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# Reflection enhances creativity: Beneficial effects of idea evaluation on idea generation

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ABSTRACT

The present study aimed to explore the neural correlates underlying the effects of idea evaluation on idea generation in creative thinking. Participants were required to generate original uses of conventional objects (alternative uses task) during EEG recording. A reflection task (mentally evaluating the generated ideas) or a distraction task (object characteristics task) was inserted into the course of idea generation. Behavioral results revealed that participants generated ideas with higher originality after evaluating the generated ideas than after performing the distraction task. The EEG results revealed that idea evaluation was accompanied with upper alpha (10–13 Hz) synchronization, most prominent at frontal cortical sites. Moreover, upper alpha activity in frontal cortices during idea generation was enhanced after idea evaluation. These findings indicate that idea evaluation may elicit a state of heightened internal attention or top-down activity that facilitates efficient retrieval and integration of internal memory representations.



## 1. Introduction

Creative products require both originality and effectiveness (Runco & Jaeger, 2012). This two-criterion statement has become a popular view since the 1960s. Creative responses are not only suggested to be original, but also appropriate (Jackson & Messick, 1965), relevant (Kneller, 1965), and worthwhile (Cropley, 1967). Nowadays, creativity is clearly defined as the ability to produce work that is novel (original, unique) and useful (Runco & Jaeger, 2012; Sternberg & Lubart, 1996). Based on such definitions, idea generation and idea evaluation constitute two fundamental processes of creative thinking (Runco, 2003; Sowden, Pringle, & Gabora, 2015). That is, generative processes are required to formulate original ideas, evaluative processes are required to select and/or refine those ideas into a form that is of value (Howard-Jones & Murray, 2003).

Generative and evaluative processes are emphasized in various models of creativity. The blind variation and selective retention (BVSR) theory of creativity (Campbell, 1960) is a two-step model in essence, which lays stress on the importance of totally random or "blind" variation, followed by selection of better ideas and their retention by the culture. The Darwinian theory of creativity (Simonton, 1999, 2007, 2010, 2013), which has its roots in the BVSR theory, includes a similar two-step process in which the production of ideas is followed by judgment of those ideas. The Geneplore model (Finke, Ward, & Smith, 1992) suggests that creative thinking consist of two stages, namely generation and exploration. Generation involves retrieval of items from memory, formation of associations between items, and synthesis and transformation of the "pre-inventive" structures. Exploration involves identifying the attributes of these pre-inventive structures and considering their potential function in different contexts.

It is suggested that idea generation and idea evaluation alternate during creative thinking process (Basadur, Graen, & Green, 1982; Kleinmintz, Goldstein, Mayseless, Abecasis, & Shamay-Tsoory, 2014; also see Sowden et al., 2015). This is also presented in artists' accounts of their own creative process. They often describe the process as alternating between rough sketching of ideas and critiquing ideas, which guide the next cycle of sketching and critiquing (cited in Ellamil, Dobson, Beeman, and Christoff (2012)). Conceivably, if idea evaluation exerts positive effects on idea generation, it helps the alternating cycle between idea evaluation and idea generation as well, which further supports creative

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processes. Whereas, previous studies revealed that if participants were instructed that they could evaluate their performance against some type of objective or social standard, they exhibited lower originality as compared to idea generation without such an instruction (Harkins & Szymanski, 1988; Silvia & Phillips, 2004; Szymanski & Harkins, 1987, 1992). This suggests that self-evaluation of one's own product against external standard may reduce creativity, perhaps because worrying about whether one's own performance will meet external standard reduces intrinsic motivation (Byron, Khazanchi, & Nazarian, 2010; Silvia & Phillips, 2004), which is critical for creative cognition (Amabile, 1996; Amabile & Pillemer, 2012; Hennessey, 2000). However, it is an open question whether and how an evaluation of self-generated ideas, without considering external standards, impacts on idea generation. Notably, this question is of theoretical significance to test the models which suggest that alternating of idea generation and idea evaluation contribute to the development of creative ideas (Basadur et al., 1982; Sowden et al., 2015).

The present study aimed to explore the effects of idea evaluation on idea generation during creative thinking. Specifically, we addressed two questions. First, does idea evaluation exert positive effects on idea generation? Second, how does idea evaluation modulate brain activity patterns that benefit idea generation? Since participants were asked to alternate between idea generation and idea evaluation for several times in the experiment, we preferred to use Electroencephalography (EEG) to explore the neural correlates underlying idea generation and idea evaluation because of its high temporal resolution.

Recent EEG studies have revealed that signals in several frequency bands, such as the theta (4–8 Hz), alpha (8–13 Hz), and beta (13–30 Hz) bands, are associated with creative thinking (Dietrich & Kanso, 2010). Particularly, EEG activity in the alpha band has been found to be highly sensitive to certain creativity-related factors (Fink & Benedek, 2014). First, the performance of creativity-demanding tasks induces stronger alpha event-related synchronization (ERS; i.e., task-related bandpower increases relative to baseline) than the performance of more "convergent" or intelligence-related tasks (Bazanova & Aftanas, 2008; Fink, Benedek, Grabner, Staudt, & Neubauer, 2007; Fink, Grabner, et al., 2009; Martindale & Hasenfus, 1978). Likewise, alpha ERS was found to be related to divergent rather than convergent modes of thinking within the same task (Jauk, Benedek, & Neubauer, 2012), as well as successful rather than unsuccessful insight problem solving (Cao, Li, Hitchman, Qiu, & Zhang, 2015). Second, more original ideas are accompanied by a stronger alpha activity at central–parietal (and to some minor extent also at anterior-frontal) sites (Fink & Neubauer, 2006; Grabner, Fink, & Neubauer, 2007). Third, alpha ERS correlates with an individual's creativity level (i.e., higher creative individuals showing stronger alpha power than lower creative ones when performing creativity tasks) (Fink, Grabner, et al., 2009; Fink, Graif, & Neubauer, 2009; Jausovec, 2000; Martindale, Hines, Mitchell, & Covello, 1984). Fourth, alpha ERS is sensitive to a verbal creativity training (Fink, Grabner, Benedek, & Neubauer, 2006) and to short-lasting creativity interventions (i.e., exposure to other people's ideas and induction of positive affect) (Fink, Schwab, & Papousek, 2011). Fifth, enhancing alpha power of the frontal cortex using 10 Hz transcranial alternating current stimulation (10 Hz-tACS) increases creativity, but 40 Hz-tACS unfolds no effects, which suggests that alpha activity in frontal brain areas is selectively involved in creativity (Lustenberger, Boyle, Foulser, Mellin, & Frohlich, 2015). Therefore, in this study, we analyzed EEG activity in the theta, alpha, and beta bands, but mainly focused on the activity in the alpha band.

Traditionally, alpha ERS has been considered to reflect cortical deactivation (Pfurtscheller & da Silva, 1999), whereas alpha event-related desynchronization (ERD; i.e., bandpower decreases) reflects cortical activation (Klimesch, 1999). However, alpha ERS has recently been demonstrated to reflect the absence of stimulus-driven, external bottom-up stimulation and, thus, a form of top-down activity (Payne & Sekuler, 2014; von Stein & Sarnthein, 2000) or a state of heightened internal attention (Benedek, Bergner, Koenen, Fink, & Neubauer, 2011; Benedek, Schickel, Jauk, Fink, & Neubauer, 2014; Fink & Woschnjak, 2011; Handel, Haarmeier, & Jensen, 2011; Jaarsveld et al., 2015; Jensen & Mazaheri, 2010; Klimesch, Sauseng, & Hanslmayr, 2007) that facilitates the (re-) combination of semantic information that is normally distantly related.

In the present study, participants were required to solve the Alternative Uses Task (AUT; Guilford, 1967) problems. The AUT is a typical creativity-related task. We administrated two kinds of interventions during the course of creative idea generation. One was to ask participants to *mentally evaluate the generated ideas* (reflection task). This task involves examination and intuitive evaluation of the creative output (Morewedge & Kahneman, 2010). The other was to ask participants to perform the *object characteristic task* (OC task), which required retrieving typical characteristics of conventional objects (such as "shoes" or "a coat hook"). The OC task is a relatively "convergent" task, involving the retrieval of prevalent, typical, or directly stimulus-related information (Binder, Desai, Graves, & Conant, 2009; Fink, Grabner, et al., 2009; Fink et al., 2010). In such a design, reflection required participants to evaluate the generated ideas, while performing the OC task distracted them from doing so. The EEG activity during solving the AUT problems was recorded in both conditions. Differences in behavioral performance and in EEG activity (in theta, alpha, and beta bands) changes from the pre- to the post-intervention period of idea generation were compared. We hypothesized that after a period of reflection, (1) participants would generate ideas with higher originality, and (2) changes in EEG activity related to the improvement of performance would be detected, probably most prominent in the alpha frequency band.

## 2. Methods

### 2.1. Participants

Twenty healthy right-handed college students (10 males, 10 females; range from 19 to 26 years of age, $M = 23.45$, $SD = 2.01$) of various academic disciplines participated individually in the study. They were all native Chinese speakers. They gave written informed consent prior to the EEG recording session, and received about 15 US dollars for their participation after the experiment. Due to technical problems, the data of four persons had to be excluded from the EEG analyses. The protocol of the experiment was approved by the Institutional Ethics Committee at East China Normal University.

### 2.2. Experimental task

The Alternative Uses Task (AUT) was used as the target task. It requires respondents to generate as many unusual and original uses for commonly used objects as possible, such as paperclip ("making a ring", "cleaning fingernails"). The AUT is a well-established creativity-demanding task, and performance on this task has been demonstrated to be a reliable predictor of creative potential (Runco & Acar, 2012). The AUT has been widely used in the studies on creativity (Kaufman, Plucker, & Baer, 2008; Runco, 1991, 1999; Runco & Mraz, 1992).