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Temporal dynamics and potential neural sources of goal conduciveness, control, and power appraisal☆

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ABSTRACT

A major emotion theory, the Component Process Model, predicts that emotion-antecedent appraisal proceeds sequentially (e.g., goal conduciveness > control > power appraisal). In a gambling task, feedback manipulated information about goal conduciveness (outcome: win, loss), control (perceived high and low control), and power appraisals (choice options to change the outcome). Using mean amplitudes of event-related potentials, we examine the sequential prediction of these appraisal criteria. Additionally, we apply source localization analysis to estimate the neural sources of the evoked components of interest. Early ERPs (230–300 ms) show main effects of goal conduciveness and power but no interaction effects suggesting *goal obstructiveness assessment* of task-relevant feedback information. Late ERPs (350–600 ms) reveal main effects of all appraisals and interaction effects representing the *integration of all appraisal information*. Source localization analysis suggests distinct neural sources for these appraisal criteria.

1. Introduction

An important area of emotion research concerns the neural mechanisms of emotion elicitation and differentiation. The fact that similar events elicit different emotions in different people or in the same person at different times and in varying intensities renders the study of the underlying mechanism of emotion elicitation and differentiation highly challenging. Appraisal theories (for an overview, see Moors, Ellsworth, Scherer, & Frijda, 2013; Scherer, Schorr, & Johnstone, 2001) defend their view that the way people evaluate an event determines the type of elicited emotion. They conceptualize a specific cognitive process – *appraisal* – through which events are evaluated on a number of different criteria (e.g., novelty, relevance, pleasantness, goal congruence, agency, and coping potential). The combination of appraisal results for different criteria determines the type of emotion and its intensity.

The organization and neural correlates of appraisal processes remain largely unexplored. Urgent need for empirical clarification concerns (a) whether appraisal criteria are processed sequentially or in parallel, and (b) to what extent the processing of different criteria is tied to specific neural substrates (e.g., goal obstructiveness appraisal might be related to cognitive processes reflected by an event-related potential [ERP] component ~230–300 ms after stimulus onset) (cf. Moors et al., 2013). To date, only a few electroencephalography (EEG)-ERP studies have investigated the temporal organization of appraisal processes (Gentsch, Grandjean, & Scherer, 2013; Grandjean & Scherer, 2008; van Peer, Grandjean, & Scherer, 2014). These studies examined the temporal structure of appraisal processes as specified by the Component Process Model (CPM, Scherer, 1984, 2001, 2009). The results indicate that EEG–ERP measures of event processing can indeed be related to the operation of particular appraisal criteria such as novelty, goal/task relevance, intrinsic pleasantness, goal conduciveness, and power. Consistent with the prediction of the CPM, the results also indicate that appraisal criteria were processed sequentially (indicated by sequential effects on subsequent ERP components and sequentially organized distinct spatiotemporal scalp maps) and presumably also in parallel (suggested by separate main effects on the same ERP component in the absence of interaction effects) immediately

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after stimuli onset. Nonetheless, it remains inconclusive whether sequential appraisal effects on ERP components also occur for other appraisal criteria such as control appraisal and whether these appraisal processes have distinct markers, and to what extent they are tied to specific neural sources or networks.

In the present study, control appraisal (i.e., assessment of perceived situational control) is added to the manipulation of goal conduciveness (motivational valence or goal congruency evaluation of an event, e.g., a win is goal conducive/congruent and a loss is goal obstructive/incongruent) and power appraisals (i.e., assessment of choice options) in an experimental gambling task for the first time. To date, these appraisal criteria have not been jointly investigated in ERPs and their potential neural sources have not been explored. We applied the traditional ERP approach to investigate their temporal dynamics and we added source localization analysis to estimate the neural sources of the ERPs. The central research issues are reviewed in the subsequent paragraphs.

2. Appraisal processes

The CPM (Scherer, 1984, 2009) hypothesizes a fixed sequential and cumulative operation of appraisal checks (*sequence hypothesis*). These predictions are established on the notion of limited information processing resources and on phylogenetic, ontogenetic, and micro-genetic (logical) considerations (see Scherer, 1984, 2001, 2009; Scherer, Zentner, & Stern, 2004 for more details). While appraisal theories largely agree on the types of appraisal criteria, there is disagreement on whether all criteria are always implicated in appraising events and to what extent they are processed sequentially (e.g., Roseman, 2001; Smith & Ellsworth, 1985; Smith & Kirby, 2009a; Smith & Lazarus, 1993). Experimental data are needed to solve these issues. In the present study, we will focus on the sequential organization of processed appraisal information related to the appraisals of goal conduciveness, control, and power.

Despite the long tradition of appraisal theories, only a few studies have been designed to examine the temporal organization of appraisal criteria and the related cognitive processes using EEG–ERP recordings (Gentsch et al., 2013; Grandjean & Scherer, 2008; van Peer et al., 2014). Results of these studies support the view of a sequential organization of appraisal processes immediately following event onset. Grandjean and Scherer (2008) manipulated novelty, goal/task relevance, intrinsic pleasantness, and goal conduciveness appraisal in a modified visual Oddball task using affective pictures. They found a sequential order of these appraisal criteria and identified specific time intervals for each criterion: (a) novelty (∼0–130 ms), (b) intrinsic pleasantness (∼100–130 ms), (c) goal/task relevance (∼130–380 ms), and (d) goal conduciveness appraisal (∼250–380 ms). Furthermore, single and cumulative effects of sequential appraisal processing of novelty (∼200–300 ms) and intrinsic pleasantness (∼300–400 ms) were investigated in more detail in a visual Oddball task (van Peer et al., 2014), indicating that the processing of intrinsic pleasantness depends on the preceding processing of novelty. Gentsch et al. (2013) used feedback to manipulate goal conduciveness and power appraisal in a gambling task. The results suggest that goal conduciveness (∼230–300 ms) is initially appraised and is followed by power appraisal (∼350–600 ms). To sum up, these studies consistently found converging evidence for sequential processing of appraisal criteria in EEG–ERP recordings. However, potential neural sources of these effects have not yet been addressed, for example, by applying a source localization analysis.

3. Control and power appraisal

In appraisal theories, determining the degree of situational control (control appraisal) and personal resources (power appraisal, e.g. available options to change an event or its consequences) are important for discriminating among unpleasant affective states such as anger, sadness, disgust, frustration, and fear (e.g. Lazarus, 1991; Roseman, Antoniou, & Jose, 1996; Scherer, 2001; Smith & Ellsworth, 1985). The CPM conceptualizes three separate appraisal criteria for the assessment of coping potential (Scherer, 2001, 2009): (1) Control appraisal evaluates the extent to which an event or its outcome can be controlled by agents (people or animals). For example, the weather and the lottery are usually uncontrollable, whereas the behavior of a friend or the duration of a meeting is relatively controllable. If control is possible, (2) power appraisal subsequently assesses the options to act on the event and the available resources to attain or maintain current goals or needs. Resources can be knowledge, physical strength, money, other people, or rational analysis (French & Raven, 1968; Klein, 1998). If control is impossible, (3) adjustment appraisal evaluates how well one can adjust to the consequences. In the present study, we investigate the processing of control and power appraisals in ERPs.

4. Processes underlying goal conduciveness, control, and power appraisals

The neural mechanisms that underlie the processing of control and power appraisals are not well understood. The results of our previous study (Gentsch et al., 2013) indicate that high power appraisal could be related to cognitive processes of context updating, mental resource investment, and enhanced encoding that operate between 350 and 600 ms after event onset (cf. Kok, 2001; Olofsson, Nordin, Sequeira, & Polich, 2008; Polich & Kok, 1995). Previous studies on perceived personal ability (e.g., Pecchinenda & Smith, 1996; Smith & Kirby, 2009b) and power appraisal (van Reekum, 2000) have manipulated task difficulty or shooting power in a computer game, respectively. For example, Pecchinenda and Smith (1996) demonstrated that in the most difficult task condition of an anagram task, low power appraisal was related with task disengagement and reduced skin conductance activity. Also van Reekum (2000) showed that low power appraisal lead to task disengagement and prolonged reaction times. In our previous study, low power appraisal showed less positive P300 amplitudes compared to high power appraisal. Less positive P300 amplitudes may reflect reduced processing depth, which indirectly indicates disengagement in the presence of low power appraisal. To date, only one EEG–ERP study investigated power appraisal (Gentsch et al., 2013), but there is no published EEG–ERP study which investigated control evaluation as it is conceptualized by appraisal theories.

Neural correlates associated with goal conduciveness appraisal are usually investigated in the form of motivational valence evaluation in monetary gambling tasks (e.g., Gehring & Willoughby, 2002; Hajcak, Moser, Holroyd, & Simons, 2006; Nieuwenhuis, Yeung, Holroyd, Schurger, & Cohen, 2004; Pfabigan, Alexopoulos, Bauer, & Sailer, 2011; Philiastides, Biele, Vavatzanidis, Kazzer, & Heekeren, 2010). In these tasks, feedback stimuli convey information about the motivational valence (e.g., win or loss) and the magnitude of the outcome (small or large). Two ERP components are commonly investigated in this context. (1) The FN, which is a negative deflection occurring in feedback-locked ERPs between approximately 200 and 300 ms after feedback onset over medial-frontal electrode sites, and (2) the P300/P3b, which is a positive deflection, maximal over parieto-occipital electrode sites between 350 and 600 ms after feedback onset.

Depending on the task and research focus of the study, the FN is labelled differently (e.g., feedback[-related] negativity, F[R]N; [feedback] error-related negativity, [f]ERN; or medial-frontal negativity, MFN). Despite these labels, similar cognitive processes might underlie these negative peaks (Nieuwenhuis et al., 2004), pre-