and odors or other chemosensory stimuli to induce affect and emotional changes (see Table 10.1 for methods). Experience-sampling methods (also known as diary methods, ecological momentary assessment, or ambulatory assessment) are useful for tracking these real-world objects and events that have the capacity to induce affective and emotional changes. Details on experience-sampling methods, supporting technology, and analysis methods

for the interested reader can be found in Mehl and [Conner \(2012\)](#) and in Reis, Gable, and Maniaci, Chapter 15 in this volume.

### **A Measuring Evoked States**

Measuring general affective and more specific emotional changes is complex and fraught with difficulties. A persistent challenge is that many researchers implicitly use the measurement model depicted in Figures 10.1a or 10.1b (called an effect-indicator model), which is consistent with classical measurement theory (cf., [Barrett, 2000](#); [Barrett, 2006a](#), 2011a). In this view, a stimulus triggers a latent emotional state indexed by a set of measured variables that are strongly correlated with one another (because of their common cause). In such a model, an emotion, such as anger, would have a characteristic facial expression (e.g., a scowl), a characteristic body change (e.g., an increase in heart rate with an increase in blood pressure), and a characteristic change in subjective experience (e.g., fury), and each of these measures would be strongly correlated with one another (because of their common, latent cause). Each emotion category is assumed, in essence, to be a psychological “type” with a biological core. If emotions worked this way, then it would only be necessary to measure one observable (e.g., facial muscle movements, cardiovascular changes, or self-reports of experience) because the others would be redundant with it (being so highly correlated). Although the evidence is strongly suggestive that measurements of valence taken across different measurement modalities do correlate with one another, as do different measures of arousal, and that positive affect seems to have a distinct profile from negative affect, it is now well known that the same cannot be said for anger, sadness, fear, disgust, or happiness as discrete emotional states ([Barrett,](#)

2006a; Cacioppo, [Berntson, Larsen, Poehlmann, & Ito, 2000](#); [Lindquist et al., 2012](#); [Mauss & Robinson, 2009](#)). Given the tremendous variation in instances within an emotion category (such that sometimes blood pressure goes up, sometimes it does not; sometimes a person approaches, at other times they withdraw), it is necessary to capture and model individual emotional instances.

[Insert Figure 10.1a and 10.1b here]

An alternative to the effect indicator model of emotion is to measure multiple modalities within a single study and combine them using a causal indicator model (see Figure 10.1c for the formal model and Figure 10.1d for an exemplar model; as explained by Barrett [2000](#), [2011a](#); [Coan 2010](#)). In this measurement approach, measures are not expected to correlate with one another, but instead their aggregate realizes or constitutes an instance of the latent construct in question (for a discussion of latent constructs using the “causal indicator” approach, and how these latent constructs differ theoretically from those estimated with the more popular and familiar “effect indicator modeling” approach, see [Barrett, 2011a](#); [Bollen & Lennox, 1991](#)). By definition, in the causal indicator approach, instances of emotion within the same emotion category can vary from one another without violating the assumptions of the latent construct model. Furthermore, an instance of emotion can only be measured using more than one measurement modality, and using only one measure (e.g., skin conductance) constitutes a violation of the measurement model. This approach (which is usually applied to modeling socioeconomic status, for example) is well suited to the study of emotion where subjective reports, physiological measurements, and behavioral observations rarely, if ever, strongly correlate

(Barrett, 2006b). For measures, references, and the major advantages and disadvantages of each set of measures, see Table 10.2 and a more extensive Supplemental Table 10.2 at <http://www.affective-science.org/publications.shtml>.

[Insert Figure 10.1c and 10.1d here]

## **B Facial Muscle Activity**

Facial electromyography (or facial EMG) measures facial muscle activity that varies as a function of whether someone is in a pleasant or an unpleasant state. Interestingly, because the skin serves as a low pass filter of the muscle activations occurring beneath the skin's surface, very small changes in facial EMG can be detected that do not necessarily result in externally observable movement of the features of the face (e.g., Cacioppo, Bush, & Tassinari, 1992; Cacioppo, Petty, Losch, & Kim, 1986; Tassinari & Cacioppo, 1992). Thus, facial EMG provides a tool for detecting very subtle facial muscle activation even if the participant later inhibits or otherwise aborts the full expression of an initiated facial response. A meta-analysis by Cacioppo et al. (2000) showed that facial EMG can frequently though not invariantly distinguish pleasant from unpleasant affective states (e.g., Cacioppo, Martzke, Petty, & Tassinari, 1988). Unpleasant affective states are most likely to be associated with increased activation over the corrugator supercillii muscle region (e.g., Schwartz, Fair, Salt, Mandel, & Klerman, 1976), whereas pleasant affective states are most likely to be associated with activation over the zygomaticus major muscle region (e.g., Harmon-Jones & Allen, 2001). However, there are no consistent and specific facial EMG-based “signatures” for specific emotion states such as anger, fear, or disgust (for reviews, see Barrett,



2011b; Russell et al., 2003), despite the fact that posed expressions are used in emotion perception research.

## **B Vocal Acoustics**

Vocal acoustics (i.e., the auditory parameters of a person's speech) are sometimes used to index a person's affective state, particularly the sender's level of arousal (for a review, see Bachorowski & Owren, 2008). Although some researchers argue that certain patterns of vocal acoustics correspond consistently and specifically to certain emotional states (e.g., Patel et al., 2011), other summaries of the literature refute that claim (e.g., Russell et al., 2003). Even studies claiming that specific vocal acoustics differentiate emotions tend to find evidence for more basic underlying dimensions that characterize the vocal acoustics across emotions. Patel et al. (2011) recently found three dimensions corresponding to the physiological processes involved in the production of vocal sounds (e.g., one dimension characterized by pressure on the subglottis and vocal fold adduction, one by the quality of vocal fold adduction, and one by either low or high mean frequency of the vocal output). At least one of these dimensions (subglottal pressure/vocal fold adduction) seems related to arousal because it distinguishes sounds made during the experience of relief from sounds made during joy, anger, and fear (Patel et al., 2011). Measures of vocal acoustics provide an observer-independent assessment of affective or emotional state. As with several of these measures, however, assessing vocal acoustics requires specialized equipment and expertise (see Table 10.2).

## **B** Observer Ratings

Researchers often attempt to measure emotion in the laboratory by asking trained or untrained raters to infer a participant's mental state by observing his or her behavior. Implicit in asking a perceiver to make such judgments assumes that each emotion has a prototypical expression displayed in the face, voice, or body for all the world to see (i.e., it is assumed that faces, voices, and body movements are "read-outs" or "signals" of an emotional state). The majority of studies reporting that non-expert perceivers are able to "recognize" emotional behaviors typically have experimental methods that include contextual constraints that lead to a higher percentage of judgments that agree with the experimenter's expectations (such as providing a limited number of emotion words and having perceivers choose the relevant term from this smaller set; for evidence on the importance of emotion words in producing accurate emotion perceptions, see Barrett, Lindquist, & Gendron, 2007; Barrett et al., 2011; Gendron, Lindquist, Barsalou, & Barrett, in press; Lindquist & Gendron, 2013). Often perceivers are asked to distinguish two emotions that differ in valence (e.g., anger vs. happiness) or arousal (e.g., anger vs. sadness), such that affective distinctions are actually driving the observed effects and it cannot be concluded that emotion differences are present. Of note, facial expressions usually occur only when another person is present (e.g., Fernández-Dols & Ruiz-Belda, 1995; Russell et al., 2003) or in the implied presence of another person (Fridlund, 1991). This suggests that facial expressions are more like communicative symbols than signals of specific mental states (see Barrett, 2011b).

## **B Behavior**

When using behaviors to index the internal state of a participant, it is important to remember that doing so is essentially a formalized instance of theory of mind. Just as all human perceivers infer intentionality, desires, goals, and personality traits to other humans by observing their behavior (Malle & Holbrook, 2013), experimenters infer these mental states in their participants. In experiments that aim to measure emotion, experimenters typically rely on prototypical scripts to link behaviors to mental states, with the underlying assumption that a given behavior indicates the presence of a single emotion category. This assumption is hard to justify in mammals, which have considerable behavioral flexibility and tremendous behavioral variability within any emotion category (e.g., aggression or withdrawal could indicate fear). For example, rats do many things in threatening or dangerous situations that could correspond with fear; they freeze (e.g., LeDoux, Iwata, Cicchetti, & Reis, 1988), startle (e.g., Hitchcock & Davis, 1987), avoid the threat (e.g., Vazdarjanova & McGaugh, 1998), or attack (e.g., Blanchard, Hori, Rodgers, Hendrie, & Blanchard, 1989), and each of these so-called fear behaviors is produced by a distinct neural circuit and has distinct autonomic nervous system correlates that prepare the body for action. The specific behavior emitted fits the immediate situation with which the animal must cope. Similarly, when measuring emotional behavior in humans, we need to consider a priori which behavior will best allow the participant to cope with the constraints of the experimental situation, which may or may not be the same as the “prototypic” emotional behavior prescribed by the script. The same holds true

for measuring affect – if the situation demands it, people can approach even when threatened ([Jamieson, Koslov, Nock & Mendes, 2013](#)).

## **B Autonomic Nervous System Activity**

For more than a century, scientists have attempted to use psychophysiological measures to assess affect and emotion. These measures (e.g., changes in heart rate or blood flow) are often controlled by both the sympathetic nervous system, which when activated, often results in greater arousal, and the parasympathetic nervous system, which when activated, often results in reduced arousal. Most scientists agree that autonomic changes are integral to affect and emotion. Yet it is important to realize that many non-affective or non-emotional states (e.g., involving attention, mental effort, etc.) also result in autonomic changes.<sup>3</sup> In fact, both branches of the autonomic nervous system are involved in energy management (i.e., the sympathetic nervous system, when activated, results in greater catabolic activity or greater use of energy stores, and the parasympathetic nervous system, which, when activated, results in greater anabolic or energy-conserving processes). Similarly, cortisol, often considered a “stress” hormone in the psychological literature, is important for managing metabolic activity in the body. This observation implies that changes in affect and emotion have direct implications for energy balance and maintaining homeostasis.

Certain “myths” about the autonomic nervous system prevail in the emotion and affect literature and have led to misperceptions, methodological problems, and unwarranted inferences when interpreting results (see [Table 10.3](#)). Perhaps the most important misconception is that discrete emotions like anger, sadness, fear, disgust, and happiness can be distinguished by consistent and

specific autonomic signatures. [Cacioppo et al. \(2000\)](#) provided a thorough meta-analysis of the then-extant literature on the psychophysiology of emotion, which, along with other recent reviews (e.g., [Barrett, 2006b](#); [Lindquist et al., in press](#)), suggested that there are no consistent and specific autonomic signatures for discrete emotions, although autonomic measures can sometimes distinguish a person in a positive versus negative state ([Cacioppo et al., 2000](#)), a threat versus a challenge state ([Quigley et al., 2002](#); [Tomaka, Blascovich, Kibler, & Ernst, 1997](#)), or whether someone is highly aroused or not ([Bradley, Codispoti, Cuthbert, & Lang, 2001](#)). Other summaries of the literature note that it is important to consider situational context when interpreting the emotional meaning of autonomic changes ([Kreibig, 2010](#)).

When using psychophysiological measures, researchers should carefully consider the epoch over which the affective or emotional response is measured. Autonomic responses in the laboratory typically will have the largest amplitude when an affective event is initiated, and often (but not always) amplitudes diminish as the stimulus continues. Because autonomic changes are the predominant means by which the body produces the initial, fast changes in a peripheral organ like the heart or lungs (i.e., on the order of milliseconds to seconds), autonomic effects will predominate over these shorter time periods. Slower-acting physiological systems (e.g., endocrine or immune changes) will predominate when stimuli are extended (e.g., minutes to hours). Physiological systems also have a dynamic range (i.e., minimum to maximum) under normal physiological conditions. If the basal state of autonomic activation is near one end of the physiological range, there can be physiological constraints on reactivity,

which must be considered. For example, if an individual's basal heart rate is near either end of the dynamic range of one of the autonomic branches, as might occur for heart rate when a person is standing (i.e., where basal sympathetic activity is high, see [Berntson, Cacioppo, & Quigley, 1993](#)), then an affect induction may not be able to cause any further sympathetically mediated increase in heart rate (for a discussion, see [Berntson, Cacioppo, & Quigley, 1991](#)). It is also important to eliminate or statistically control for substances participants may have ingested that can impact their autonomic responses to affective stimuli. Examples include medications and non-medicinal substances like alcohol, caffeine, or illicit drugs. In addition, researchers should screen for chronic diseases and acute illnesses that could impact autonomic function either directly (e.g., diabetes or heart disease) or because medications commonly used to treat these diseases have autonomic effects (e.g., asthma). Even in young, healthy participants, these precautions will reduce variability and enhance the researcher's ability to detect affectively induced autonomic changes, which is critical given the notoriously high variability of physiological measures.

## **B Central Nervous System Activity**

Affect can be measured by recording electrical, metabolic, or hemodynamic changes in the brain and researchers consistently attempt to use these measures to measure emotion. The use of these methods in the science of affect and emotion is hotly debated because they rely on “reverse inference,” or the idea that it is possible to infer a mental state from the measurement of a physical state (see note in [Table 10.3](#), Myth 3 concerning the same issue when making psychophysiological inferences; see also Cacioppo & [Tassinari, 1990](#)). Different

measures (e.g., electroencephalography [EEG], event-related potentials [ERPs], magnetoencephalography [MEG], functional magnetic resonance imaging [fMRI], and positron emission tomography [PET]) provide somewhat different information about brain activity, and there are common misperceptions about what can be inferred about affect and emotion with these methods. Because both electrical and magnetic measurements of changes under the scalp's surface (EEG/ERP and MEG, respectively) have some spatial imprecision, they can only localize the source of signals to larger brain areas (i.e., relative to fMRI, which is better at localizing activation to more specific coordinates in space); MEG has slightly better spatial resolution than EEG/ERP, because magnetic fields are less distorted by the skull and scalp than are electrical fields (Cohen, Nisbett, Bowdle, & Schwarz, 1990; Leahy, Mosher, Spencer, Huang, & Lewine, 1998). This poor spatial specificity makes it hard to localize the signal to specific brain structures or spatial locations in the brain (which, when known, can be useful for understanding what psychological processes might be invoked during a given experiment). Although it has limited spatial resolution, the temporal resolution of EEG and MEG is on the order of milliseconds. Thus, EEG/ERP and MEG are ideal for revealing the time course of affective and emotional events, but less suited for spatial localization than fMRI or PET. The hardware costs and physical space constraints are fewer for EEG, so it has benefits over MEG in this regard.

Compared with studies using fMRI or PET, relatively fewer studies have used EEG/ERP to investigate changes in affective or emotional experiences, and even fewer have used MEG (although see, e.g., Morel, Ponz, Mercier, Vuilleumier, & George, 2009). Perhaps the best-known series of studies to use

EEG to investigate emotion have assessed the lateralization of responses to pleasant and unpleasant affect. These studies generally link pleasant affect to relatively greater electrical activity in the left frontal lobe and unpleasant affect to relatively greater activity in the right frontal lobe (Ahern & Schwartz, 1985; Davidson, Ekman, Saron, Senulis, & Friesen, 1990). Studies have also assessed the lateralization of anger experience (e.g., Harmon-Jones & Allen, 1998, 2001). More commonly, researchers use ERP methods to study emotion perception (as participants are viewing posed, caricatured facial expressions, e.g., a scowl for anger, a pout for sadness, etc.). The evidence from these studies suggests that early ERPs (80–180ms) reflect the categorization of a face as a face (vs. non-face), as generally affective (neutral vs. valenced), as positively versus negatively valenced, or as displaying some degree of arousal (Eimer & Holmes, 2007; Palermo & Rhodes, 2007). Other studies find that later components (peak activations up until 230 msec) are differentially sensitive to anger and fear faces that are incongruously paired with fear and anger body postures (Meeren, Van Heijnsbergen, & DeGelder, 2005). These findings suggest that these later components reflect a distinction between discrete emotions, because a person would have to perceive that faces were depicting anger versus fear in order to experience the face and body postures as incongruous in this task. Of interest, the time window required for distinguishing among different discrete emotions is approximately the same as that required for semantic processing of other visual stimuli (e.g., Schmitt, Münte, & Kutas, 2000).

As discussed by Berkman, Cunningham, and Lieberman (Chapter 7 in this volume), fMRI measures hemodynamic activity in the brain (i.e., blood flow



inferred from changes in blood oxygen levels), and PET is a measure of metabolic changes (i.e., most commonly, glucose metabolism), which can be assessed during affective or emotional tasks. Relative to MEG or EEG, fMRI and PET have poorer temporal resolution because there is a lag of several seconds between stimulus onset and resulting hemodynamic or metabolic changes (e.g., the hemodynamic response reflects not only blood flow changes to a given stimulus, but also the influences of whatever occurred for about 32 seconds beforehand). However, fMRI and PET have better spatial resolution, and are thus better for studies concerned with the spatial location of neural activation during evocative events. A growing number of studies have investigated the brain basis of affect and emotion predominantly using fMRI. Emerging meta-analytic evidence indicates that positive and negative affect show different patterns of neural activity, although different meta-analyses do not consistently agree on what those differences are ([Kringelbach & Rolls, 2004](#); [Wager et al., 2008](#)). Analyses generally agree, however, that discrete emotional states such as anger, sadness, fear, disgust, and happiness do not show consistent and specific increases in neural response during the experience of discrete emotions ([Lindquist et al., 2012](#), although see [Vytal & Hamann, 2010](#), for a different perspective). Instead, fMRI/PET data support the idea that there are a set of more fundamental psychological building blocks that, in combination, give rise to the variety of discrete emotional states ([Barrett, Mesquita, Ochsner, & Gross, 2007](#); [Kober et al., 2008](#); [Lindquist et al., 2012](#)).

## **B Endocrine, Immune, and Inflammatory Changes**

A growing number of studies use changes in endocrine, immune, or inflammatory markers in an attempt to measure affect or emotion. Endocrine, immune, and inflammatory measures provide a broader assessment of peripheral physiological change and can be obtained alongside more traditional autonomic nervous system measures. They do, however, have the distinct disadvantages of being expensive and potentially difficult to obtain in the typical psychology lab, require control over multiple extraneous variables (at minimum, statistically, for factors like time of day or when the person last ate), and require considering how to minimize the possibility that taking a sample itself will induce an affective change (e.g., pain from a needle stick or disgust induced by providing a saliva sample). Endocrine and immune system changes occur on the order of minutes to hours, making their temporal features less optimal for detecting the typically fast (i.e., milliseconds to seconds) and frequently more fleeting changes evoked by affective or emotional stimuli.

## **B Subjective Experiences**

In principle, it should be possible to use objective measures of emotion (in the face, body, or brain) to measure how a person is feeling without asking for a self-report. If emotions should be measured and modeled using an “effect indicator” latent model as depicted in Figure 10.1a, then aspects of an emotional response are connected by a single common cause, and it should be possible to measure the more easily observable aspects of emotion (e.g., facial movements, vocal acoustics, peripheral physiology) to learn something about a person’s subjective experience (which itself is not observable without a self-report). Furthermore,

using an effect indicator model, when there is lack of correspondence between verbal reports and these objective measurements (as there almost always is), researchers often assume that the verbal reports are invalid. Similarly, if a person says he is angry but pouts (which is typically perceived as sadness), researchers usually would believe him to feel sad, because behavior would trump verbal report as a way of indexing subjective experience. In practice, objective measures in the brain and body tend to be weakly correlated with one another, and together they do not consistently and specifically distinguish between instances of anger, sadness, fear, and so on (Barrett, 2006a; Barrett, Lindquist et al., 2007; Lindquist et al., 2012). As a result, objective measures cannot be used as proxy measures of emotional experience. Scientists are not able to use any single measurement, or profile of measurements, to indicate when a person is feeling anger, fear, sadness, or anything similar. If we want to know whether a person is experiencing an emotion, we have to ask her/him. Verbal reports are inappropriate for revealing the *processes* that produce subjective experiences (i.e., how emotions are caused), but barring social desirability concerns, they are the only way to assess the *content* of subjective experiences of emotion (i.e., what people are feeling; Barrett, 2006b; Barrett, Mesquita et al., 2007).

When asking a participant to characterize subjective experiences, most researchers simply present a set of adjectives and ask the participant to rate how well each word describes his or her immediate feeling state (for a list of typical measures and references, see Table 10.2). This rating process assumes that the feeling state is static and can be held constant while it is compared to different emotion or affective concepts to produce the best match, so that the process of

comprehending and rating emotion or affect-related words will not change the experience at hand. It is possible, even likely, however, that thinking about emotion adjectives can change how a participant feels, rather than just reflect that feeling, and so adjective rating scales should be used judiciously. Furthermore, what appears to be a simple judgment actually draws on a set of complex processes including (1) the participants' access to phenomenal or "raw" experience, (2) his or her ability to verbalize this experience as "reflective" feelings that can be communicated in awareness, (3) knowledge of the emotion words and related emotion concepts represented by the words, (4) having sufficient executive attention resources to move from item to item to render a set of ratings, and (5) social desirability concerns.

With these points in mind, there are important considerations when using adjective scales to measure subjective experience. First, participants will report how they are feeling using whatever measure a researcher gives them, regardless of what the scale is called, even when the items are not entirely appropriate. For example, if a participant is feeling angry, but is given the Beck Depression Inventory ([Beck & Steer, 1987](#)), she will likely use the items given to communicate how unpleasant they feel. Thus, it is important to measure both the emotion of interest and other closely related emotions for discriminant validity. Second, there are individual differences in emotional granularity, or the extent to which people represent their experiences in distinctive categorical terms. Minimally, this means that not everyone is able to report on the difference between a sad, angry, guilty, or any other feeling, but it also suggests that some people don't *feel* these experiences distinctly and instead experience more general

affective changes (Barrett, 1998, 2004; Barrett & Bliss-Moreau, 2009b; Feldman, 1995). As a result, some individuals use emotion words to refer to distinct experiences, whereas others use the same words to represent their feelings in more basic affective terms (that is, they use the same words for what those words have in common, which is unpleasant feeling).

In addition to asking people to describe their emotional experiences with a set of emotion words, it is also possible to assess emotional experiences by measuring how people judge the world around them during an emotional episode. Sometimes these are called emotional “appraisals” (e.g., Akinola & Mendes, 2008; Lerner & Keltner, 2001), but this is also a case of “world-focused” emotion (Lambie & Marcel, 2002; Lindquist & Barrett, 2008). In the appraisal approach to emotion, appraisals are often thought of as the cognitive mechanism that automatically evaluates a stimulus, which in turn triggers a specific emotion (Ellsworth & Scherer, 2003). But from another theoretical perspective, appraisal judgments reflect world-focused experiences of emotion by describing how a person experiences the world during a particular emotional episode (cf., Barrett, Mesquita et al., 2007; for a consistent theoretical view, see Clore & Ortony, 2008). For instance, during fear, people (at least in a Western cultural context) experience a world full of risk (e.g., Lerner & Keltner, 2001; Lindquist & Barrett, 2008b). In anger, they experience others as blameworthy.

There continues to be debate regarding whether or not a person can feel both pleasant and unpleasant at the same time (for a discussion, see Barrett & Bliss-Moreau, 2009a), with no resolution of this debate in sight. Therefore, an experimenter has to make an explicit decision as to whether hedonic valence will

be measured with one bipolar item (ranging from pleasant to unpleasant) or two unipolar items (ranging from neutral to pleasant and neutral to unpleasant). It is important to keep in mind that many participants impose bipolarity on ambiguously unipolar scales – for example, how sad you are, anchored from “not at all” to “intensely,” where “not at all” is interpreted by many respondents as “happy” (Carroll & Russell, 1996). This problem is reduced, but not eliminated, by explicitly labeling scale anchors. Further, although there continues to be debate over the theoretically most valid way to parse affective space (e.g., Cacioppo & Gardner, 1999; Russell & Barrett, 1999), all affective properties (valence/arousal, approach/avoid, positive activation/negative activation) are related to one another and can be derived from one another (Carroll, Yik, Russell, & Barrett, 1999; Yik, Russell, & Barrett, 1999) as long as the entire affective space is adequately sampled (Barrett & Russell, 1998).

Finally, the issue of response scaling goes well beyond the debates about bipolarity. Concerns about how people use Likert-type scales are gaining momentum in the science of self-report (e.g., Bartoshuk, 2000; Bartoshuk, Fast & Snyder, 2005), and so scale considerations should be carefully considered in any study that involves the measurement of subjective experience. Many studies simply have participants indicate the extent to which an adjective describes his or her immediate feeling state on a scale from low to high (e.g., 1 = not at all, 5 = very much). Recent work by Bartoshuk et al. (2005) indicates that there are strong individual differences in how people interpret such anchors and use such scales, going well beyond the old discussions of response styles. As a result, some researchers are now adopting a general labeled magnitude scale approach, where

vague Likert-type scale choices are explicitly anchored to an absolute set of comparisons, to allow different individuals to be calibrated to one another in their scale usage (Bartoshuk, 2000).

### **A Tips, Tricks, and Secrets for “Best Practices”**

A psychologist’s task is to discover facts about the mind (e.g., changes in affect or emotion) by measuring responses from a person (e.g., reaction times, perceptions, eye or muscle movements, bodily changes, or perhaps electrical, magnetic, blood flow, or chemical measures related to neurons firing). In so doing, psychologists use ideas (in the form of concepts, categories, and constructs) to transform their measurements into something meaningful. The relation between any set of numbers (reflecting a property of the person, or the activation in a set of neurons, a circuit, or a network) and a psychological construct depends on a set of theoretical assumptions. All scientists make such assumptions, whether or not they explicitly express them. First and foremost, then, it is critical for researchers to be clear and explicit about their guiding theoretical framework. Theory not only prescribes a strategy for analysis and interpretation, but it also guides what stimuli can be used for an induction, the dependent variables to be measured, as well as when and how manipulation checks are to be performed. Having an explicit theoretical view of emotion also maximizes the possibility that the researcher will make design choices that permit strong inferences about the psychological processes at work as reflected in the measures observed. Researchers also must be attentive to the methodological limitations of their chosen induction and measurement methods; the goal may be

to induce and measure an emotional state, but the findings might only permit inferences about affect.

Let us consider briefly two different examples, one in which the scientific question is about affect more generally, and the other in which the question concerns a specific emotional state, such as “fear,” to make explicit some of the considerations needed when designing an affect vs. an emotion study. If negative affect is the phenomenon of interest, then, as we noted earlier, it will be especially critical to ensure that activation of conceptual knowledge about specific emotions is minimal or nil so as to permit making inferences solely about negative affect without the confound that the participant activated a particular emotional concept like “fear.” A focus on negative affect also requires the researcher to be cautious about the timing and nature of manipulation checks so that conceptual knowledge about particular emotions is not activated too early and thereby impact the affect induction. If instead we are interested in studying the impact of the specific emotion state of “fear,” then we must also consider how and when a stimulus primes or activates conceptual knowledge about that emotion state. We also need to consider the possibility that even within an emotion category like fear, there can be tremendous variation in the objective responses measured across individuals as a function of individual variability or the context within which fear is elicited. We submit that this is not a bug due to the experimental design, but rather a feature of how the emotion system is built such that different responses are evoked when circumstances call for different adaptations required for meeting particular goals. Also, when studying a specific emotion like fear, then the researcher must also induce and compare appropriate “control” emotions that



differ from the focal emotion on dimensions of valence (e.g., by inducing anger or another negative emotion). These emotions experimentally control for the possibility that any effects that appear to be stemming from fear are not simply a function of just any negatively valenced state. And note that researchers will be on the firmest inferential grounds for interpreting their measured face, voice, bodily, or central nervous system outcomes by not just inducing two negatively valenced emotions, but also by equating them for the induced arousal. Lastly, to make claims about a response being specific to a given emotion (e.g., fear), researchers should rule out the possibility of having evoked another emotion with the same valence (e.g., anger); in other words, the fear induction should specifically induce fear and not anger, and the reverse should be true for the anger induction.

Finally, when using biological measures to try and index general affective states, or more specific emotional states, it is important to remember that peripheral physiology was not engineered to help us express emotion – it evolved for homeostasis and metabolic regulation. This means that only a small proportion of the variance in biological measures reflects changes in mental states. Furthermore, bodily state measures such as measures of heart rate or skin conductance have their own limitations. These include often being multiply determined by both sympathetic and parasympathetic autonomic changes (i.e., heart rate) that make the autonomic determinants unclear, being sensitive to many psychological effects other than just affect or emotion (e.g., familiarity of stimuli, prior learning about stimuli), or even just being affected by changes in the physical environment (e.g., skin conductance can be altered by the humidity and

temperature of the testing room). The limitations and caveats of each induction type and measurement modality must be considered in making inferences and in ruling out potential confounding effects. In sum, following these suggested guidelines and utilizing the resources summarized here based on our current state of knowledge should lead us toward a more valid and replicable science of affect and emotion.

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**Table 10.1.** Affect and emotion induction techniques including methods, exemplar references, advantages, and disadvantages

Laboratory Inductions	Representative stimulus sets and references	Advantages	Disadvantages	Effect size (g)
Films*	<b>Methods and typical stimulus sets:</b> (Gross & Levenson, 1995; Philippot, 1993; Schaefer, Nils, Sanchez, & Philippot, 2010).	Ease of presentation	Participant familiarity can introduce variability	.53–.66
Images*	<b>Methods and typical stimulus sets:</b> (Bradley et al., 2001; Lang et al., 1993) e.g., International Affective Picture System or IAPS; (Lang et al., 2008).	Ease of presentation	Slides do not sample all aspects of affective space	.58–1.03
Faces	<b>Methods and typical stimulus sets:</b> e.g., the Ekman and Friesen set (Ekman & Friesen, 1978), the Japanese and Caucasian Facial Expression of Emotion set (JACFEE; Matsumoto & Ekman, 1988); the Montreal Set of Facial Displays for Emotion (Beaupré & Hess, 2005).	Ease of presentation	Most faces are used in studies of emotion perception. It is not clear whether faces shift feelings or prime concepts.	n/a

Sounds/ Voices	<p><b>Methods and typical stimulus sets:</b> e.g., International Affective Digitized Sounds (IADS) (Bradley &amp; Lang, 2007); Sounds can be affective because of their representational content (e.g., buzzing bees), because their acoustical properties make them intrinsically affective (e.g., sirens, human voices can speak neutral words or sentences with an affective tone, or prosody as in (Banse &amp; Scherer, 1996; Bliss-Moreau, Owren, &amp; Barrett, 2010), or stimuli can be nonlinguistic emotional utterances (e.g., grunting in anger; Simon-Thomas et al., 2009); or naturalistic (e.g., pilots speaking during dangerous flights). The latter have limitations (see Scherer, 2003), including that they confound emotional semantic content with prosody.</p>	Ease of presentation	Most prosody stimuli are used in studies of emotion perception; sounds with acoustical properties that act directly on the nervous system (e.g., sirens) shift feelings; sounds with representational content (e.g., the sound of bees, affective prosody) might prime concepts.	n/a
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Music*	<p><b>Methods and typical stimulus sets:</b> The Continuous Music Technique (Eich &amp; Metcalfe, 1989) pairs classical music (with no explicit semantic content) with imagined events (either hypothetical or autobiographical) with the intent of intensifying feelings.</p>	<p>Music can be played in the background to keep evocative states elevated throughout an experiment</p>	<p>Music does not reliably induce specific discrete emotions (e.g., anger vs. anxiety) although it can induce valence effects (positive vs. negative vs. neutral)</p>	.41–.65
Imagery and Recall*	<p><b>Methods and typical stimulus sets:</b> Open-ended imagery instructions are used in the Continuous Music Technique (see above) or scripts can be used. In the Scenario Immersion Technique, participants read (or hear) embodied scenarios and experience a narrative as it unfolds (e.g., Wilson-Mendenhall, Barrett, Simmons, &amp; Barsalou, 2011). Another imagery approach involves gathering autobiographical details from the participant and then constructing idiographic narratives</p>	<p>Ecologically valid; content can be idiosyncratically manipulated</p>	<p>Participants vary in the ability to engage in mental imagery which will increase variability</p>	<p>.42–.61 (Imagination) .39–.51 (Autobiographical recall)</p>

(Olatunji, Babson, Smith, Feldner, & Connolly, 2009). This differs from true autobiographical recall because the scenarios are constructed by the researchers into a structured narrative. The Velten technique (Velten, 1968) is a form of guided imagery; participants are given statements describing positive or negative self-evaluations and asked to imagine situations that apply to them (e.g., Carter et al., 2002). Recall and Velten had equal efficacy to other imagery approaches in the Lench et al. (2011) meta-analysis (table 1).

Words	<p><b>Methods and typical stimulus sets:</b></p> <p>Typically, valenced words are used in evaluative priming paradigms where subliminally presenting a negative word (e.g., “murder”) prior to a same-valenced object (e.g., a snake) speeds a participant’s latency to respond (Ferguson,</p>	Ease of presentation	Most words are used in studies of evaluative priming; as induction stimuli, it is not clear whether words shift feelings or prime concepts	.02–.49
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	<p>Bargh, &amp; Nayak, 2005); exemplar words can be found in the Affective Norms for English Words set (ANEW); like IAPS images, ANEW words have been rated for valence and arousal (Bradley &amp; Lang, 1999) and discrete emotions (Stevenson, Mikels, &amp; James, 2007).</p>			
<p>Bodily Movements and Postures</p>	<p><b>Methods and typical stimulus sets:</b> e.g., facial muscle manipulation using a pen held in the teeth vs. lips (Strack et al., 1988). Nonfacial bodily movements include asking participants to use approach or avoidance-related flexion or extension-based muscle movements or head movements (see example outcomes in the supplemental version of this table), or take postures suggestive of a particular emotion state (e.g., Duclos et al., 1989, Study 2, postures of fear, sadness, or</p>	<p>May be a relatively implicit manner of shifting feelings</p>	<p>Researchers must present a good cover story to prevent demand characteristics</p>	<p>.34–.60</p>

	anger) or a gross change in posture (e.g., slumping; Stepper & Strack, 1993, Study 1).			
Peripheral physiological manipulations	<b>Methods:</b> e.g., injections of epinephrine (Schacter & Singer, 1962); exercise: (Ekkekakis et al., 2011); oxytocin: (for review, see Norman, Hawkley et al., 2011); botox into facial muscles: (Davis et al., 2010).	Acts directly on peripheral physiological systems and can be quite potent	Requires expertise to administer safely	n/a
Confederates	<b>Methods:</b> e.g., using a confederate to induce anger (Cohen et al., 1996); using a confederate to induce jealousy in participants by forming a bond with one participant, and then choosing to work with another participant in a subsequent task (DeSteno, Valdesolo, & Bartlett, 2006).	Ecologically valid	A good cover story is critical so participants cannot guess the confederate's role; requires extensive planning at design and implementation	.37–.54
Motivated performance	<b>Methods and typical stimulus sets:</b> e.g., the Trier Social Stress Task (TSST; Kirschbaum et al., 1993); a variation of the TSST are used to induce either unpleasant feelings of social rejection or	Ecologically valid	Requires screening to ensure that participants who will find the task too evocative do not participate (e.g.,	n/a

	<p>pleasant social approval by varying whether audience members were unsupportive or supportive (Akinola &amp; Mendes, 2008) or altered their speech prosody to induce shame (negative feedback in a warm tone) or anger (negative feedback in a condescending tone; Kassam &amp; Mendes 2013).</p>		<p>participants with social anxiety)</p>	
Virtual reality	<p><b>Methods and typical stimulus sets:</b> e.g., experience of a virtual park (Riva et al., 2007); virtual reality exposure therapy for treating anxiety (e.g., Michalyszyn, Marchand, Bouchard, Martel, &amp; Poirier-Bisson, 2010). <u>Virtual park:</u> Participants explored a virtual urban park (with trees, benches, lights, walking paths). Affect was induced by changing background music, lighting, shadows, and the presence of other people. <u>Virtual reality</u></p>	<p>Advantages include good experimental control and repeatability, potential for enhanced believability of manipulations, and ability to present well designed social manipulations to heterogeneous samples to enhance generalizability (Blascovich &amp; Bailenson, 2011)</p>	<p>The downside of this technology is the cost and the need for some degree of technological sophistication, especially in programming (Blascovich &amp; Bailenson, 2011)</p>	n/a

	<p><u>exposure therapy:</u> Virtual reality used to induce affect in the treatment of anxiety, particularly for exposure therapy. A meta-analysis showed effects comparable to clinical <i>in vivo</i> exposures (Powers &amp; Emmelkamp, 2008).</p>			
Physically Real Stimuli (including Experience Sampling)	<p><b>Methods and typical stimulus sets:</b> Real stimuli include: spiders/snakes to test avoidance of feared objects (Teachman, 2007), sky diving and mountaineering in extreme sports enthusiasts (Castanier, LeScanff, &amp; Woodman, 2011), foods or other substances to induce disgust or pleasure (Jabbi, Swart, &amp; Keyzers, 2007), nociceptive stimuli (Lovallo et al., 1985), and chemosensory (i.e., odor) stimuli (for review, see Yesharun &amp; Sobel, 2010).</p>	Ecologically valid and impactful	More difficult to administer and more idiographic variation, and thus reduced experimental control. They are also often more costly and time-consuming to use; experience sampling requires knowledge of multivariate analysis methods	n/a

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*Note:* Effect sizes shown (where applicable) are the 95% confidence interval provided in Lench et al. (2011). Effect sizes are Hedges'  $g$  (.2 considered a small effect,

.5 considered medium, and .8 considered large). \*Inductions with effect sizes greater than .5 in Table 1 of Lench et al. (2011).

**Table 10.2.** Measures, references, and advantages and disadvantages of methods for measuring the impact of affect and emotion inductions.

Measurement Domain	Measures (with typical abbreviations) and References	Advantages	Disadvantages
Facial Muscle Activity	<ul style="list-style-type: none"> <li>• For methodological details on recording facial EMG, see e.g., (Fridlund &amp; Cacioppo, 1986; Tassinari, Cacioppo, &amp; Geen, 1989; Tassinari, Cacioppo, &amp; Vanman, 2007).</li> <li>• Facial electromyography (fEMG) to measure emotion or affective variables includes such sites as the zygomaticus major muscle region (“smiling”) and the corrugator supercilii muscle region (“scowling”)</li> </ul>	<ul style="list-style-type: none"> <li>• Sensitive to subtle and/or fleeting changes in muscle activation.</li> <li>• The ability to distinguish positive from negative affective states.</li> </ul>	<ul style="list-style-type: none"> <li>• Special equipment and expertise are needed</li> <li>• Fairly elaborate cover stories are needed to prevent participants from guessing the true nature of the experimental questions since muscle activity is voluntarily controlled</li> <li>• Skin preparation can be tedious and uncomfortable for participants</li> <li>• We can currently only measure with reasonable specificity a small number of muscle</li> </ul>



			<p>regions in the face</p> <ul style="list-style-type: none"> <li>• Participants typically make more facial muscle movements when another person is present (or implied (Fridlund, 1991)</li> <li>• There are no consistent and specific facial EMG-based “signatures” for specific emotion states such as anger, sadness, fear, or disgust</li> </ul>
Vocal Acoustics	<ul style="list-style-type: none"> <li>• For an in-depth discussion of measuring vocal acoustics, see Owren &amp; Bachorowski (2007)</li> </ul>	<ul style="list-style-type: none"> <li>• Provides an observer-independent measure</li> </ul>	<ul style="list-style-type: none"> <li>• Requires some specialized equipment and expertise</li> </ul>
Observer Ratings	<ul style="list-style-type: none"> <li>• The most popular coding system is the Facial Action Coding system (FACS; Ekman &amp; Friesen, 1978). Observers rate activity in each of 44 facial action units (AUs). The AUs are visible facial muscle movements and are singly, or in combinations, hypothesized to be characteristic of specific emotions.</li> <li>• The Maximal Descriptive Facial Movement</li> </ul>	<ul style="list-style-type: none"> <li>• Uses a standardized measurement tool</li> </ul>	<ul style="list-style-type: none"> <li>• Typically time-consuming and resource-intensive</li> </ul>

	<p>Coding System (MAX) for use with infants (Izard, 1979)</p> <ul style="list-style-type: none"> <li>• Child Facial Coding System for coding facial pain expressions (Gilbert et al., 1999)</li> <li>• The Facial Expression Coding System (FACES) for facial muscle movements related to affect rather than discrete emotions; facial actions are rated as positive/negative and for intensity (Kring &amp; Sloan, 1991).</li> </ul>		
Behavioral Changes	<ul style="list-style-type: none"> <li>• Behaviors used to measure affect include: approach (e.g., push a lever toward the stimulus) or avoid tendencies (pull a lever away from a stimulus) as an index of positive or negative feelings toward that stimulus (e.g., Chen &amp; Bargh, 1999), or whether someone consumed a drink as evidence of positive affect (Winkielman, Berridge, &amp; Wilbarger, 2005).</li> <li>• Behaviors used to index the experience of specific emotions include pride measured as a greater tendency to persevere on difficult tasks (Williams &amp; DeSteno, 2008), fear measured as greater risk aversion (Lerner &amp; Keltner, 2001; Lindquist &amp; Barrett, 2008a), or social behaviors, e.g., cooperation during the experience of gratitude (DeSteno et al., 2010) or jealousy (DeSteno et al., 2006).</li> </ul>	<ul style="list-style-type: none"> <li>• The potential to measure “unconscious” emotion or affect</li> <li>• Easily measurable behaviors for affect as approach or avoidance states</li> <li>• Behaviors are often observer-independent measures</li> </ul>	<ul style="list-style-type: none"> <li>• No one-to-one correspondence between behaviors and discrete emotional states</li> </ul>
Autonomic Nervous System Activity	<ul style="list-style-type: none"> <li>• For an introduction, see Stern, Ray, and Quigley (2001). For more advanced users, see Cacioppo, Tassinary, and Berntson (2007). Papers on specific systems/ measures are available at: <a href="http://www.sprweb.org/journal/index.cfm#guidelines">http://www.sprweb.org/journal/index.cfm#guidelines</a></li> <li>• Common measures include heart rate (HR; inverse of heart period), blood pressure (BP), cardiac output (CO), total peripheral resistance (TPR), stroke volume (SV), respiratory sinus arrhythmia (RSA, also known as high frequency heart period variability), electrodermal activity (EDA; including event-related skin conductance responses [ERA-</li> </ul>	<ul style="list-style-type: none"> <li>• Measures can distinguish positive from negative affective states. The measures are often observer-independent, in that most of them are not at all, or only minimally, affected by volitional changes on the part</li> </ul>	<ul style="list-style-type: none"> <li>• There are no consistent and specific patterns of autonomic response for specific emotion states such as anger, fear, sadness, or disgust.</li> <li>• These</li> </ul>

<p>SCRs], nonspecific skin conductance responses [NS-SCRs], or tonic skin conductance level [SCL]), respiratory rate, tidal volume (<math>V_T</math>), the electrogastrogram (EGG), pupillary diameter, or face or hand temperature.</p>	<p>of the participant</p>	<p>measures require equipment and expertise.</p> <ul style="list-style-type: none"> <li>• These measures are resource intensive both in preparing participants for recordings, and in the reduction of data post-acquisition.</li> <li>• Measures require careful thought regarding the nature of the psychological state that can be inferred from the physiological measures.</li> </ul>	
<p>Central Nervous System Changes</p>	<ul style="list-style-type: none"> <li>• Methods include electroencephalography (EEG) from which one can derive event-related potentials (ERPs), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and more recently, functional near-infrared spectroscopy (fNIRS). For methods, see Fabiani, Gratton, and Federmeier (2007); Pizzagalli, (2007).</li> <li>• Both EEG and MEG results from electrical activity in the brain that is the net effects of ionic currents flowing between neurons across the synapse.</li> </ul>	<ul style="list-style-type: none"> <li>• These measures reveal something about the processes underlying affect and emotion that are not necessarily accessible via conscious self-report or observable behavior (for an example, see</li> </ul>	<ul style="list-style-type: none"> <li>• Require “reverse inference”</li> <li>• Expense and access to equipment</li> <li>• Complex data analysis</li> <li>• Extensive need for</li> </ul>

- EEG is a measure of electrical changes in the brain recorded as voltage changes and MEG is a measure of magnetic field changes at the scalp
- Event-related electrical or magnetic changes to affective or emotional stimuli are event-related potentials (ERPs) in EEG studies or event-related magnetic fields (ERFs) in MEG studies
- Source imaging can be used with MEG (MEG and MRI paired) or EEG to better localize measures to a specific anatomical structure

Lindquist et al., 2012).

expertise in data acquisition, data analysis and neuroanatomy

- Cannot achieve optimal temporal and spatial resolution simultaneously
- Emotions cannot be clearly and unambiguously assessed (i.e., measures do not reliably differentiate anger from sadness from fear; Lindquist et al., in press).
- Concerns with false-positive findings attributable to the typical use of multiple comparisons across voxels in the brain

Endocrine, Immune, and

• Example measures: anger and testosterone; (Peterson & Harmon-Jones, 2011); immunoglobulin

• Provides a peripheral

• Some measures are

Inflammatory Changes	A (immune factor in saliva), and disgust (Stevenson, Hodgson, Oaten, Barouei, & Case, 2011); basal levels of the pro-inflammatory cytokine, IL-18 and negative affect with a sadness induction (Prossin et al., 2011); IL-6 response to a motivated performance task eliciting anger and anxiety (Carroll et al., 2011)	physiological measure that goes beyond what can be measured using traditional psychophysiological measures	<p>difficult to obtain in the typical psychological lab</p> <ul style="list-style-type: none"> <li>• Requires control over numerous extraneous variables, e.g., factors like time of day, time of last meal, menstrual cycle phase, etc.</li> <li>• Assays can be expensive</li> <li>• The temporal characteristics of measures are slow relative to the brief nature of affective and emotional changes</li> </ul>
Subjective Experience	<ul style="list-style-type: none"> <li>• Example measures to assess affect include an affect grid (Russell et al., 1989), rating dial, or joystick to measure each of the dimensions of affective state or Self-Report Manikins (Bradley &amp; Lang, 1994).</li> <li>• Example measures to assess emotion include the Current Mood Questionnaire (Barrett &amp; Russell, 1998), the Positive Affect and Negative Affect Scale–Extended (Watson &amp; Clark, 1994), and the Differential Emotions Scale (DES; Izard, Dougherty,</li> </ul>	<ul style="list-style-type: none"> <li>• Self-report is currently the only valid way of assessing subjective experience</li> </ul>	<ul style="list-style-type: none"> <li>• Measures of discrete emotional states tend to measure pleasant or dysphoric affect (although there are notable</li> </ul>

Bloxom, & Kotsch, 1974)

individual  
differences)

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**Table 10.3.** Common myths observed in studies of emotion and affect that measure autonomic nervous system activity

Myth 1. Autonomic nervous system arousal, particularly in the sympathetic nervous system, is a unitary construct.

One of the most pervasive assumptions about the autonomic nervous system is that arousal is unitary, leading some to assume that a single measure of function or activation will suffice to represent autonomic arousal across the entire body. This cannot be assumed. This arose from early physiological work (e.g., Cannon, 1915, 1932), suggesting that activation in the sympathetic branch of the autonomic nervous system was predominant under conditions of bodily activation, and that it exerted highly coordinated action on organs throughout the body. Instead, it is now clear in humans and nonhuman animals, in particular among mammals, that there is target-specific and exquisitely tuned control of changes in activation of both the sympathetic and parasympathetic nervous systems. Although a more generalized activation of sympathetic outflows can occur, this typically happens under intensely evocative circumstances. A nice demonstration of the regional specificity of sympathetic activation was shown in a study in which investigators used microneurography (i.e., peripheral nerve recordings in awake humans) to record muscle sympathetic nerve activity simultaneously in a participant's leg and arm. In this study, mental arithmetic increased activation of the sympathetic nerves to muscles in the leg, but did not simultaneously alter sympathetic nerve activity to the arm (Anderson, Wallin, & Mark, 1987). For a useful review of the regional and organ specificity of sympathetic nervous system activity, see Morrison (2001).

Myth 2. Sympathetic activation is always accompanied by parasympathetic withdrawal (or vice versa).

This myth is another legacy of Cannon's writings. We now know that not all activation in the sympathetic and parasympathetic nervous systems is reciprocally coupled (i.e., a pattern of increased activity in one autonomic branch accompanied by decreased activity or withdrawal, in the other branch [for discussion, see Berntson et al., 1991]). Although reciprocal coupling is common, it is not ubiquitous. Nonreciprocal modes of control can occur as an increase or decrease in activity in one autonomic branch with no change in activity of the other branch, or even as simultaneous activation or inhibition of both autonomic branches. Coactivation has been demonstrated in both humans and rats during attentional orienting (Gianaros & Quigley, 2001; Quigley & Berntson, 1990). Several authors have suggested that coactivation and coinhibition likely have important functional consequences (Berntson et al., 1991; Paton, Boscan, Pickering, & Nalivaiko, 2005).

Myth 3. Changes in skin conductance specifically reflect changes in arousal.

Few measures of autonomic function have been as popular for measuring emotional or affective states as skin conductance (or more broadly, electrodermal activity). For example, Lang and colleagues have consistently shown that the magnitude of skin conductance responses to International Affective Picture Set (IAPS) slides and other stimuli is related to changes in the self-reported arousal elicited by these stimuli (e.g., Bradley et al., 2001). Although the eccrine sweat glands have the advantage of receiving input from only the sympathetic branch of the autonomic nervous system and correlating positively with self-reported arousal, skin conductance also is responsive to numerous physical conditions including temperature, humidity and skin hydration, and to many mental states including the relative familiarity vs. novelty of a stimulus, mental effort, etc. To permit strong inferences about the psychological process of interest, experimenters using skin conductance measures must carefully control contextual and stimulus variables (Cacioppo & Tassinary, 1990).

Myth 4. Affective or emotional states are accompanied only by efferent outflow from the brain to the peripheral, autonomically innervated target organs, without impact on afferent inputs to the brain.

Psychophysiological autonomic measures are often interpreted as if they only reflect efferent autonomic outflow from the central nervous system to the periphery. However, affective autonomic responses result from the delicate interplay between afferent and efferent nerve traffic over time. Measures of organ function will reflect (within seconds) both efferent outflow from the central nervous system and afferent inflow to the central nervous system from organs like the heart and gastrointestinal tract. Unfortunately, our understanding of afferent (or interoceptive) impacts and our ability to measure them, especially in humans, is less well developed than our ability to measure peripheral target organ changes. This makes it difficult to distinguish co-occurring efferent and afferent effects. Fortunately, brain imaging studies can now provide at least some composite information about afferent peripheral activation during affective states (e.g., Critchley, 2005).

Myth 5. Autonomic changes in the body only exist to support affective or emotional states.

This is, of course, an overstatement. It is not uncommon, however, for researchers to fail to consider that physiological measures must be interpreted in view of the overall, concurrent functioning of the body. Autonomic functions subservise not just our affective states but our very survival. This does not mean that affective states are not themselves critical to survival, but rather that they occur in the context of other basic functions like breathing, movement of blood through the body and digestion of food, all of which happen concurrent with our changing affective and emotional states.



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## Footnotes

- <sup>1</sup> Even the distinction between “cognition” and “emotion” is culturally relative (e.g., [Lutz, 1985](#); for a discussion, see [Barrett, 2009](#)).
- <sup>2</sup> Researchers often describe images (or other stimuli such as music, odors, other people, etc.) as “beautiful,” or “distasteful,” with the assumption that pleasure or displeasure is an inherent quality of the stimulus. Stimuli are only pleasant, or distasteful, however, because they alter a perceiver’s affect in some way ([Barrett & Bliss-Moreau, 2009a](#)). Nonetheless, people often experience affect as a literal property of a stimulus, and we can ask participants to report on the affective or emotional qualities of a stimulus (i.e., world-focused; Lindquist & Barrett, 2008) or on their own state (i.e., self-focused). The caveat about manipulation checks noted in the film section applies to images as well – labeling the emotional content of an unpleasant picture during viewing reduces subsequent self-reported distress to that picture ([Lieberman, Inagaki, Tabibnia, & Crockett, 2011](#)), so researchers should consider carefully when and how to measure subjective responses.
- <sup>3</sup> In addition, a so-called third branch of the autonomic nervous system, the enteric nervous system, is a specialized nerve plexus lying with the walls of the gastrointestinal system that controls motility and secretion in parts of the intestinal tract and receives modulatory input from the two primary autonomic nervous system branches ([Grundy & Schemann, 2007](#)). Activity of this branch is rarely measured in studies of emotion or affect, although it represents a potential novel avenue for future research.