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The Emotion Process: Event Appraisal and Component Differentiation

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Abstract

Much emotion research has focused on the end result of the emotion process, categorical emotions, as reported by the protagonist or diagnosed by the researcher, with the aim of differentiating these discrete states. In contrast, this review concentrates on the emotion process itself by examining how (*a*) elicitation, or the appraisal of events, leads to (*b*) differentiation, in particular, action tendencies accompanied by physiological responses and manifested in facial, vocal, and gestural expressions, before (*c*) conscious representation or experience of these changes (feeling) and (*d*) categorizing and labeling these changes according to the semantic profiles of emotion words. The review focuses on empirical, particularly experimental, studies from emotion research and neighboring domains that contribute to a better understanding of the unfolding emotion process and the underlying mechanisms, including the interactions among emotion components.

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INTRODUCTION AND SCOPE

Past reviews of the emotion literature have generally adhered to the classic view of emotion differentiation, assuming a limited set of discrete emotions (identified by verbal category labels); these past reviews generally report research that seeks evidence for differential physiological and behavioral response profiles for these categories. In contrast, this review adopts a dynamic view of the emotion process, focusing on the factors that trigger an emotion episode and drive response differentiation in a continuous fashion and treating categorization and labeling as secondary, optional steps.

Rather than highlighting differences between emotion theories (see Moors 2009, Scherer 2009b), this review focuses on the commonalities of these theories and summarizes empirical literature relevant to the emotion process in a fairly theory-independent way. In doing so, the review adopts a resolutely nomothetic stance, selecting the included material based on concrete predictions and reviewing the empirical evidence to date. Privileged are hypothesis-driven studies that have used some kind of experimental manipulation in the laboratory or controlled variation in the field; the review also gives special weight to studies using advanced methodology (in particular, measures that go beyond subjective verbal report of emotion labels, providing objective assessment of different aspects of emotional response components). Given this emphasis, ideographic approaches are not considered. Due to space limitations, neuroscience work is also largely excluded.

COMMON GROUND AMONG EMOTION THEORIES

Theorists generally agree that emotion should be viewed as an interface between an organism and its environment, constantly mediating between changing events and social contexts on the one hand and the individual's responses and experience on the other (Mulligan & Scherer 2012). There is also substantial agreement that emotion episodes comprise different components such as appraisal of the situation, action preparation, physiological responses, expressive behavior, and subjective feelings. To provide a framework for this review, we focus on two central concepts: elicitation, in particular via appraisal processes, and differentiation. Frijda & Scherer (2009) proposed distinguishing four major functions of emotion that each dominate a different stage of the process: (*a*) the appraisal of events that happen to us in terms of their relevance and consequences for our needs, plans, and values (elicitation of an emotion episode); (*b*) the preparation of action appropriate for dealing with or adapting to these events both mentally, in the form of states of action readiness or action tendencies, and physically, in the form of physiological responses; (*c*) the integration of information acquired from these two steps into a central representation that allows monitoring and regulation of the potential responses; and (*d*) often, although not always, the categorization and communication of the emotion episode to other people.

Imagine the following situation: During a party, you happen to overhear two of your friends saying unpleasant things about you. Would this elicit an emotional reaction in you, and if so, which one? In response to this question, in a sample of more than 3,000 working adults in different countries, 42.8% indicated that they would feel anger, 23.8% contempt, 0.7% fear, 14.2% good humor, 2.3% guilt, 38.3% sadness, 4.0% shame, and 5.0% worry (K.R. Scherer, unpublished manuscript). Responses were obtained with a forced choice list of emotions. In many cases, respondents indicated more than one emotion, suggesting the experience of mixed or blended emotions. Most likely, with open response options, an even larger range of different emotional reactions would be obtained, including no emotional reaction at all. Ideally, psychological science should provide a theoretical framework that predicts for whom an emotion episode will be triggered in this situation (elicitation), what the nature of the reaction will be (differentiation), what type of nonverbal feeling will be experienced (representation), and how it will be verbally described (categorization, labeling).

Figure 1 illustrates the complete emotion process, in line with the definition of functions and components proposed above. Emotions are not random events—they occur when something happens to us. In the elicitation stage, triggers of emotions can be objects (visual, verbal, olfactory), acts of nature, the behavior of others, and our own actions. Possible elicitors can also be internal processes, such as imagination or memories of events, hormonal changes or drug effects, and voluntary decisions to experience certain emotions. The elicitors impacting our organism are filtered by our sensory organs and subject to intensive information processing, most often through multilevel appraisals (e.g., in the example discussed above, "Do they really mean this? Did I do something wrong? What will this mean for our relationship? What can I do?").

The appraisal results produce differentiation—various action tendencies and corresponding physiological responses, motor expressions, and feelings (e.g., a tendency to aggress or avoid, an increase or decrease of muscle tonus, brow lowering or raising, and feeling hot or cold). The continuous changes in these mental and bodily components are integrated and centrally represented as feelings (in nonverbal form) (see Moors 2017, Scherer 2009a); these responses can be categorized and labeled with emotion terms (e.g., anger, fear, sadness) or descriptions referring to dimensions (e.g., feeling good or bad, feeling aroused or calm) (see Scherer 2001, 2009a). Most of the relevant research to date has measured feelings with self-report via rating scales with emotion or dimension labels. Given the difficulty of the task, there have been virtually no attempts to measure the nonverbal content of the central representation.

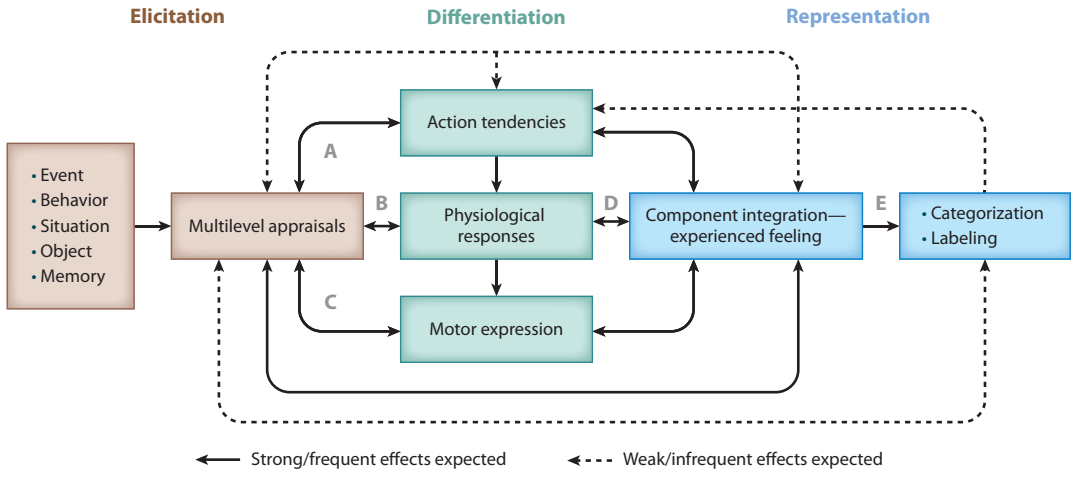

Figure 1

The dynamic architecture of a multicomponent emotion process model reflecting the widely held assumption that emotion episodes are processes that are elicited by a cognitive evaluation or appraisal of events, producing synchronized changes in several components. The hypothetical model illustrates the assumed mechanism. While the initial causal effects move from left to right, the assumption is that there is a high degree of recursiveness, i.e., the result of the initial impact of one component on another is expected to feed back to the eliciting component, setting off another round of processing likely to affect the ultimate outcome. This is why most of the arrows in the model are bidirectional, as feedback effects have already been shown or are highly probable. This article focuses on the empirical evidence for the hypothesized effects of initial evaluation results, categorized by the major appraisal criteria described in the literature, on major response components—motivational action tendencies (A), physiological reactions (B), and motor expressions (C). It is assumed that these response components also interact among each other. The conjoint effects of these interactions are continuously represented in central regions of the brain, likely to become accessible to consciousness in the form of nonverbal feelings (D). These feelings can consequently be categorized and labeled with emotion words or verbal emotional expressions (E). Due to space restrictions, effects D and E are not discussed in the article. Figure modified with permission from Scherer (2009a).

Most emotion theorists do not fundamentally disagree about the emotion process as conceptualized in **Figure 1**, but they differ in the components on which they focus. In addition, theories that focus on similar components differ with regard to the details of the mechanisms involved. For instance, theories postulating that some kind of appraisal initiates the emotion process tend to assign different weights to the various appraisal criteria and thus have put forward different hypotheses regarding the influence of these criteria on the other components of the emotion episode. Proposals range from template-based stimulus mapping, as in simple stimulus–response models, to attribution models (focusing on the attribution of stimuli to different types of causes), social judgment models (focusing on social relationships), decision theories (focusing on values and expectancies of action alternatives), and appraisal theories (proposing a set of appraisal criteria or dimensions such as goal relevance, valence, control, agency, and fairness) (for reviews of various theories, see Moors 2009, 2017; Scherer 2009b; Scherer & Peper 2001). The fact that different theories have different focuses does not necessarily make them incompatible. The remainder of this review does not focus on potential differences. Rather, it presents a summary of empirical research that speaks to a variety of theoretical predictions in the literature.

AN APPROACH TO ORGANIZING EMPIRICAL WORK REGARDING THE EMOTION PROCESS

The relevant empirical work is systematically organized by relationships among components of the emotion episode (**Figure 1**). Despite the fact that many contemporary emotion theorists endorse

a componential view, many others continue to study emotions by focusing on emotion categories, thereby neglecting to address the entire emotion process and the relationships among components. Nevertheless, scanning the literature reveals a substantial body of research on these relationships. Most of this research, however, has studied the relationship between only two components at a time, with the exception of a few studies that have studied several components simultaneously (Bossuyt et al. 2014, Gentsch et al. 2014).

For this review, three paths have been selected: from appraisal to action tendencies, from appraisal to physiological responses, and from appraisal to motor expression (facial, vocal, and gestural). The choice to include appraisal in each of the relationships is based on the postulate, widely shared among emotion theories, that it is the nature of the appraisal process that determines the nature of the remaining stages in the emotion process. For each relationship, research is considered for each of five major appraisal criteria (see Ellsworth & Scherer 2003): novelty or expectedness, valence (intrinsic and extrinsic), agency, control or power, and fairness. Many studies have focused on the isolated influence of one of these criteria; some have addressed the influence of patterns of two or more. In this review, we focus on initial appraisal after the occurrence of an event and do not address the copious literature on reappraisal as part of emotion regulation.

In experimental research about relationships among components, one component must be manipulated, and the other component must be measured. It is useful to discuss the methods for manipulation and measurement up front and highlight some of their advantages and disadvantages.

METHODS FOR THE MANIPULATION AND MEASUREMENT OF COMPONENTS

Manipulation

Manipulation of overt bodily components can be done directly or indirectly (see Moors & Scherer 2013). For instance, physiological responses can be produced directly by injection of chemical substances or indirectly via behavior (e.g., running up the stairs leads to a rise in heart rate). Likewise, facial muscles can be activated directly via electrical current or indirectly via instructions to tense the muscles in particular ways.

Mental components can, in principle, only be manipulated indirectly, but also in this case, some methods are more indirect and others are more direct. Appraisals of events can be manipulated indirectly by presenting real events (e.g., insulting a participant) or virtual events (e.g., pictures, films, words, stories) that the researcher expects to be evaluated in a particular way. They can also be manipulated by asking participants to imagine or recall these events (e.g., recall an episode in which you were insulted). These methods are indirect in that the researcher makes no mention of the appraisal criteria under study. More direct methods ask participants to imagine or recall events described in evaluative terms (e.g., imagine or recall a negative event in which you had low control) (Fast & Chen 2009, Galinsky et al. 2003, Kuppens et al. 2003, Lammers et al. 2008) or present the evaluative terms themselves to prime particular appraisals (Smith & Bargh 2008). Manipulating appraisals with indirect methods has the advantage that the researcher can control the nonevaluative features of the event. The more direct methods, however, have the advantage that the researcher can control the evaluative features of the event. All methods, except imagination and recall, have the further advantage that they allow manipulating the appraisal in a fairly unobtrusive way, thereby diminishing the risk for demand, as well as the risk for activating participants' convictions about relationships between appraisals and other components (Parkinson 1997).

Action tendencies, which are also considered to be mental entities, are manipulated indirectly via instructions to act in certain ways (e.g., to approach or avoid) (Kozlik et al. 2015). The feeling

component has been manipulated indirectly by instructing people to imagine or remember an instance of a specific emotion or affect and to relive it.

AU: action unit

Stimulus–response compatibility task: experiment in which stimulus features and response features are either compatible (e.g., positive stimulus and positive response) or incompatible (e.g., positive stimulus and negative response)

Measurement

Methods for the measurement of components can be organized according to two dichotomies: an objective–subjective dichotomy and a direct–indirect dichotomy. Objective methods are ones in which the measurement output is verifiable by others, which is the case with overt behavioral (e.g., facial movement coding, acoustic voice analysis) and (neuro)physiological (e.g., heart rate, skin conductance, electroencephalogram) measures. Subjective methods are not verifiable by others and typically rely on verbal self-reports.

Methods are direct if the values of the to-be-measured variable are directly read out from the measurement outcome; they are indirect if the values of the to-be-measured variable are derived from another variable that is assumed to influence the to-be-measured variable (De Houwer & Moors 2010). For instance, behavioral choice can be taken as a direct measure of behavior and as an indirect measure of action tendencies (Martinez et al. 2011), based on the assumption that action tendencies influence behavior. The combination of both dichotomies results in four types of methods: direct and indirect objective methods and direct and indirect subjective ones.

Overt bodily components can, in principle, be measured with all types of methods, but are best measured by direct objective ones. For instance, physiological responses are sometimes reported by the person having them (i.e., direct subjective), but more often they are measured with technical devices for registering heart rate, skin conductance, and blood pressure (i.e., direct objective). Facial expressions are measured with direct objective methods such as the facial action coding system (FACS; Ekman & Friesen 1978), in which observers code visible facial action units (AUs) (i.e., actions of parts of the face), or with electromyography (EMG), a technique that registers visible and invisible facial muscle movement in an area of the face. Vocal expressions can be measured by acoustic analysis of voice and speech (Juslin & Scherer 2005).

Mental components can be measured with all types of methods except direct objective ones. Appraisals of events and central representations or feelings have been measured with self-report (i.e., direct subjective), but also with stimulus–response compatibility tasks relying on reaction times (i.e., indirect objective). Action tendencies have likewise been measured with self-report (Frijda et al. 1989) and stimulus–response compatibility tasks (i.e., indirect objective) (Kozlik et al. 2015).

With these methods in mind, the following three sections review empirical research pertaining to paths A, B, and C of the model shown in **Figure 1**. Paths D and E are not discussed due to space limitations and lack of a coherent body of empirical literature guided by theoretical predictions.

PATH A: FROM APPRAISAL TO ACTION TENDENCIES AND BEHAVIOR

This section discusses research on the link between appraisal criteria and action tendencies or overt behavior. This link has been studied by researchers inside, but more often by researchers outside, the emotion domain.

Appraisal Criteria: Novelty or Expectedness and Goal Relevance

Early observations in animal research have led to the idea that both novel or unexpected and goal-relevant events produce tendencies for orientation and exploration, both of which can be considered forms of approach tendencies. More recent attentional bias research confirms these

earlier observations. Novel or unexpected as well as goal-relevant stimuli lead to a shift in attention, which can be considered a mental action tendency (e.g., Brosch et al. 2013).

Appraisal Criterion: Valence

Valence is used as an overarching concept covering both (*a*) intrinsic valence (or pleasantness), which is the appraisal of a stimulus as merely positive or negative, and (*b*) valence that derives from goal congruence, which is the appraisal of a stimulus as goal congruent or goal incongruent (i.e., one form of extrinsic valence). Evidence for the influence of intrinsic valence and evidence for the influence of goal congruence are discussed together because only a few studies (e.g., Aue & Scherer 2011) have attempted to empirically disentangle these types of valence.

A large body of evidence supports the view that positive and negative stimuli, respectively, lead to the tendencies to approach and avoid. In stimulus–response compatibility tasks, participants are instructed to approach positive stimuli and avoid negative ones on compatible trials, and to approach negative stimuli and avoid positive ones on incompatible trials. Responses are typically faster and less error prone on compatible than on incompatible trials. This effect has been obtained across a variety of response modalities, such as pulling or pushing a lever, approaching or avoiding a manikin on a computer screen, nodding or shaking the head, and stepping forward or backward (for a review, see Kozlik et al. 2015). The effect has been interpreted as evidence that valenced stimuli activate action tendencies, which facilitate similar instructed action tendencies (Krieglmeyer et al. 2013).

Alternative accounts for the link between intrinsic valence and approach or avoidance have been proposed. Eder & Rothermund (2008) argued that compatibility effects are not evidence that valenced stimuli spontaneously activate action tendencies. Instead, these effects could be produced by semantic overlap between the valence of the stimuli and the valence of the instructed responses. Other studies show that negative stimuli do not always lead to an avoidance tendency but sometimes to an aggressive tendency, and that the latter can be seen as one specific type of approach tendency (Berkowitz & Harmon-Jones 2004, Krieglmeyer & Deutsch 2013). However, if approach and avoidance tendencies are conceptualized on a higher level of abstraction, as tendencies to increase and decrease physical or social contact, the tendency to aggress can be viewed as a strategy for ultimately decreasing contact (Frijda 1986).

Negative stimuli lead not only to an avoidance tendency, but also to a tendency to repair. This is supported by research on cognitive control and conflict monitoring (Botvinick 2007, Dignath et al. 2015). Studies in this area show that conflict stimuli (i.e., stimuli that call for two competing actions, such as Stroop stimuli), which are incongruent with the goal to perform well on the task, instigate the tendency to adjust one's behavior (i.e., put in more effort to overcome the conflict) and activate the tendency to avoid subsequent conflict.

Appraisal Criteria: Agency and Intentionality

Agency refers to the source or cause of a negative stimulus or event: the self, another person, or impersonal circumstances. Intentionality refers to whether an animate agent (self, other) produced the stimulus intentionally and is to blame for it. We discuss two effects: the influence of other- or circumstances-agency or -blame regarding a negative stimulus on the tendency to aggress (Effect 1) and the influence of self- or nonself-agency regarding a negative stimulus on the tendency to repair (Effect 2).

Effect 1: agency or blame + valence → tendency to aggress. Early research showed evidence for higher aggressive tendencies when a person is blamed more for the occurrence of a negative

event (e.g., Kulik & Brown 1979; for a review, see Berkowitz & Harmon-Jones 2004). Recent studies have investigated reappraisal, rather than first-time appraisal, of agency (for a meta-analysis, see Barlett 2013). Participants are first led to believe that another person caused them harm (other-agency), after which they receive mitigating information indicating that the person did not cause the harm or was not responsible for it (circumstances-agency). These studies show a reduction in aggression after the presentation of some but not all types of mitigating information (see also Barlett et al. 2016).

Effect 2: agency + valence → tendency to repair. One line of research examines the influence of self- or other-agency on the tendency to repair when the negative event happened to another person. In an early lab study by Carlsmith & Gross (1969), participants who caused harm (shocks) to another person (self-agency) were more likely to comply with an unrelated request than those who observed someone else cause the harm (other-agency). A field study by Konecni (1972) obtained the opposite pattern of results. Participants who caused harm themselves (self-agency) repaired less but avoided more than participants who watched someone else cause it (other-agency). Later studies focused on the role of guilt feelings as a mediator between self-agency appraisal and repair behavior, with some studies showing evidence in favor of (Nelissen et al. 2007) and others evidence against this interpretation (Parkinson & Illingworth 2009).

Another line of research examines the influence of self- or nonself-agency on the tendency to repair when the negative event happened to the participant. The evidence is mixed in this case as well. Zeelenberg & Beattie (1997) showed, using an ultimatum game paradigm, that self-agency combined with a negative stimulus leads to regret and that more regret leads to a stronger tendency to repair. A different result was obtained by Bossuyt et al. (2014), who used a computer game to manipulate agency regarding a negative game event. They showed stronger feelings of regret but not a stronger tendency to repair in the self-agency compared to the circumstances-agency trials. A subsequent recall study showed that control, rather than agency, is crucial for the tendency to repair and suggested that previous studies found an effect of agency because they confounded agency with control.

Appraisal Criteria: Control and Power (+ Valence)

People have control over a stimulus when they have a goal that concerns the stimulus (e.g., the goal to change it) and when this goal is a crucial condition for the occurrence of the envisaged effect (e.g., a change in the stimulus) (Moors & De Houwer 2006). It is worth distinguishing between different types of control, as they exert different influences on action tendencies. General control is control over a wide range of stimuli, either based on repeated experience of control in the past or based on verbal information. Situational control refers to control over a current stimulus. General control may influence the situational control one has over a current stimulus, but both types of control may also come apart, as when a person is used to being good at math but is confronted with an unsolvable math problem. Situational control can be split into (*a*) retrospective control, which refers to the control one had in bringing about an already present stimulus (e.g., one made an error), and (*b*) prospective control, which refers to the expectation of being able to turn a current negative stimulus into a positive one in the future (e.g., one expects to be able to solve a problem). Retrospective control shows strong overlap with self-agency plus intentionality, as discussed in the previous section, and is not revisited in this section.

Much research focuses on social power, defined as control over other people or their resources (Fleischmann et al. 2018). Social power is often operationalized as a form of general control (over stimuli in general) and not as situational control (over a current stimulus).

In the following sections, we discuss empirical findings in favor of and against four effects: the influence of general and prospective control on (*a*) the tendency to aggress or engage in other antisocial behavior (Effect 3), (*b*) the tendency to approach or avoid (Effect 4), (*c*) the tendency to be active or passive (Effect 5), and (*d*) the influence of control in the sense of a specific action (e.g., one can escape) on the tendency to engage in that action (e.g., to escape) (Effect 6).

Effect 3: high (low) control (+ valence) → more (less) aggressive or other antisocial tendencies. This section separately considers data for general and prospective control. The strongest evidence for the influence of high general control on the tendency to aggress (and other forms of antisocial behavior) comes from research on social power, in which high-power participants were more likely to act aggressively, as manifested in familial aggression, crime against minorities, sexual harassment, bullying, and corruption (Guinote 2017).

These effects are typically explained as mediated by the activation of neural circuits known as the behavioral approach system (BAS) and the behavioral inhibition system (BIS) (Gray & McNaughton 1996). High power both increases activation of the BAS, leading to a stronger tendency to approach one's goals, and decreases activation of the BIS, leading to less inhibition of aggressive strategies to reach these goals. Both elements contribute to increased aggression. Low power, in contrast, increases activation of the BIS, resulting in decreased aggression.

A different set of studies suggests that people high in power engage more in prosocial than in antisocial behavior (Chen et al. 2001, Fleischmann et al. 2018). In an attempt to reconcile these contrasting findings, Guinote (2017) argued that high power increases the pursuit of salient goals. Various moderators (e.g., task demands, organization and national culture, and personality traits and needs) determine whether the salient goals are selfish or prosocial. Selfish goals lead to more corrupt and antisocial behavior, whereas prosocial goals lead to more social behavior.

The hypothesis that high and low prospective control over a negative event should, respectively, lead to the tendencies to aggress and avoid has intuitive appeal (Ellsworth & Scherer 2003, p. 580), yet experimental evidence for it is scarce (see Berkowitz & Harmon-Jones 2004). However, to the extent that, in studies in which general control (social power, self-efficacy) was manipulated, this manipulation also influenced participants' prospective control, these studies can be considered as indirect support for the link between high (low) prospective control and the tendency to aggress (avoid).

Effect 4: high (low) control → tendency to approach (avoid). The observation that high control sometimes leads to antisocial and sometimes to prosocial tendencies, and that both of these tendencies can be captured under the denominator of approach tendencies, has led some researchers to propose that the relationship between control and action tendencies is best described as a relationship between high (low) control and approach (avoidance) (Guinote 2017), which is consistent with the BAS and BIS explanation.

Several findings speak more directly to this relationship. For instance, Smith & Bargh (2008) manipulated power by using a priming procedure. Their results revealed that high-power participants had a stronger tendency to approach than low-power participants and non-power-primed participants. The groups showed no difference in the tendency to avoid.

Effect 5: high (low) control + negative valence → tendency to be active (passive). Several effects that have been described as effects on the tendency to approach (avoid) could be reinterpreted as effects on the tendency to be active (passive) because, in many studies, the approach behaviors were more active than the avoidance behaviors (but see Smith & Bargh 2008 for an exception). A number of research findings yield more direct support for the link between control and

activity (or the intensity of action tendencies). This section separately considers data for general control, prospective control, and the combination of both types of control.

Early studies in the learned-helplessness literature established that subjects (animals, humans) confronted with a series of uncontrollable aversive stimuli in a training phase (unavoidable shocks or loud noise, unsolvable puzzles) showed decreased effort leading to impaired performance in a test phase compared to subjects who were trained with controllable stimuli (e.g., Hiroto 1974, Seligman 1975). This can be interpreted as evidence that high (low) general control leads to the tendency to be more (less) active. More recent findings from the achievement motivation literature are in line with these results. Students or workers often exhibit more persistence, resulting in better performance, when they have high (compared to low) self-efficacy (for meta-analyses, see Multon et al. 1991, Talsma et al. 2018) and when they have an internal (compared to an external) locus of control (for a review, see Galvin et al. 2018).

Further support for the link between high (low) general control and the tendency to be active (passive) comes from research on social power. Galinsky et al. (2003) found that power holders have an increased action orientation, irrespective of whether this action was prosocial or antisocial.

The studies cited on learned helplessness, achievement motivation, and social power speak not only to the influence of general control on the tendency to be active or passive. Insofar as the manipulation of general control (or social power) in the training (or priming) phase transferred to the stimuli in the test phase, these studies also provide evidence—albeit indirectly—for the influence of high (low) prospective control on the tendency to be active (passive).

Research on achievement motivation provides more direct evidence for the latter link. In this research, prospective control, or the expectancy to be able to perform a particular task, is typically operationalized in terms of task difficulty—with easy (difficult) tasks considered as easy (difficult) to control. Expectancy-value theories argue that the expectancy to succeed in a task interacts with (i.e., is moderated by) the value attached to succeeding in the task (Nagengast et al. 2011): High prospective control only leads to the tendency to be more active if the outcome of the action is also desired.

Other studies, by contrast, showed a different pattern of results: Low prospective control did not lead to passivity, but rather to reactance (resistance, opposition). This effect is also opposite to Effect 3. In an early study, Donnerstein & Wilson (1976) observed that participants who had to solve a math task under high-intensity noise displayed more aggression when they had low than when they had high control over the noise. Wortman & Brehm (1975) reconciled these contradictory results by arguing that, when participants initially experience a low amount of failure, they still expect some control over the stimulus, which generates a reactive tendency. As failures accumulate, they expect less control, which results in a passive tendency.

In some studies on achievement motivation, general and prospective control were manipulated or varied orthogonally. A meta-analysis by Stajkovic & Luthans (1998) reported that participants with high (low) self-efficacy had high (low) work performance for easy, medium, and difficult tasks. Yet the effect was most pronounced for easy tasks, suggesting an additive effect of general and prospective control on the tendency to be active. A somewhat different pattern of results was obtained by Smith & Kirby (2009), who asked participants varying in subjective and objective math ability to solve easy versus difficult math problems. They also found that higher-ability participants had higher persistence and higher performance, but only for the difficult tasks. Importantly, the effect was mediated by appraisals of higher prospective control (which they termed problem-focused coping potential).

Effect 6: control in the sense of a specific action → tendency to engage in that action. McCloskey et al. (2005) showed that having more options to control an aversive outcome does

not always lead to an aggressive tendency; sometimes it leads to an escape tendency (i.e., the reverse of Effect 3). This is in line with older studies (e.g., Cherek et al. 1990) that show that aggressive responses were maintained when they were rewarded by escape from point loss but were extinguished when they were no longer rewarded. This is in line with expectancy-value theory, according to which the action tendency activated is in large part determined by the expected utility of the action (Moors 2017, Moors et al. 2017).

Autonomic nervous system (ANS): responsible for control of the bodily functions that are not consciously directed, such as heartbeat

Appraisal Dimension: Fairness

Most research relevant to the influence of fairness on action tendencies or behavior is conducted with the ultimatum game (for reviews and meta-analyses, see Güth & Kocher 2014, van Damme et al. 2014), in which a first player proposes a division of a sum of money between themselves and a second player. If the second player accepts this division, then the money is divided as indicated; if they reject it, then neither player receives anything. A recurring observation is that second players reject unfair offers, causing harm to both players. Thus, this research documents the influence of unfairness on the tendency to engage in costly aggression. Rejecting any division that delivers more than zero has been labeled as irrational, at least if the (selfish) goal to maximize profit is the only goal that is considered. If the (altruistic) goal for fairness is taken into account, however, then rejecting unfair offers no longer qualifies as irrational.

The standard explanation for the observed effects is that receiving an unfair offer leads to a negative emotion, which, in turn, leads to rejection (e.g., Matarazzo et al. 2016). Alternative explanations leave out (full-blown) emotions as mediating entities (Bierbrauer et al. 2017, Civai 2013, Moors & Fischer 2018, Schank et al. 2017).

Bediou & Scherer (2014) manipulated both the goal incongruence and the fairness of offers in an ultimatum game. They found that participants' rejection rates of these offers were more influenced by goal incongruence than by fairness.

PATH B: FROM APPRAISAL TO PHYSIOLOGICAL RESPONSES

Since the work of the pioneers of emotion research (Darwin, Irons, James, Wundt), the physiological correlates of emotion have occupied a central position in emotion research, generating a remarkable number of studies. The underlying assumption guiding this work was that different emotions could be clearly distinguished by different profiles of physiological responses. Kreibig (2010) reviewed 134 articles on autonomic nervous system (ANS) reactions to different emotions. Scrutiny of the evidence does not confirm the a priori expectation of a clear-cut differentiation of the major emotions. Out of the large number of parameters measured in these studies (20 cardiovascular, 3 electrodermal, and 13 respiratory variables), only heart rate and respiration rate showed stable effects pointing in the same direction (in concurrent evidence from at least three studies). The differentiation afforded by these two parameters mostly concerns the typical level of arousal for specific emotions: sympathetic responses for high-arousal emotions such as anger, fear, joy, and surprise, in contrast to parasympathetic responses for low-arousal emotions such as sadness, contentment, and affection. In line with the framework proposed in this review, variants of specific emotions (e.g., acute versus anticipatory sadness and sadness with or without crying) suggest that it is not so much the nature of the emotion but the type and urgency of the action tendency involved (e.g., heart rate increases as threat becomes more acute and requires faster responding).

Pecchinenda (2001) suggested that the disappointing results of this research tradition are due to the lack of theory-based predictions regarding the pattern of ANS activity associated with each

emotion. She proposed that, rather than focusing solely on the final outcome (the emotion category), researchers should place greater emphasis on emotion-antecedent information processing. Early studies that measured the physiological effects of specific appraisal outcomes support the notion that physiological activity associated with emotional reactions is organized around the personal meaning attributed to the situation through an appraisal process (Pecchinenda 2001, pp. 306–7).

The next sections discuss evidence on the effect of appraisal criteria—often mediated by action tendencies—on physiological responses in the peripheral nervous systems.

Appraisal Criteria: Novelty or Expectedness and Goal Relevance

There is solid evidence that novel and unexpected stimuli in all sensory modalities elicit not only an attentional (see above) but also a physiological orienting response, characterized by massive changes in the ANS (e.g., an increase in muscular tone and skin conductance, a decrease in heart rate, pupil dilation, and a pause in respiration that is often followed by an increase in respiratory depth and a decrease in respiratory rate) (Reisenzein et al. 2018). Likewise, Aue et al. (2007) showed that highly goal-relevant (threatening) pictures increased heart rate more than did neutral pictures. The orienting response serves to recruit extra sensory and cognitive resources to identify and make sense of the source of the novelty or unexpectedness and the goal relevance (Nieuwenhuis et al. 2011).

Appraisal Criterion: Valence (+ Novelty)

Much work has examined the effects of intrinsic valence and goal congruence on autonomic indicators, especially cardiac and electrodermal responses. Yet many of the relevant studies were concerned with mediating effects such as situational context and individual differences, often related to clinical symptoms. There is a large amount of research on intrinsic valence involving sensory input such as touch, sound (music), and visual stimuli (pictures) (e.g., Hamm et al. 2003, Lang 2014, Triscoli et al. 2017, Sumpf et al. 2015). Goal congruence (reward or punishment) has often been studied by comparing winning and losing in a gaming context or by comparing success and failure in ability tasks (Lole et al. 2012, Löw et al. 2008, Richter & Gendolla 2009, Silvia et al. 2014).

Recent research has compared the physiological effects of intrinsic valence and goal congruence. Van Reekum et al. (2004) used a computer game to manipulate these appraisals in a game context, and they measured a range of physiological reactions. Goal congruence had little effect on muscle activity but significant autonomic effects, including changes to the interbeat interval and pulse transit time of heart rate, skin conductance, and finger temperature. The manipulation of intrinsic valence had comparatively little impact on physiological responses.

Aue & Scherer (2008, 2011) simultaneously manipulated the intrinsic valence and the goal congruence (reward value) of pictures and found that pictures that were both intrinsically positive and goal congruent were associated with higher zygomaticus activity, lower corrugator activity, and higher heart rate than pictures that were either intrinsically negative or goal incongruent. The two appraisals had somewhat similar response patterns, but they were not identical: Intrinsic valence had more robust effects on facial EMG (Aue & Scherer 2011), whereas only goal congruence significantly influenced mean skin conductance, forehead temperature, and finger temperature. Goal-incongruent events produced stronger physiological mobilization than goal-congruent ones, as manifested in less habituation in mean skin conductance over the experiment (see also Van Reekum et al. 2004). There was also evidence that the efferent effects of the two appraisals combined multiplicatively, and that predictability of goal congruence influenced the impact of goal congruence on somatovisceral responding (Aue & Scherer 2008).

Delplanque et al. (2009) used intrinsically positive and negative odors and manipulated the novelty of these odors to examine the effect of these appraisal criteria on several psychophysiological parameters. They found a relative heart rate deceleration in response to novel odors and a relative acceleration in response to negative ones, confirming the classical distinction between orienting and defense reflexes.

Appraisal Criterion: Control or Power (+ Valence)

Lazarus & Folkman (1984) first differentiated between threat and challenge appraisals, corresponding to low and high prospective control, respectively. Tomaka et al. (1993, 1997) found that cardiac reactivity during active coping with stressors was positively related to challenge appraisals and negatively related to threat appraisals, whereas vascular reactivity was positively related to threat appraisals and negatively related to challenge appraisals. Recent research has confirmed the influence of threat versus challenge appraisals (based on perceived control and support) on cardiovascular reactivity (for recent examples, see Gaab et al. 2005, Gramer & Supp 2014, Harvey et al. 2010; for reviews, see also Denson et al. 2009, Kemeny 2009).

Some studies combined appraisals of control and goal congruence (e.g., Chalabaev et al. 2009, Pecchinenda & Smith 1996, Weinstein & Quigley 2006). Johnstone et al. (2005) studied participants performing a computer task in which they could lose or gain points (goal congruence manipulation) under two levels of difficulty (control manipulation). Skin conductance indicated higher sympathetic arousal for losses than for gains, particularly when difficulty was high.

PATH C: FROM APPRAISAL TO EXPRESSION

Appraisals and action tendencies produce motor expressions because they are generally functional for the preparation of elicited action tendencies. These reactions comprise (*a*) effects of physiological changes, (*b*) the preparation of specific instrumental motor actions such as information search and approach or avoidance behaviors, and (*c*) the production of communication signals (see Mortillaro et al. 2011, Scherer 2013). A few exceptions notwithstanding (e.g., Lee et al. 2013), these functions have rarely been studied experimentally. Most studies on expression have been devoted to people's recognition of a small number of basic emotions from facial, vocal, and gestural expressions (decoding), while only a few studies have targeted the production of these expressions (encoding) (for a review, see Scherer et al. 2011). As in the work on physiological responses, most work on expression encoding has taken a holistic approach by asking actors to portray specific emotions and then measuring the expressions. Yet it is possible to take a functional approach that develops predictions about links between specific appraisals and specific facial, vocal, and gestural expressions (see Scherer et al. 2017).

The next sections discuss the production of expression driven by appraisals for facial, vocal, and gestural expressions.

Facial Expression

Scherer et al. (2018) reviewed actor portrayal studies in which facial expressions of discrete emotions were coded using the FACS (Ekman & Friesen 1978). Earlier predictions about emotion-specific facial expressions (see Ekman 1997) were only partially confirmed. Many AUs were used by actors as part of their portrayals of many different emotions. Mehu & Scherer (2015) also showed that only a minority of facial AUs were associated with specific emotions. This is compatible with the hypothesis that appraisals combine in many different configurations, resulting in a large variety of different emotions and emotion blends. Although the main rationale for actor

portrayal studies has been to find evidence for the existence of emotion-specific facial expressions and the ability of judges to recognize these, it is possible to analyze the results of these studies for evidence of this alternative hypothesis. Thus, the plausibility of the assumed functions of certain facial expressions expected to be generated by specific appraisals can be investigated by considering the links between the dominant appraisal configurations for major emotions (e.g., unexpectedness, goal obstruction, and other-agency for anger) and the type of facial AUs consistently found for these emotions. This approach was taken by Scherer & Ellgring (2007, pp. 125–6), who interpreted their empirical data on the facial expressions in actor emotion portrayals by discussing the probability of certain appraisals being involved in generating these emotions.

More direct evidence for the hypothesis that appraisals drive specific facial actions can be obtained when appraisals are manipulated in the laboratory and their effects on the face are measured. Appraisals manipulated in the laboratory may not produce facial actions that can be detected through visual inspection, which is why EMG measurement is often used to measure the innervation of specific muscles. A growing body of evidence documents specific muscle activation in response to experimental stimulus manipulations that can be interpreted in terms of appraisals, such as novelty (Stekelenburg & van Boxtel 2002) and valence (Hamm et al. 2003, Heller et al. 2014, Larsen et al. 2003, Neta et al. 2009).

Recent work on facial expressions examined the appraisals of goal relevance, intrinsic valence, goal congruence, and prospective control. Aue et al. (2007) found that biological threat stimuli (high goal relevance) produced increased activity over the cheek region that resembles the fear grin. They also found that winning a reward (goal congruent) led to increased activity over the cheek region (zygomaticus, smiling), whereas losing (goal incongruent) led to increased activity over the brow region (corrugator, frowning). Aue & Scherer (2008, 2011) further confirmed the central role of the zygomaticus and corrugator muscles as reliable signatures for valence (particularly intrinsic valence). Wu et al. (2012) showed similar effects when they manipulated appraisals via a priming procedure. Lanctôt & Hess (2007) used pictures and a PacMan game to manipulate appraisals of intrinsic valence and goal congruence. They replicated the basic pattern reported above, but they also found that intrinsic valence led to significantly faster facial reactions than goal congruence, as predicted by Scherer (2001). The olfaction study by Delplanque et al. (2009) showed that both novel and negative odors produced an increase in frontalis (brow) activity, and that intrinsically negative odors produced an increase in corrugator activity. They also obtained a clear sequence, with novelty effects preceding intrinsic valence effects.

Gentsch et al. (2015a,b) found several main effects on the facial EMG measures over the corrugator, cheek, and frontalis regions for goal congruence (starting approximately 600 ms after feedback onset) and prospective control appraisals (starting approximately 800 ms after feedback onset). They also confirmed the sequence hypothesis, showing that the appraisal of goal congruence preceded that of prospective control. In addition, they obtained interaction effects suggesting amplified goal congruence effects when control was high, in contrast to invariant goal congruence effects when control was low.

Using a different approach, K.R. Scherer, A. Dieckmann, H. Ellgring, M. Mortillaro, and M. Unfried (manuscript under revision) asked professional actors to facially enact a sequence of events in a scenario in which appraisals of the protagonists were sequentially varied. Results showed that actors produced the predicted facial actions significantly more frequently for appraisals of high novelty, positive and negative valence, and low prospective control.

An indirect method to study the effect of appraisal on facial expressions is to use a recognition approach in which judges are asked to infer appraisals from facial expressions. Using this judgment method, Mehu & Scherer (2015) showed that facial behavior plays a significant role both in the recognition of specific emotions and in the judgment of affective dimensions such as arousal,

valence, and potency. A mediation model revealed that the association between facial behavior and recognition of the signaler's emotional intentions is mediated by perceived affective dimensions. The authors concluded that the classification of emotional expressions into discrete categories may therefore rely on the perception of affective dimensions and, presumably, their underlying appraisals.

Scherer et al. (2018) directly tested the claim that observers first detect specific appraisals from different facial muscle actions and then use implicit inference rules to categorize and name specific emotions. They reported three experiments in which various configurations of facial AUs expressed by synthesized avatars were judged for appraisals or emotions, and their results confirmed that participants can, indeed, infer appraisals and emotions in line with predictions from appraisal theories.

Vocal Expression

Empirical work on emotional expression has been dominated by study of the face until very recently. This is quite surprising, as there is an extraordinary amount of evolutionary continuity and interspecies similarity (at least for mammals) in the vocal channel of emotion expression (Briefer 2012). As is the case for facial expression, much of the work on the human voice has been fairly atheoretical, basically attempting to identify the vocal profiles that differentiate specific emotions.

Scherer (1986) proposed a theoretical framework to predict emotion-specific vocal expressions as the result of a sequence of appraisals likely to result in action tendencies and physiological [ANS and somatic nervous system (SNS)] changes that could affect vocalization in a specific fashion. The following examples illustrate this approach and are accompanied by available empirical evidence for several appraisal criteria.

Appraisal criterion: novelty or expectedness. The orienting response (see above) is likely to produce corresponding changes to the settings of the extrinsic and intrinsic laryngeal muscles, leading to raised fundamental frequency (f0; heard as pitch) due to the raised vocal fold tension and respiratory changes affecting voice intensity and speech fluency.

Appraisal criterion: valence. The expected occurrence of a goal-congruent event is likely to lead to relaxation. The person can engage in resting behavior, and the resources expended during goal pursuit can be replenished. This should be accompanied by ANS activity characterized by parasympathetic dominance, a balanced tone in the striated musculature, and relaxed respiration. Frijda (1986) reviewed evidence for parasympathetic dominance in rest and recovery states, including a tendency for abdominal rather than thoracic breathing and increased saliva production. This response pattern is consistent with measurements of expressed contentment in speech, which is characterized by low f0, low to medium intensity, and relatively slow articulation. In contrast, the unexpected occurrence of a goal-congruent event might be expected to trigger an approach tendency, accompanied by general sympathetic arousal preparing for activity, such as deeper and faster respiration and an increase in skeletal motility. For example, for vocally expressed elation, increases in f0 and f0 range are typically observed, as well as increases in the energy of the harmonics and the rate of articulation (Johnstone et al. 2001).

Smiling is likely used to signal to others the presence of something goal congruent or intrinsically positive (see the section titled Facial Expression), whether expected or unexpected. Smiling has the effect of shortening the vocal tract and widening the mouth opening, which causes a rise in formant frequencies and often a rise in f0 (Bachorowski et al. 2001).

The perception of a stimulus of high intensity and negative valence can elicit a defense response, which leads to cardiovascular and muscular changes that facilitate moving or turning away from the

Somatic nervous system (SNS): also called the voluntary nervous system; the part of the peripheral nervous system associated with the conscious, voluntary control of body movements via skeletal muscles

Fundamental frequency (f0): the lowest frequency of a periodic waveform with several harmonics, e.g., the voice, heard as pitch

stimulus (see the section titled Path B: From Appraisal to Physiological Responses). Such changes could be expected to change the length and form of the vocal tract, likely affecting voice quality.

To jointly study intrinsic valence and goal congruence, Johnstone et al. (2005) modified a popular computer game to present stimuli that were either congruent or incongruent with the goal of winning and were accompanied by intrinsically positive or negative sounds. Acoustic analysis of the standardized vocal utterances requested from the participants revealed that mean energy, f0 level, utterance duration, and the proportion of the voiced part of the utterances varied with goal congruence, whereas spectral energy distribution depended on intrinsic valence. Pitch dynamics depended on the interaction between goal congruence and intrinsic valence.

Appraisal criterion: prospective control (+ valence). The appraisal criterion of prospective control becomes especially important in the case of negative events (see Gentsch et al. 2015a). This is true for many species of animals, including humans. In the case of high control, especially in the presence of an aggressive tendency (e.g., in dominance fights), acoustic changes occur, including a rise in vocal energy (heard as loudness) and changes in formant structure (Briefer 2012, Ko et al. 2015). Low or no prospective control, especially when leading to disengagement or resignation, should produce low sympathetic activity and lax muscle tone, which will likely produce decreases in f0 and f0 range, vocal intensity, the energy of the harmonics, and the rate of articulation. This pattern has repeatedly been found in measurements of speech expressing sadness or disappointment (Goudbeek & Scherer 2010, Johnstone et al. 2001). When control is moderate or uncertain, as in states of stress or high mental workload, a sympathetic response is to be expected, resulting in high f0, high vocal intensity, and faster articulation (Johnstone et al. 2001, Paulmann et al. 2016).

Johnstone et al. (2005) examined the effect of goal congruence and prospective control in a computer task in which participants lost or gained points under two levels of difficulty. Results showed interactions between gain or loss and difficulty: f0 was higher for losses than for gains when difficulty was high but not when difficulty was low. Electroglottal measures showed shorter glottal open times for losses than for gains (suggesting raised laryngeal tension). Skin conductance indicated higher sympathetic arousal for losses than for gains, particularly when difficulty was high.

Multiple appraisal criteria. Apart from a few isolated attempts to manipulate appraisals, most of the work on vocal expressions asked professional actors to portray sets of specific emotions (portrayal studies) whereas some studies asked professional actors to enact scenarios designed to elicit specific emotions (Stanislavski method). In a review of 104 studies on vocal expressions, Juslin & Laukka (2003) concluded that the patterns of vocal parameters found across studies were generally consistent with the theoretical predictions of Scherer (1986).

From these portrayal and enactment studies, one can also derive indirect evidence for the role of appraisal criteria by using the profiles of these emotions on the major affective dimensions of arousal, valence, and potency. The important role of arousal in determining vocal parameters in the expression of emotion is well established. There is less evidence for the contribution of valence and potency to vocal emotion expression. To investigate these dimensions further, Goudbeek & Scherer (2010) used this indirect approach to analyze a large corpus of emotion enactments [the Geneva Multimodal Emotional Portrayal (GEMEP) corpus (Bänziger & Scherer 2010, Bänziger et al. 2012)] comprising 12 emotions that systematically vary with respect to valence, potency, and arousal. The acoustic profiles found for specific emotions confirmed earlier findings obtained from a similar corpus (Banse & Scherer 1996). In addition, Goudbeek & Scherer (2010) used composite scores for acoustic parameters to determine the predictive power of these parameters for the underlying dimensions of arousal, valence, and potency. They confirmed that arousal

dominated many vocal parameters, but they could also identify parameters that are specifically related to valence and potency, in particular spectral balance and spectral noise.

Belyk & Brown (2014) suggested that weaker effects for valence and potency may depend on differences between emotion families. In an enactment study, they divided emotional vocalizations into motivational, moral, and aesthetic families. The results showed that valence interacted with emotion family for both pitch and amplitude, suggesting that there may not be a common acoustic code for valence across families of emotions.

Another reason for weak effects is that most research to date has assumed linear relationships and has used multivariate linear statistics to analyze the data linking acoustic parameters to the expression of different emotions. However, there is also a possibility of curvilinear relationships, as in the case of positive valence being expressed by either low or high intensity depending on the respective emotion family or on other factors such as task difficulty (see Johnstone et al. 2005) or emotional intensity (Bachorowski & Owren 1995).

Another indirect dimensional approach to vocal expression of emotion was reported by Laukka et al. (2005), who used five vocally enacted emotions with weak and strong emotion intensity and asked listeners to rate each enactment on arousal, valence, and potency. The portrayals were also acoustically analyzed (e.g., by analyzing speech rate, voice intensity, f0, and spectral energy distribution). Results showed (*a*) distinct rating patterns for arousal, valence, and potency for the different emotions; (*b*) significant correlations of all three affective dimensions with several vocal cues; and (*c*) the successful prediction of all affective dimensions except valence from the vocal cues.

Laukka & Elfenbein (2012) directly investigated the inference of appraisals from vocal expressions. They had actors produce vocal enactments, after which they asked participants to rate the situations that led to these enactments in terms of appraisal criteria (i.e., novelty, intrinsic valence, goal congruence, urgency, agency, prospective control, and fairness). The perceived appraisal profiles for the different emotions showed high inter-rater agreement and were generally in accordance with predictions based on appraisal theory. The appraisal ratings also correlated with a variety of acoustic measures related to pitch, intensity, voice quality, and temporal characteristics of the enactments. A recent follow-up study reported by Nordström et al. (2017) compared an Australian and an Indian sample and found that appraisal criteria inferred from vocal expressions were consistent across cultures.

Gestural Expression

The literature on gestural and other bodily expression is extremely scarce compared to that on facial and vocal expression (but see de Gelder 2006, Lhommet & Marsella 2015). Dael et al. (2012a,b) developed a body movement coding system, which allows one to describe visible activity (gestures) in parts of the body, without interpreting this description in terms of emotions (similar to FACS for the face). They applied the system to the GEMEP corpus mentioned above (which contains multimodal videos of enactments) to investigate the extent to which gestural expression patterns support different predictions in the literature. The results showed that few emotions were characterized by a prototypical gesture pattern, and that most emotions were variably expressed by multiple patterns, which may reflect configurations of appraisals and action tendencies. To follow up on this, Dael et al. (2013) investigated how the expression of emotions that vary on arousal, valence, and potency influences the perception of dynamic arm gestures. Participants rated the arm movements of all emotional expressions from the GEMEP corpus with muted sound and blurred faces on six spatiotemporal characteristics that were found to be related to emotion in previous research (amount of movement, movement speed, force, fluency, size, and height or vertical position). Arousal and potency were found to be strong determinants of the perception

of gestural dynamics, whereas the differences between positive and negative emotions were less pronounced. These results confirm the importance of arm movement in communicating major affective dimensions and show that gesture forms an integrated part of multimodal nonverbal emotion communication.

CONCLUSION AND FUTURE OUTLOOK

Perhaps surprisingly to the reader, this review rarely mentions the standard emotion terms that provide the backbone of classic emotion research, such as anger, sadness, contempt, fear, joy, shame, or guilt, and avoids the discussion of whether there are discrete emotions, how many there are, and whether some of them are more basic (and universal) than others. Similarly, this review does not attempt to review the relative merits of different emotion theories in terms of plausibility or empirical support. Instead, the review focuses on the components of the emotion process about which there is substantial agreement (although there may be disagreement about the roles assigned to each) and on the causal links among them. The purpose of this change of emphasis is to bring new perspectives to the attention of empirical emotion researchers interested in examining the underlying mechanisms, rather than a limited number of basic emotions as the outcomes of these mechanisms.

The classic approach in emotion research has been to start with the end product of the emotion process—individual emotions, as labeled by emotion words—and to try to empirically determine the specificity of these emotions in terms of elicitors and response profiles across the different components. This is problematic for at least two reasons. The first is that terms like anger, fear, sadness, and joy are not homogeneous classes. The anger category may manifest itself as slight irritation or violent rage, sadness as depressed resignation or intense despair, and fear as slight worry or terrorized panic, with an infinite number of intermediate states for each. Moreover, blends or mixtures of emotions are extremely common (Scherer & Meuleman 2013, Scherer et al. 2004). This extreme variability in the outcomes of emotion processes makes it exceedingly difficult to organize systematic research by emotion labels. The second reason is that it is highly likely that the labeling of an emotion episode occurs at the very end of the process, as an outcome (see **Figure 1**). Ideally, hypothesis-guided research specifies the causal factors and their expected interactions in determining the outcome. This is not the case in research that fixes the outcome as a class, given that this type of research does not allow specifying theoretical predictions and is thus reduced to associative measures of class differentiation. The research reviewed in this article illustrates an alternative approach, which emphasizes the underlying mechanism of the emotion process and the dynamic interactions among components. This approach should contribute to building a coherent and plausible theoretical framework that can guide future research.

This does not imply that emotion labels should be banned from emotion research, but rather that they should be placed where they belong: at the end of the emotion process. They should be treated as one class of dependent variables, allowing for a large variety of type and intensity (see the sidebar titled Model Testing in Semantic Sedimentation). This is of particular importance to applied research in real-life settings, where the emotions encountered and studied are generally more subtle, often constituting blends rather than strong prototypical exemplars. Adopting a process approach, in addition to fostering hypothesis-guided designs, may also facilitate emotion research in ecologically valid contexts.

This review discusses relationships among appraisals and three other components. Testing the complete model shown in **Figure 1**, however, would require obtaining evidence for relationships among all of the components. In this review, some patterns of convergence across multiple components are clearly discernible. For instance, novelty appraisal generates an orientation

MODEL TESTING IN SEMANTIC SEDIMENTATION

Since multicomponent data sets that allow sophisticated model fitting have not yet appeared, it is profitable to explore alternative routes to examine the relationships among the components in the emotion process model. One possibility is to exploit the sedimentation of real-world mechanisms in the semantics of emotion words. Scherer & Fontaine (2018) used a large data set on the semantic facets of 24 major emotion terms in 28 world languages. This data set provides very stable profiles on 142 facets covering all emotion components. Using principal component analysis, the authors determined four appraisal factors (valence, novelty, prospective control, and other-agency), five response component factors (approach versus rejection, assertive versus submissive, high versus low autonomic arousal, control action tendency, and orientation) and four feeling factors (bad versus good, strong versus weak, calm versus restless, and tired). The factor scores were used to test the process model in **Figure 1** with theoretically guided hierarchical regression analyses. Two of the significant results were that bad (good) feeling is predicted by valence and novelty appraisals, strongly mediated by approach (rejection) and assertive (submissive) response factors, and that weak (strong) feeling is predicted by valence and other-agency, strongly mediated by assertive (submissive) tendencies and strengthened by control action tendencies.

tendency that seems to be manifested by eyebrow raising in the face. Positive valence appraisal leads to the tendency to approach corresponding to smiling (AU12), and negative valence leads to the tendency to avoid corresponding to frowning (AU4). Control and power appraisal results in the tendency to be active (in the antisocial or prosocial sense), which apparently leads to loud, powerful vocalizations (vocal energy). A combination of unexpectedness, negative valence, and high control appraisals results in effort mobilization and activation that are likely to result in massive changes in the ANS and SNS (especially heart rate and muscle tension). A major task for future model fitting is the detailed examination of the interaction between the components and the degree of coherence of the different components. This will require large-scale collaborations among research teams with different methodological competencies.

Component coherence is also a central issue for the questions of (*a*) when an emotion episode begins or what differentiates it from other, nonemotional, episodes and (*b*) when it becomes conscious. A possible way to answer the first question is to define the start of an emotion episode by an increased synchronization and coherence among the various components beyond a certain threshold and its end by the coherence dropping below a threshold. The degree of coherence might, in turn, be determined by the goal relevance of the event. The nature of the emotion episode could be seen to be determined by the specific patterning over time of recursively generated appraisal results. Such a kaleidoscopic arrangement of appraisal results can generate a near infinite number of different emotion episodes without clear categorical boundaries (Scherer 2009a).

A possible way to answer the second question is to argue that a person will become aware of an altered state after a second threshold of coherence has been reached. A plausible underlying mechanism is the central sensorimotor integration and representation of changes in all synchronized components in the central nervous system (CNS), which receives massive projections from both cortical and subcortical CNS structures (including proprioceptive feedback from the periphery) and serves to monitor and regulate the degree of system coherence. Thus, the degree of coherence among components might generate awareness, leading to the experience of feelings. People can focus on micromomentary changes of feeling, but they usually become aware of them as temporal chunks with phenomenal unity. These chunks might occur when a certain level of component synchronization persists.

Research into component coherence and temporal chunking has barely begun. However, there are increased interest and promising first investigations in both psychology and neuroscience. In 2014, the journal *Biological Psychology* devoted a special issue, titled "Whither concordance? Autonomic psychophysiology and the behaviors and cognitions of emotional responsivity," to this topic. This type of advanced research requires complex dynamic measurement of changes in both the appraisal and response components, and sophisticated statistical and mathematical tools are required for the analysis. Recently, Rügamer et al. (2017) developed and successfully applied a new historical function-on-function regression model to measure the cross-correlation of brain processes (electroencephalographic data) and muscle innervation (EMG data) that were simultaneously recorded from participants while they were playing a computerized gambling task (Gentsch et al. 2014). Our understanding of the nature of the emotion process is intimately tied to further progress in this direction.

SUMMARY POINTS

1. We propose that research move from a discrete emotion approach to an emotion process approach with an emphasis on the mechanisms and determinants underlying the unfolding of emotion episodes, treating emotion labels as dependent variables.
2. The starting point for this movement is a process model (shared across many theories) according to which emotion episodes comprise the following components: stimulus appraisal, action tendencies, physiological responses, motor expression, experienced feeling, and (in some cases) categorization and labeling.
3. Three relationships in the process model are selected for a review of the pertinent literature: the effect of different appraisal criteria on (*a*) action tendencies or behavior, (*b*) physiological responses, and (*c*) motor expression (in face, voice, and gestures).
4. The review of research pertaining to relationships between appraisal and other components is organized by the criteria of novelty or unexpectedness, (intrinsic and extrinsic) valence, agency, control or power, and fairness.
5. Research on the influence of appraisal on action tendencies or behavior draws a complex picture of how the various appraisal criteria influence action tendencies such as antisocial versus prosocial tendencies, approach versus avoidance tendencies, and tendencies to be active versus passive.
6. Work on physiological responses has searched for differences between discrete emotions but has yielded few reliable patterns; in contrast, there is consistent evidence of stable correlates of appraisal criteria on physiological correlates in the ANS and SNS, in particular for cardiovascular parameters and muscle tension.
7. Facial expression has been a mainstay of emotion research since Darwin, yet it has been difficult to show consistent differences in facial muscle activation patterns between discrete emotions, even in actor portrayal studies; in contrast, experimental work on the effects of appraisal manipulations shows well-replicated effects, especially for the effect of valence on the zygomaticus (smile) and corrugator (frown) muscles.
8. Vocal expression has been relatively neglected in research, but recent literature using advanced acoustic analyses shows many consistent response patterns, particularly linked to control or power appraisals.

FUTURE ISSUES

1. Almost all of the work on emotion has been confined to the laboratory and, in many expression studies, to actor-portrayed emotions, highlighting the need to branch out toward more ecologically valid settings, despite the effort and cost involved. One promising avenue might be the use of virtual reality environments and synthetic avatars that can be easily manipulated.
2. While much of the work reviewed above has focused on the relationships between pairs of components, several studies have measured two or more components, some of which reveal coherence and others interaction effects, suggesting the importance of complex multifactorial designs and advanced dynamic measurement rather than before–after designs.
3. A process approach requires explicit causal modeling, as well as sophisticated statistical techniques, particularly with respect to time series modeling and model fitting. While there are some promising developments, much remains to be done.
4. One of the components in the process, the experienced feeling before categorization and labeling, has been neglected, as it has often not been clearly separated from emotion. This should become one of the priorities in future theorizing and research, in collaboration with neuroscientists.
5. Psychological constructionism argues that individuals construct their own categorization of experience and choose an emotional label accordingly. This is undoubtedly true, but it is essential to theoretically link this act to what precedes it in the emotion process, allowing at least some degree of prediction.

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