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Sensitivity of EEG upper alpha activity to cognitive and affective creativity interventions

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ABSTRACT

We investigated whether creative cognition can be improved by means of cognitive and affective stimulation and whether these interventions are associated with changes of EEG alpha activity. Participants were required to generate original uses of conventional objects (Alternative Uses task, AU) while the EEG was recorded. In the cognitive stimulation condition, participants worked on the AU task subsequent to the exposure to other people's ideas. In the affective stimulation condition, they had to think creatively in positive affective states, induced via emotionally contagious sound clips. Creative cognition generally elicited alpha synchronization, most prominent in the prefrontal cortex and in the right hemisphere. The interventions were associated with stronger prefrontal alpha activity in the upper alpha band (10–12 Hz) than the control condition (no intervention), possibly indicating a state of heightened internal awareness, which might have a beneficial impact on creativity.

1. Introduction

Neuroscientific approaches to the study of creativity, which is commonly defined as the ability to produce work that is both novel and useful within a certain social context (see, e.g., Flaherty, 2005; Stein, 1953; Sternberg and Lubart, 1996), have produced valuable insights into potential brain correlates underlying this prominent mental ability domain. As nicely delineated in recent reviews of relevant neuroimaging studies in the burgeoning field of creativity (Arden et al., 2010; Dietrich and Kanso, 2010), brain activity has been investigated in response to divergent (as opposed to convergent) thinking (e.g., Mölle et al., 1999; Razumnikova, 2000), during insightful problem solving or the subjective experience of "AHA!" (e.g., Jung-Beeman et al., 2004; Sandkühler and Bhattacharya, 2008), likewise during the performance of classic creativity tasks such as the unusual uses test (e.g., Chávez-Eakle et al., 2007; Folley and Park, 2005), or in relation to musical creativity or visual art (e.g., Bhattacharya and Petsche, 2005).

Brain correlates underlying different facets of creative cognition have mostly been investigated in employing EEG techniques. Research in this field has been stimulated by the pioneering work of Colin Martindale who showed that highly creative individuals were more likely to exhibit higher EEG alpha wave activity (i.e., EEG activity approximately in the frequency range between 8 and 12 Hz) than less creative individuals while performing the classic Alternate Uses (AU) test, which requires individuals to generate original uses of conventional, everyday objects (Martindale and Hines, 1975). In Martindale and Hasenfus (1978), a higher level of alpha activity has been observed while participants were instructed to think of a story (i.e., inspirational phase) than during an analog of creative elaboration (i.e., writing down the story). Interestingly, this effect was more pronounced when individuals were explicitly instructed to be original in doing their responses (cf. Martindale and Hasenfus, 1978).

Meanwhile the particular role of EEG alpha activity in the context of creative cognition has been corroborated in a series of studies employing a broad range of different creativity-related task demands (e.g., Bazanova and Aftanas, 2008; Fink et al., 2007; Jaušovec, 2000; Jaušovec and Jaušovec, 2000; Jung-Beeman et al., 2004; Razumnikova, 2000; Martindale, 1999; Sandkühler and Bhattacharya, 2008). Specifically, on the basis of existing evidence in this field it can be concluded that EEG alpha activity varies as a function of the creativity-related task demands (the more creative a task the higher the level of alpha activity; Fink et al., 2007; Martindale and Hasenfus, 1978) and subjective experience of insight (more alpha in insight vs. non-insight solutions; Jung-Beeman et al., 2004; see also Bowden et al., 2005). Also, EEG alpha activity has been observed to be related to an individuals' creativity level (more alpha in higher creative individuals; e.g. Fink et al., 2009a,b; Jaušovec, 2000; Martindale and Hines, 1975) and to the originality of responses (Fink and Neubauer, 2006, 2008; Grabner

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et al., 2007; Martindale and Hasenfus, 1978). In addition, research in this field also suggests that alpha activity increases as a result of a verbal creativity training (Fink et al., 2006). The training was composed of exercises requiring participants to originally complete or compose words, to build three-word sentences, to generate slogans or nicknames, or to think of original descriptions to a given verbal stimulus (see also Benedek et al., 2006). Results indicate that the training was effective in improving creativity, and training effects were also apparent at the level of the brain, as it was reflected in stronger frontal alpha activity in the training than in the control group after completing the training.

Alpha synchronization has traditionally been considered as a functional correlate of cortical idling, presumably reflecting a reduced state of active information processing in the underlying neuronal networks (Pfurtscheller et al., 1996). However, in the meanwhile more and more studies suggest that synchronization of alpha activity does not merely reflect cortical deactivation or cortical idling (a highly readable review on this topic is given in Klimesch et al., 2007). In fact, alpha synchronization appears to be especially relevant during internal processing demands, for instance when participants are required to hold information temporarily in mind. For instance, Klimesch et al. (1999) reported a study (entitled "'Paradoxical' alpha synchronization in a memory task") in which event-related synchronization of alpha activity has been observed during the retention interval of a memory task. In another study, Sauseng et al. (2005) interpreted their findings of prefrontal alpha synchronization during working memory processing in a manner that "… frontal areas must not become involved in (distracting) new activities as long as an ongoing working memory task is carried out" (p. 154). Quite similarly, Jensen et al. (2002) interpreted their finding of an increase in occipital–parietal alpha synchronization with increasing memory load as being indicative of some kind of suppression of the input from the visual system, which would disturb working memory processing in frontal brain areas. Nicely in support of this view, von Stein and Sarnthein (2000) argue that alpha activity could reflect the absence of stimulus-driven, external bottom up stimulation and, thus, a form of top-down activity which "is maximal in situations where cortical processes … are driven by free floating associations, mental imagery, planning etc." (p. 311).

Along these lines, the observed alpha synchronization during creative cognition (see e.g., Fink et al., 2007, 2009a,b), could reflect the absence of stimulus-driven, external bottom-up stimulation and, thus, a form of top-down activity (cf. von Stein and Sarnthein, 2000), or a state of heightened internal attention facilitating the (re-)combination of semantic information that is normally distantly related. In a similar vein, alpha synchronization during creative idea generation could also reflect a state of enhanced concentration or alertness of involved brain circuits (cf. Knyazev et al., 2006; see also Knyazev, 2007).

This study was designed to investigate the sensitivity of EEG alpha activity to two short-term creativity interventions (i.e., cognitive and affective stimulation) which have been observed to yield beneficial effects on creative cognition in relevant behavioral and neuroscientific research, in order to examine whether changes in EEG alpha activity may in part explain these effects. Cognitive stimulation in the context of creative idea generation, which is conceptualized as a cognitive process involving "both the retrieval of existing knowledge from memory and the combination of various aspects of existing knowledge into novel ideas" (Paulus and Brown, 2007, p. 252), is realized via the exposure and active attendance to other people's ideas. As it is the case in classic group-based brainstorming techniques (Osborn, 1957), each single idea or solution a person generates to a specific problem may stimulate new ideas or solutions in others. Relevant literature from the behavioral or cognitive creativity research tradition suggests that creative performance increases as a result of such idea sharing or idea exchange processes (Dugosh et al., 2000; Dugosh and Paulus, 2005; Paulus and Brown, 2007; Paulus and Nijstad, 2003).

Furthermore, neuroscientific studies in this research field also emphasized the particular role of positive affect in the context of creative cognition. Relevant literature in this field of research suggests that positive affect has a beneficial influence on cognition and creative problem solving (Ashby et al., 1999; Baas et al., 2008). Induced positive mood and higher levels of current positive mood have been shown to be related to several functions closely associated with creativity, such as greater spread of activation in associative networks (Bolte et al., 2003; Isen et al., 1985; Rowe et al., 2007), a more flexible and broader attentional focus (Compton et al., 2004; Wadlinger and Isaacowitz, 2006), greater ability to disengage from no longer relevant stimulus categories (Dreisbach and Goschke, 2004), improved ability to inhibit prepotent motor responses (Van der Stigchel et al., 2011), and a greater number of responses in the Alternative Uses task (Phillips et al., 2002). Increased emotional arousal has been related to brain activation in the right hemisphere in right parieto-temporal and prefrontal regions; effects on prefrontal activation may additionally be lateralized depending on valence, with relatively greater activation in the left prefrontal cortex being associated with positive or approach-related affect and relatively greater activation in the right prefrontal cortex associated with negative or withdrawal-related affect (Davidson, 2003; Hagemann et al., 2005; Harmon-Jones et al., 2010; Heller, 1993; Heller et al., 2003; Papousek et al., 2009). Specific studies have shown that creativity may be enhanced by emotional arousal as such. Both positive and negative high-arousal moods (such as cheerfulness and anger) led to better performance in creative tasks than did positive and negative low-arousal moods (such as serenity or sadness). However, the findings also indicated that the processes underlying the performance enhancement differed according to valence: Positive high-arousal affect seems to influence creativity because of enhanced cognitive flexibility, whereas enhanced persistence seems to underlie the beneficial effect of high-arousal negative affect (De Dreu, et al., 2008). Consequently, a high-arousal positive affect (cheerfulness) was chosen for the affective intervention in the present study.

In this study, participants' task was to generate original or creative uses of conventional everyday objects (AU task) while the EEG was recorded. Three different experimental conditions were realized. In the cognitive stimulation condition, participants worked on the AU task subsequent to a short intervention in which they were – as it is the case in classic group-based creativity techniques such as brainstorming – confronted with creative ideas of other people (cf. Dugosh et al., 2000; Dugosh and Paulus, 2005). In the affective stimulation condition, participants had to generate creative ideas after the presentation of sound clips of merrily laughing people. Relevant experimental studies demonstrated that positive affect is contagious from short auditory stimuli comprised of human vocal affect expressions such as laughter (Hietanen et al., 1998; Meyer et al., 2005; Warren et al., 2006). In the control condition no intervention was applied. In each experimental condition, participants were instructed to respond as creatively and as originally as possible to the presented stimulus words. We expect that participants generate ideas of higher originality when they are cognitively and affectively stimulated, as compared with the control condition in which no intervention is applied. At the neurophysiological level, the creativity interventions should be reflected in changes of EEG alpha activity patterns. Given that this is the first study in this field which investigates potential brain mechanisms related to affective and cognitive creativity interventions, this study must be considered as rather exploratory, and the formulation of specific hypotheses may be rather difficult. However, based on recent findings in this field (e.g. Fink et al., 2009a,b), we might generally assume alpha activity in bilateral frontal and right parietal brain regions as being particularly sensitive to creative cognition. Given the particular role of the prefrontal cortex in positive affective states, along with its prominent role in creative cognition, both creativity interventions may be assumed to be closely associated with activity in this brain region.