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Coherence explored between emotion components: Evidence from event-related potentials and facial electromyography

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ABSTRACT

Componential theories assume that emotion episodes consist of emergent and dynamic response changes to relevant events in different components, such as appraisal, physiology, motivation, expression, and subjective feeling. In particular, Scherer's Component Process Model hypothesizes that subjective feeling emerges when the synchronization (or coherence) of appraisal-driven changes between emotion components has reached a critical threshold. We examined the prerequisite of this synchronization hypothesis for appraisal-driven response changes in facial expression. The appraisal process was manipulated by using feedback stimuli, presented in a gambling task. Participants' responses to the feedback were investigated in concurrently recorded brain activity related to appraisal (event-related potentials, ERP) and facial muscle activity (electromyography, EMG). Using principal component analysis, the prediction of appraisal-driven response changes in facial EMG was examined. Results support this prediction: early cognitive processes (related to the feedback-related negativity) seem to primarily affect the upper face, whereas processes that modulate P300 amplitudes tend to predominantly drive cheek region responses.

1. Introduction

The concordance across emotion components, or, in more general terms, between activation parameters in central (e.g., brain activity) and peripheral response systems (e.g., facial muscle activity; autonomic physiology such as heart rate, respiration, or skin conductance) is one of the classic issues in psychophysiology research (cf. Fahrenberg & Foerster, 1982). The large number of studies and critical reviews (e.g., Barrett & Russell, 1999; Burdick, 1978; Bush, Luu, & Posner, 2000; Engel, Fries, Konig, Brecht, & Singer, 1999; Grandjean, Sander, & Scherer, 2008; Hajcak, MacNamara, & Olvet, 2010; Harmon-Jones, 2003; Knyazev, 2007; LeDoux, 2012; Lewis, 2005; Morecraft, Stilwell-Morecraft, & Rossing, 2004; Olofsson, Nordin, Sequeira, & Polich, 2008; Scherer, 1988, 2000; Varela, Lachaux, Rodriguez, & Martinerie, 2001) underline the importance of research on this issue. Our aim in the present study was to investigate the prerequisite of the synchronization or coherence hypothesis between central and peripheral psychophysiological measures: we investigated the plausibility of the claim that appraisal results drive the response changes in the peripheral measures (e.g., Scherer, 2009). While participants played a gambling task, we recorded simultaneously the cortical brain activity (event-related potentials, ERPs) and facial electromyography (EMG; placed over frontalis, corrugator, and cheek regions).

1.1. Concordance from the perspective of componential emotion theory

In componential emotion theory, the term 'synchronization' (Grandjean & Scherer, 2009) refers to the development of concordant, coherent, temporally correlated, or synchronized response changes in the emotion components (i.e., appraisal, facial expressions, physiological changes, action tendencies, and subjective feeling). Coherent response changes emerge despite the different response dynamics (i.e., latency, patterning, and intensity) in each emotion component during an emotional episode. We are using in this context the terms 'synchronization', 'coherence', and 'concordance' synonymously. One componential emotion theory—the Component Process Model (CPM; Scherer, 1984, 2009)—proposes

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Table 1
Results of repeated measures ANOVAs on the event-related potentials.

	FRN (234–293 ms)		P300 (344–574 ms)	
	F	η^2	F	η^2
GC	13.17***	.36	19.99***	.47
GC × channel	4.00*	.15	4.30*	.16
Power	0.30	.00	2.80	.11
Power × channel	0.00	.00	7.87*	.26
GC × power	1.46	.06	2.48	.10
GC × power × channel	2.15	.09	1.11	.05

Notes. FRN = feedback-related negativity. For the FRN and the P300 a Greenhouse–Geisser adjusted repeated measures ANOVA was performed each, with the within-subject factors of goal conduciveness (GC: win vs. loss vs. break-even), power (Power: high vs. low), and channel (FRN: Fz and FCz; P300: Pz and POz).
* $p < .05$.
*** $p < .001$.

that appraisal results[1] (central emotion component) drive or initiate the response changes in the peripheral components. This initiating input is the prerequisite of a subsequent coherent (concordant) emotional response. In the CPM, synchronization is used as shorthand to refer to the emergence of a coherent (appraisal-driven) response patterning among emotion components.

Hypothesizing a *component patterning process*, the CPM advances three central notions about the emotion process (Scherer, 2000; for more detail, see also Scherer, 2001, 2009). (1) People appraise events by means of sequentially processed appraisal checks (so-called stimulus evaluation checks, which are novelty, intrinsic pleasantness, goal conduciveness, power, and norm compatibility). (2) The result of an appraisal check changes the state of each emotion component in the direction of what constitutes an adaptive response to the event (see Table 1, Scherer, 2009, for detail). For example, the appraisal result that an event obstructs a current goal may prompt a frown (see also Scherer, Mortillaro, & Mehu, 2013; Smith, 1989, for detail). (3) The pattern of an emotional response is the cumulative synchronized result of all appraisal-induced changes in the emotion components, realized through ensuing feedback-feed-forward interactions between these components (Grandjean & Scherer, 2009).

The aim of the present study is to test the plausibility of notion (2)—the hypothesized prerequisite of coherence across emotion components—that is, whether appraisal (check) results drive the state changes in the emotion components. In particular, we tested whether the modulations of ERP components related to experimentally manipulated appraisal checks of goal conduciveness (motivational valence appraisal) and power (personal ability appraisal) drive the response changes in the facial expression component. The appraisal checks were manipulated in a gambling task during which we recorded simultaneously brain activity (ERPs) and facial muscle activity (electromyography, EMG; frontalis, corrugator, and cheek regions) to address this question.

1.2. Concordance within and across emotion components

Componential emotion theories provide little explanation about the mechanisms that can explain how the appraisal component relates to the other components and how appraisal information is integrated in each component. Appraisal theories have focused on the appraisal results that are central to particular emotions, but have rarely addressed the issue of how the information about the event is integrated within and across components (e.g., Ellsworth & Smith, 1988; Ellsworth & Tong, 2006; Kappas, 2006; Lazarus, 2001; Leon & Hernandez, 1998; Reisenzein, 1995; Roseman, 2004; Smith & Kirby, 2004, 2009; Tong, Ellsworth, & Bishop, 2009). Research that empirically investigated the appraisal process, as conceptualized by the CPM, repeatedly reported differentiated appraisal check effects in central and peripheral psychophysiological response variables (Aue, Flykt, & Scherer, 2007; Delplanque et al., 2009; Gentsch, Grandjean, & Scherer, 2013; Grandjean & Scherer, 2008; Kreibig, Gendolla, & Scherer, 2010; Lanctot & Hess, 2007; van Reekum et al., 2004).

The studies that focused on the appraisal check effects of intrinsic pleasantness (pleasantness/hedonic value appraisal) and goal conduciveness have found sequential and partly cumulative appraisal check effects in cortical brain activity (Grandjean & Scherer, 2008), facial muscle activity (corrugator and the zygomaticus regions) and heart rate responses (Aue & Scherer, 2008, 2011). Appraisal check effects in brain activity were interpreted to represent instances at which the appraisal process has achieved conclusive preliminary evaluations about an event. The CPM suggests that those instances contain sufficient information in order to *drive* the response changes in the other emotion components (see for details, Scherer, 2009). Nonetheless, based on the results of these studies, no inferences can be drawn about how the appraisal results in brain activity relate to appraisal-driven response changes in facial muscle activity and autonomic physiology because the central and peripheral measures were not concurrently recorded. Thus, a direct empirical support for the synchronization hypothesis is missing, in particular, for the prediction that appraisal results drive the initial state changes in the peripheral components. For example, the CPM suggests that an appraisal result of *goal obstruction* that modulates an ERP component (e.g., a large negative deflection on the feedback-related negativity) is causally related to a goal obstruction effect over the corrugator region (i.e., increased frowning).

Furthermore, although a few studies have concurrently recorded participants' EEG and facial EMG responses to still pictures displaying emotional facial expressions (Achaibou, Pourtois, Schwartz, & Vuilleumier, 2008), aversive scenes (Wangelin, Low, McTeague, Bradley, & Lang, 2011), or to audio recordings of emotional words (Wexler, Warrenburg, Schwartz, & Janer, 1992), these measures were analyzed and interpreted separately. Those concurrent recordings were used only to draw comprehensive conclusions from different response parameters and they fell short of investigating the coherence between the central and the peripheral measures. As a consequence, mathematical/statistical methods need to be identified that can be used to test the prerequisite of synchronization processes—the claim that (central) appraisal results drive the response changes in peripheral emotion components such as facial expression.

1.3. The present study

This study represents a first, exploratory step toward investigating the synchronization processes between two emotion components—the appraisal and the facial expression components. We investigated the cortical markers of the appraisal process in event-related potentials (ERPs) and the associated appraisal-driven changes in facial electromyography (EMG), which were concurrently recorded in response to feedback stimuli. We explored whether the appraisal result pattern, found in the ERPs,[2] similarly occurred in the facial EMG data.

[1] Appraisal *results* can be referred to as *appraisals* (plural of appraisal). The singular of appraisal refers to the appraisal *process* (cf. Moors & Scherer, 2013).

[2] ERPs are considered to constitute instances at which appraisal checks have achieved a first conclusive result about the evaluated event (Scherer, 2009). A result is conclusive or has reached 'preliminary closure' as soon as it drives efferent effects.