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Unconscious processing modulates creative problem solving: Evidence from an electrophysiological study

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ABSTRACT

Previous behavioral studies have identified the significant role of subliminal cues in creative problem solving. However, neural mechanisms of such unconscious processing remain poorly understood. Here we utilized an event-related potential (ERP) approach and sandwich mask technique to investigate cerebral activities underlying the unconscious processing of cues in creative problem solving. College students were instructed to solve divergent problems under three different conditions (conscious cue, unconscious cue and no-cue conditions). Our data showed that creative problem solving can benefit from unconscious cues, although not as much as from conscious cues. More importantly, we found that there are crucial ERP components associated with unconscious processing of cues in solving divergent problems. Similar to the processing of conscious cues, processing unconscious cues in problem solving involves the semantic activation of unconscious cues (N280–340) in the right inferior parietal lobule (BA 40), new association formation (P350–450) in the right parahippocampal gyrus (BA 36), and mental representation transformation (P500–760) in the right superior temporal gyrus (BA 22). The present results suggest that creative problem solving can be modulated by unconscious processing of enlightening information that is weakly diffused in the semantic network beyond our conscious awareness.

1. Introduction

Unconsciousness can be defined as a large reservoir of thoughts beneath our conscious awareness (Freud, 1924, 1940). The role of unconscious processes in creative problem solving has been examined with the two-string problem, in which two strings hang far apart from the ceiling so that it is not possible for participants to reach one string while holding the other (Maier, 1931). Participants in this study have frequently figured out the solution after a subtle cue (an experimenter casually brushing against one of the strings, setting it gently into motion) was displayed. It seemed to be unconscious, since participants were unaware of the experimenter's actions and did not mention them when asked about how they came up with the solution. A recent study (Dijksterhuis & Meurs, 2006) has further reported that a task was processed a moment ago and then its information was still actively processed at unconscious level while performing irrelevant cognitive tasks. In this study, instructions describing creative tasks were displayed and then participants were requested to think about the creative tasks for 3 min, or perform an additional irrelevant task for 3 min before finally completing the creative tasks. Interestingly, participants who completed creative tasks after the irrelevant task did best. The researchers have suggested

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that the mental operation happening at an unconscious level imposed by heavy working memory load facilitates solutions to creative problems.

Unconscious effectiveness and capacity are characterized by the unconscious thought theory (Dijksterhuis & Nordgren, 2006). In recent years, researchers have obtained evidence that the unconscious can successfully integrate large amounts of information in perceiving advertisements (Betsch, Schwieren, & Gütig, 2001). According to this theory, conscious thinking and memory searching during unconscious processes are more diffused or divergent than that during conscious processes. It has been believed that divergent activation in unconscious process is conducive to the generation of creative ideas (Campbell, 1960; Ghiselin, 1952; Mednick, 1962; Torrance, 1995). The unconscious has more available resources than the conscious, which is limited to processing items within the scope of awareness (Dijksterhuis & Nordgren, 2006; Freud, 1940). Furthermore, because the unconscious is capable of processing information in parallel, it spares sufficient resources for idea generation (Fleck & Kounios, 2009).

Previous studies have provided empirical evidence for understanding unconscious process and creativity. However, these studies have suffered from problems in experimental method or experimental design. For example, a survey after an experiment cannot rule out the possibility of conscious processing of a subtle cue (Maier, 1931), because intentional deception and wishful thinking may distort subjective reports. In addition, better performance of creative tasks after an irrelevant task (Dijksterhuis & Meurs, 2006), could be the result of an active generation of unconscious. As the author indicated, ''less conscious'' processing of the creative task during irrelevant task performance might be more appropriately worded than ''unconscious'' processing, since it is unclear to what extent the irrelevant task rules out relevant conscious thought for the creative task, In order to examine whether unconscious processing of cues plays a role in creative problem solving, we used the sandwich mask technique, a classic unconscious processing control method that has been employed extensively (Greenwald, Draine, & Abrams, 1996). This technique can restrict the presentation of stimuli spatially and temporally to prevent participants from conscious processing of stimulus cues.

Traditional behavioral measures of the speed and accuracy of task performance provide only indirect evidence about internal processes of the brain in the cognitive process. Event-related potential technique with high temporal resolution has made it possible for us to examine precisely the brain activity underlying unconscious processes. Therefore, in the present study we utilized an event-related potential approach and the sandwich mask technique to investigate whether and what activities of the brain are associated with unconscious processing of cues in the creative process. Based on previous studies, our research hypothesis was that unconscious processing of cues would facilitate solving creative problems with a higher answer rate or shorter response time akin to conscious cues. We further hypothesized that specific ERP components for unconscious processing of cues would be elicited by unconscious cue conditions, as compared to a no-cue condition in creative problem solving, which might be similar to ERP components under conscious cue conditions compared with no-cue conditions.

2. Methods

2.1. Participants

20 College students (seven men and thirteen women, mean age 20, range 20–24) were recruited for this experiment and paid for their participation. All of the participants were healthy without a history of neurological or psychiatric mental problems. They were native Chinese speakers, had normal or corrected-to-normal vision, and were right-handed.

2.2. Stimuli

As a classic creative task, divergent thinking problems have been widely used to investigate the creative process since the 1960s (Getzels & Jackson, 1962; Guilford, 1967; Torrance, 1962). Therefore, in our study divergent thinking problems were employed as the experimental task. In a preliminary experiment, 6 researchers selected 180 object names and 180 cues according to two rules: (1) a cue is a remotely distant from a problem in semantic relatedness and (2) a cue is able to trigger an unusual use of the object. For example, a cue ''gauge'' is remotely distant from a problem ''a roll of film'' in the semantic/knowledge network of the mind. Meanwhile, the cue ''gauge'' is able to trigger an unusual use ''tape measure'' of ''a roll of film''. Taking ''palette'' as another example, a cue ''dog training'' would help the participants come up with the answer ''frisbee''. The object names in stimulus trials were between 2 and 4 Chinese characters in length, and cues were 2 Chinese characters. The Chinese characters were presented in the New Song Ti font at size No. 30.

2.3. Procedure

This experiment employed a within-subject design with 3 conditions: unconscious cue condition, conscious cue condition and no-cue condition. Under each condition there were two blocks with 30 trials in each. The order of blocks was set as: no cue condition, conscious cue condition, unconscious cue condition, conscious cue condition, unconscious cue condition, no cue condition. 180 Object names were randomly assigned to one of 6 blocks. No object name or cue was used more than once in the 6 blocks. The experiment took place in a quiet room, and the screen was placed at a 60 cm distance from the