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Article

2013

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How to cite

SCHERER, Klaus R., MORTILLARO, Marcello, MEHU, Marc. Understanding the Mechanisms Underlying the Production of Facial Expression of Emotion: A Componential Perspective. In: Emotion Review, 2013, vol. 5, n° 1, p. 47–53. doi: 10.1177/1754073912451504

This publication URL: <https://archive-ouverte.unige.ch/unige:97885>

Publication DOI: [10.1177/1754073912451504](https://doi.org/10.1177/1754073912451504)

Understanding the Mechanisms Underlying the Production of Facial Expression of Emotion: A Componential Perspective

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Abstract

We highlight the need to focus on the underlying determinants and production mechanisms to fully understand the nature of facial expression of emotion and to settle the theoretical debate about the meaning of motor expression. Although emotion theorists have generally remained rather vague about the details of the process, this has been a central concern of componential appraisal theories. We describe the fundamental assumptions and predictions of this approach regarding the patterning of facial expressions for different emotions. We also review recent evidence for the assumption that specific facial muscle movements may be reliable symptoms of certain appraisal outcomes and that facial expressions unfold over time on the basis of a sequence of appraisal check results.

Keywords

appraisal, component process model, emotion perception, expression and perception mechanisms, facial expression

Movements of the face are central sign vehicles for the expression and communication of emotions among higher primates, particularly man. Unsurprisingly, the study of facial expression has a long history and has generated an extraordinary amount of research. What is surprising is that this sustained activity has, to date, yielded little insight into the nature of the underlying *mechanisms*. There seem to be three major reasons for this: (a) the neglect of the dynamic nature of facial expression, given the prevalent focus on static expressions or configurations; (b) the neglect of the production mechanisms for facial expressions, given that most research has focused only on emotion recognition; and (c) the relative vagueness of theoretical models about these mechanisms, which impairs clear research designs and an accumulation of evidence (Scherer, Clark-Polner, & Mortillaro, 2011).

At the most general level, a comprehensive theoretical framework is needed to study the emotion expression and perception process. To this aim, Scherer (2011) suggested the tripartite emotion expression and perception model (TEEP). This dynamic model, shown in Figure 1, is based on a combination

of the modified versions of Brunswik's (1956) lens model of perception and Bühler's (1934/1984) organon model of speech (Scherer, 1978, 1988, 2003), as well as on the first author's component process model of emotion (CPM; Scherer, 1984, 2001, 2009). It proposes that sequences of sign vehicles (including muscular movements in the face) are symptoms or externalizations of unfolding emotion processes (appraisal-driven modulations of the autonomic and somatic parts of the peripheral nervous system) with or without communicative intention of the expresser (symptom function). The observer perceives these sign vehicles as proximal percepts and, on this basis, appraises the significance of the expression, using a variety of inference and attribution mechanisms. The result can be the attribution of an emotion to the expresser and/or a variety of behavior changes (appeal function). Importantly, the socio-cultural setting strongly affects the communication process as a result of conventional feeling and display rules and, in particular, the fact that expressive signs can be part of a shared symbolic nonverbal code (representation function).

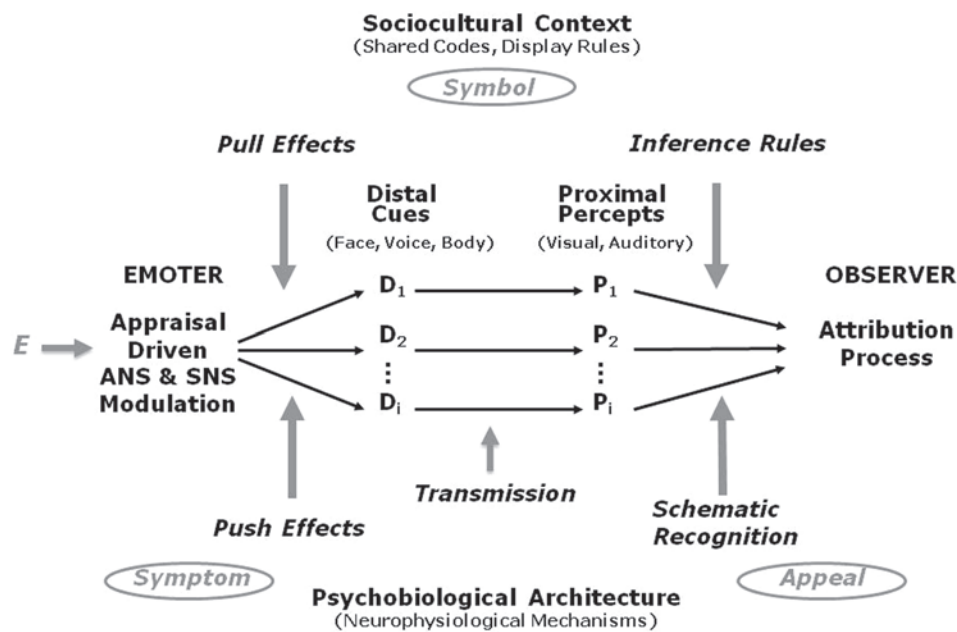


Figure 1. The tripartite emotion expression and perception model (TEEP). E = eliciting factors (events, objects, behaviors); ANS = autonomic nervous system; SNS = somatic nervous system. Reprinted from Scherer (2011).

There is ongoing debate between the proponents of different emotion theories about the functions and meanings of facial expressions. For discrete emotion theorists, the experience of one of the basic emotions will produce a prototypical response configuration that includes an *emotion-specific pattern of facial expression* (Ekman, 1992; Ekman, Sorenson, & Friesen, 1969; Izard, 1994). In contrast, componential appraisal theorists suggest that the *individual elements of facial expression are determined by appraisal results* and represent the efferent effects of the latter on motor behavior (Scherer, 1984, 1992, 2001, 2009; Smith, 1989; Smith & Scott, 1997). Other researchers suggest that facial expressions mainly convey the *action readiness* component of the emotion (Frijda & Tcherkassof, 1997) or are indicators of *valence* and *activation* (Russell, 1997). Finally, Fridlund (1994) maintains that facial expressions serve as *social messages* that evolved to convey intentions and contingencies relevant to a specific audience.

The TEEP model may help us identify the central issues in this debate. As shown in Figure 1, one needs to distinguish between the representational or symbolic meaning as part of a shared code and the subjective meaning based on the inference of the observer, the latter meaning being generally constructed from inferences concerning the origin of the visible symptoms and the observer's expectations and preconceptions. Clearly, to understand the ways in which elements of facial expressions can be symptoms (distal cues) of underlying emotion processes, we need to focus on the nature of the *production mechanisms* and the *underlying determinants*. Until now, there has been little concern with this issue, most emotion theories being rather vague about the details, with the exception of the componential appraisal approach. Here we describe the detailed assumptions

and predictions of the componential appraisal approach and the pertinent evidence to date.

The Component Process Model of Emotion

Componential appraisal theories of emotion (Ellsworth & Scherer, 2003; Frijda, 1986; Roseman & Smith, 2001; Scherer, 1984, 2001; Smith, 1989) define emotion as a process that reflects the cognitive activity, physiological arousal, action tendencies, motor expression, and subjective feeling state in reaction to salient events in the environment. Some of these theories assume that these components are linked (or even synchronized) during an emotion episode (see Scherer, 1984, 2001). Although componential theories of emotion generally do not endorse the idea of a small number of basic emotions (and potential blends), but rather consider that there is a large number of different emotions, they tend to agree that there are overarching emotion families. This view is reflected in Scherer's (1994) concept of *modal emotions*, defined as frequent patterns of appraisal occurring in response to event types that are universally encountered by organisms, such as sadness in the case of loss, or anger in the case of blocked goals (see also the notion of *relational themes* suggested by Lazarus, 1991). Thus, componential models do not fundamentally question the idea that facial expressions mark differentiated emotional states; rather, they propose that the different muscular elements present in complex expressive configurations of the face are driven by appraisals of an eliciting event, mediated by autonomic and somatic components.

One major contribution of componential appraisal theories is the effort to make the link between emotion elicitation and

Table 1. Prediction of sequential appearance of action units (AUs) in response to appraisal check results for five major emotions

Order	Appraisal domain	Check	Subcheck	AUs	Fear	Anger	Joy	Sadness	Disgust
1	Relevance	Novelty	Sudden	1 + 2, 5	**	*	*	—	*
2			Unfamiliar, unpredictable	4 + 7	**	*	*	—	*
3	Implications	Intrinsic pleasantness	Pleasant	12 + 25 + 38	—	—	**	—	—
3			Unpleasant	9, 10, 15, 39	*	—	—	—	*
4		Expectation	Discrepant	4 + 7	*	**	—	*	*
5		Goal attainment	Conducive	6 + 12 + 25	—	—	**	—	—
5			Obstructive	17 + 23, 17 + 24	*	**	—	**	—
6	Coping potential	Power/control	Low	20, 26, 27	**	—	—	**	—
6			High	23 + 25, 17 + 23, 6 + 17 + 24	—	**	*	—	*
7	Norm compatibility	External standards	Violated	10	—	*	—	—	—
7		Internal standards	Violated	14	—	—	—	—	—

Note: + Indicates AU combinations in which two or more AUs are expected to occur simultaneously. AUs separated by a comma represent alternative expressions (in some cases, two of these AUs may occur together or in close sequence). ** Indicates “strongly expected to occur in many instances”; * indicates “expected to occur in some instances” (modified from Scherer & Ellgring, 2007).

response patterning more explicit than has been the case in discrete emotion theories. Thus, theorists have elaborated detailed predictions of physiological, expressive, and motivational changes expected to occur as a result of specific appraisal outcomes (Scherer, 1984, 1992, 2001; Smith, 1989; Smith & Scott, 1997). In his CPM, Scherer (1984, 2001, 2009) defends the idea that the unique, context- and individual-specific response pattern observed during an emotional episode represents the efferent effects of sequentially accrued and cumulated appraisal results (based on the following criteria: (a) relevance of the event; (b) implications for major needs, goals, and values; (c) ability to deal with these consequences or coping potential; and (d) normative significance of the event). The model predicts that the results of sequential appraisal checks will generate appropriate response patterns.

Predictions for facial expression (Scherer, 2001, 2009; Scherer & Ellgring, 2007; see also Kaiser & Wehrle, 2001) have been elaborated from several classes of determinants: (a) the effects of physiological change; (b) the preparation of specific instrumental motor actions; and (c) the production of sociocommunicative signals. The first two determinants refer to what the first author has called “push effects,” that is, neurobiological changes that affect the expressive motor system (the symptom function). In contrast, the communicative function is served by “pull effects,” that is, particular visual or auditory signal configurations that are part of a socially shared code for symbolic exchanges. These two classes of determinants closely interact to produce complex and multimodal emotional expressions (Scherer, 1988). Given the multifactorial determination of muscles in the oropharyngeal and orofacial systems, and the fact that different demands upon the organism may be more or less prevalent depending on the specific context, predictions about the link between internal states and observable units of behavior are mostly probabilistic rather than deterministic. The final expression resulting from the sequential cumulative appraisal process can be predicted on the basis of the assumptions

and theoretically predicted appraisal profiles for major modal emotions. The facial configurations predicted as final outcomes for a number of modal emotions, as based on the mechanism described, are shown in Table 1 (for further details, see Scherer, 2001; Scherer & Ellgring, 2007). The underlying philosophy for elaborating these predictions for modal emotions is that we start with the hypothesized effects of appraisal results and consequent action tendencies (with interacting push and pull effects) and work forward (assuming sequential accumulation of elements) to larger configurations. Because the configuration predictions shown in Table 1 correspond to modal emotions (see Scherer, 1994), they are somewhat similar to prototypical patterns as proposed by discrete emotion theorists. However, the CPM mechanisms suggest that these configurations are the exception rather than the rule, the generative mechanisms based on appraisal results dynamically producing a multitude of different configurations.

Evidence for a Link between Appraisals and Facial Expressions

What is the currently available empirical evidence supporting the CPM framework and concrete predictions? Ideally, one would want a large set of video recordings of facial expressions of naturalistic emotions in which one has measured the appraisal results that have generated the emotion. Clearly, such a corpus does not exist and is unlikely to be assembled. The main problems are that we have only indirect access to appraisal processes occurring in real-life emotion episodes and that most occur in public or private settings in which it is difficult to have access to or to record the face from close up. Furthermore, in public settings, there is a strong tendency to suppress, modify, or mask emotions. For example, using unobtrusive video recordings of the faces of airline passengers reporting lost baggage to an airport agent, Scherer and Ceschi

(2000) found very few facial expressions other than smiles. Similar studies of selected expressions recorded in public can be found in the literature, but the nature of the underlying emotion is often difficult to assess (see Scherer & Bänziger, 2010). The attempt to record dynamic emotion expressions in real-life contexts should not be given up, but researchers need to be conscious of the scarcity of full-blown emotion expressions in public settings and the problems of convenience sampling that often neglects fundamental requirements of experimental control (see Scherer, 2011).

More viable research options involve experimental manipulations of appraisals, imagery tasks, and analysis of enacted expressions. A number of experimental studies have provided evidence supporting the assumption that facial actions covary with specific appraisals. In these studies, researchers recorded the electromyography activity of two or more facial muscles (corrugator supercilii, brow region: frowning; zygomaticus major, cheek region: smiling; frontalis, forehead region: eyebrow raise) in different appraisal conditions. Aue, Flykt, and Scherer (2007) used visual stimuli that varied in relevance (biological threat vs. cultural threat vs. neutral) and manipulated their goal conduciveness (monetary gain vs. loss). Consistent with the idea of more difficulty in processing cultural threat, the stimuli belonging to this category were related to higher activation of the corrugator. Furthermore, consistent with predictions, greater activity in the cheek region (smiling) was recorded when the participants thought they were winning money. Aue and Scherer (2008) used stimuli that varied in intrinsic pleasantness and manipulated goal conduciveness through a behavioral task. Results showed that the two appraisals affected activity of the facial muscles in accordance with CPM predictions: Activity in the cheek region was higher for pleasant stimuli and goal conducive events; activity in the brow region was higher for unpleasant stimuli and obstructive events. Delplanque et al. (2009) presented pleasant or unpleasant odors that were either novel or familiar to the participants and investigated physiological and facial reactions to appraisals of novelty and intrinsic pleasantness. The results showed a highly significant increase in the activity of muscle over the forehead region (frontalis) for novel stimuli and over the forehead and brow region (corrugator) for unpleasant stimuli.

Other researchers investigated the relationship between appraisals and expressions by using an imagery task. Smith (1989) tested the relationship between frowning and appraisals of anticipated effort and other agency in imagined scenarios. Results showed that effort manipulation had a strong effect on the activity of the brow region, but not other agency. From the analysis of the self-reported appraisals, it emerged that participants dissociated the two appraisals related to effort manipulation, that is, anticipated effort and perceived obstacles. The appraisal of perceived obstacles, more than anticipated effort, was particularly responsible for the frown activity. This finding was replicated by Pope and Smith (1994), who used an imagery task to study the activity of the corrugator muscle (frown) and zygomaticus major (smile) associated with appraisals of pleasantness, perceived goal obstacle, anticipated effort, and motivational congruence. Results confirmed

the association of corrugator activity with perceived goal obstacles and motivational incongruence, and the association between zygomaticus activity and subjective pleasantness.

The plausibility of the predictions made by componential appraisal theorists can be examined indirectly by asking professional actors to enact a large number of emotions by using imagery and other induction techniques and by examining which patterns of facial action units (AUs; Ekman, 1992) they produce in enacting the different emotions. Note that the special enactment procedure, in which actors are induced through a variety of techniques to reexperience earlier emotional states similar to the target emotions, is very different from portrayal approaches in which actors are encouraged or even required to produce certain patterns of AUs (see Bänziger, Mortillaro, & Scherer, 2011). Thus, Scherer and Ellgring (2007) examined the frequency with which AUs were activated in enacted expressions of several major emotions. They found very few of the prototypical facial configurations postulated for basic emotions. Nevertheless, the enacted expressions were generally recognized with high accuracy by raters. Overall, the results are highly compatible with appraisal predictions, and the authors argued that the patterns of AUs used to express emotions were in line with the functional adaptive considerations at the basis of the componential model of emotion. More recently, using the same paradigm on a new corpus of emotional expressions (Geneva Multimodal Emotion Portrayals; Bänziger et al., 2011), Mortillaro, Mehu, and Scherer (2011) analyzed the facial expressions of four positive emotions: interest, joy, pride, and pleasure. Results showed that these emotions could not be discriminated from single facial movements. Nevertheless, differences in facial activity emerged when the expressions were contrasted in terms of the appraisals underlying the emotions. In particular, the appraisal dimension of novelty—suddenness—was reflected in the degree of eye opening. Other possible links were advanced: cheek raise (AU6) for intrinsically pleasant emotions and eyelid tightening (AU7) for goal obstructive emotions. Overall, the study strengthened the plausibility of interpreting single facial movements in terms of appraisals. The same suggestion is also advanced by Mehu, Mortillaro, Bänziger, and Scherer (2012) in their investigation of the role of facial muscles in conveying reliable emotional information. The authors found that some individual AUs, although not indicative of an emotion category per se, convey emotional meaning in that perceivers use these movements to evaluate the authenticity of the emotional expression.

Supporting evidence for the predictions of the CPM is available concerning three appraisal checks: (a) Appraisal of novelty is associated with activity in the forehead (eyebrow raise) and eyelid opening; (b) appraisal of intrinsic pleasantness is associated with activity of the zygomaticus major, cheek raise (pleasant events), and the corrugator (unpleasant events); and (c) goal conducive events are associated with activity of the zygomaticus major and goal obstructive events with increased activity of the corrugator muscle. Predictions of facial movements for the remaining appraisal dimensions of the CPM—coping potential and normative significance—have not been tested.

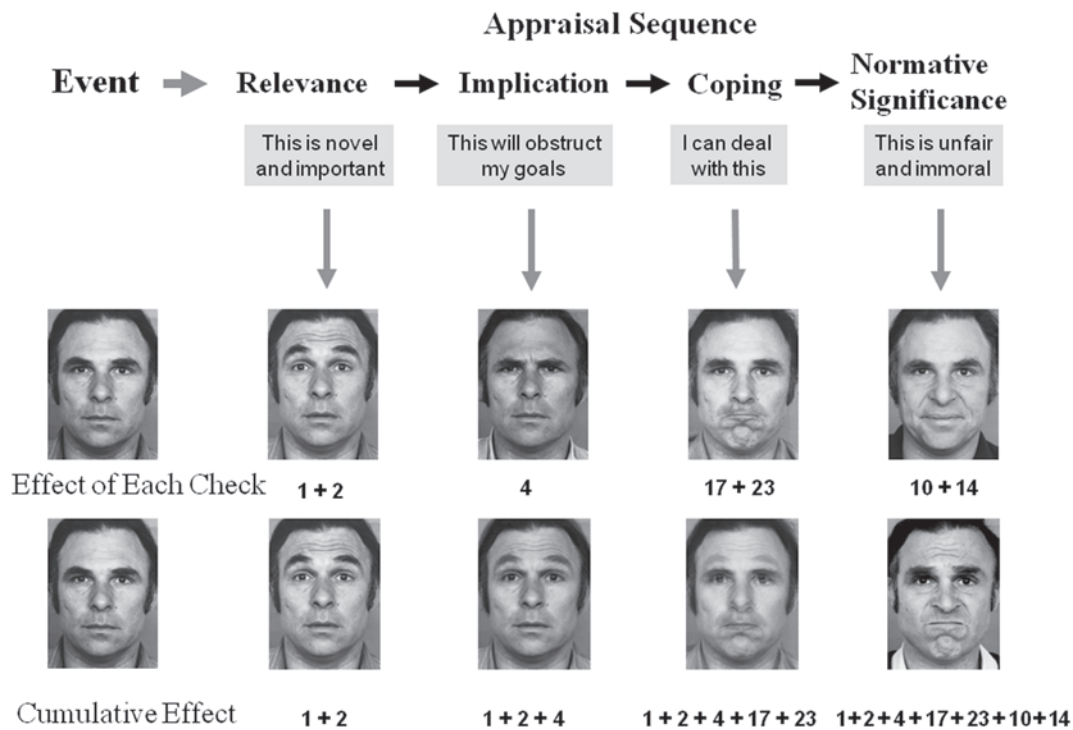


Figure 2. Example of cumulative and sequential effects of appraisals on facial expressions as hypothesized by the component process model. Numbers refer to action unit numbers as defined in the FACS manual. Reprinted from Scherer and Ellgring (2007).

The Sequential Hypothesis of Appraisal Unfolding

As briefly indicated, the CPM assumes that different appraisal checks recursively occur in a fixed order (based on phylogenetic, ontogenetic, and microgenetic grounds; Scherer, 2001, 2009). If facial actions were indeed determined by the outcome of sequential appraisal checks, specific facial movements (mediated by physiological concomitants or functional action preparation; e.g., tuning of sensory organs for information intake or fight or flight) should also occur in a discriminable sequence rather than arising simultaneously. The suggested process is illustrated in Figure 2 (reproduced from Scherer & Ellgring, 2007). A list of predictions can be drawn up for sequence patterns that can be expected for certain emotions in connection with the postulated appraisal structure (see Table 1).

Only a few studies have investigated the temporal unfolding of facial movements in the framework of appraisal theory. Thus, Aue et al. (2007) showed that, as predicted by the CPM, the effect of stimulus relevance appeared earlier in the activity of both corrugator and zygomaticus than the effect of goal conduciveness appraisal. Lancôt and Hess (2007) investigated the onset of movement in three facial muscles (corrugator supercilii, zygomaticus major, and orbicularis oculi) in response to appraisals of intrinsic pleasantness and goal conduciveness. In the framework of a video-game paradigm, the authors manipulated these two appraisals and found that muscles were activated more rapidly in response to evaluation of intrinsic pleasantness

than to evaluation of goal conduciveness, suggesting that the former is evaluated prior to the latter.

In the Delplanque et al. (2009) odor study, the authors found an increase in muscle activity over the forehead region for novel stimuli, in comparison to familiar stimuli, at about 100 ms after the presentation of the stimulus. In contrast, the effect of pleasantness on frontalis and corrugator was observed about 500 ms after the presentation of the stimulus, supporting the hypothesized sequence of appraisal checks. Finally, Krumhuber and Scherer (2011) investigated the sequence of facial AUs displayed in the expression of five emotions. From the analysis of 100 expressions taken from the Geneva Multimodal Emotion Portrayal corpus (Bänziger et al., 2011), the authors found that individual AUs reached their apexes at different times in the expression of different emotions. Although specific predictions concerning the timing of AU4 (frowning) were not confirmed, general results support the notion of sequentiality of facial movements in the expression of emotion.

These few studies show preliminary evidence for some elements of the sequential hypothesis: evaluation of novelty preceding evaluation of intrinsic pleasantness, in turn preceding evaluation of goal conduciveness.

Conclusion

Limited space does not allow us to expand on the consequences of the component patterning model for the remaining parts of the TEEP model. In a recent review of studies on cross-cultural

emotion recognition (Scherer et al., 2011), we reported the extent to which the area suffers from the lack of theoretical grounding and absence of concern about the dynamic nature of emotional expression. Thus, a review of the emotion recognition literature has demonstrated the need to at least complement the study of static photos with dynamic multimodal—or at least facial—stimuli and that many of the hotly debated issues (e.g., universality vs. cultural specificity of expression) cannot be fruitfully discussed, given the lack of comprehensive research designs.

We also argue for the need to study expression production and perception in a single paradigm (e.g., using the TEEP model) on the basis of clear theoretical predictions. Thus, the discussion of the type of information that observers can reliably infer from facial expressions (emotion labels, appraisals, valence and arousal, action tendencies, or social messages; see Scherer & Grandjean, 2008) would greatly profit from measuring or manipulating production factors such as the nature of the facial AUs used and the sequence of their occurrence. In addition, researchers should turn toward other aspects of the appeal function of facial signs, such as contagion, empathy, or behavior change, rather than exclusively pursuing the question of accurate recognition based on verbal labels. Although there is some work on these issues, it is generally conducted outside of the area of emotion expression research.

In addition, the third function of facial signals contained in the TEEP model—the symbolic or representational function of facial movements—has been generally neglected by emotion researchers. This is all the more problematic because the likelihood is high that few expressions are the result of pure push effects in the sense of a classic symptom function. Given the widespread occurrence of expression control, modification, and masking, as well as sheer strategic manipulation (Scherer & Bänziger, 2010), we need to know much more about the way in which facial signals are part of a shared representational and symbolic code. If anything, the extraordinary increase in the use of graphic emoticons in interpersonal communication over the Internet demonstrates the degree of codification attained.

We conclude that the facial expression mechanisms proposed by componential appraisal theory are not only plausible, having a high degree of explanatory power, but are also supported by recent studies from different laboratories. Specifically, the highly controlled experimental work reported earlier provides strong evidence that certain appraisal outcomes (a) reliably produce the predicted facial AUs, and (b) generally occur in the theoretically postulated sequence. Not all hypotheses of the CPM have been studied or confirmed, but we believe that, given the small number of researchers working in this area, the available evidence is extremely promising. Even more important, the level of details of the predictions should allow other researchers to test them and replicate or disconfirm findings. Although some of the work described earlier is based on basic emotion categories (given the need to compare with other theories), the CPM account of facial expression mechanisms is much more general, assuming that all facial movements, even outside of

what would strictly be considered an emotion episode, can potentially be explained by the underlying architecture. This work is still at the beginning, limited to a handful of research groups. It is to be hoped that the accumulating evidence will encourage other investigators to use this promising paradigm. We believe that such a paradigm shift is likely to make headway in solving the three fundamental problems outlined earlier: neglect of the dynamics of facial expression, neglect of the production mechanisms, and lack of explicit and comprehensive theoretical models to guide research.

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