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Creativity and sensory gating indexed by the P50: Selective versus leaky sensory gating in divergent thinkers and creative achievers

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ABSTRACT

Creativity has previously been linked with atypical attention, but it is not clear what aspects of attention, or what types of creativity are associated. Here we investigated specific neural markers of a very early form of attention, namely sensory gating, indexed by the P50 ERP, and how it relates to two measures of creativity: divergent thinking and real-world creative achievement. Data from 84 participants revealed that divergent thinking (assessed with the Torrance Test of Creative Thinking) was associated with selective sensory gating, whereas real-world creative achievement was associated with "leaky" sensory gating, both in zero-order correlations and when controlling for academic test scores in a regression. Thus both creativity measures related to sensory gating, but in opposite directions. Additionally, divergent thinking and real-world creative achievement did not interact in predicting P50 sensory gating, suggesting that these two creativity measures orthogonally relate to P50 sensory gating. Finally, the ERP effect was specific to the P50 – neither divergent thinking nor creative achievement were related to later components, such as the N100 and P200. Overall results suggest that leaky sensory gating may help people integrate ideas that are outside of focus of attention, leading to creativity in the real world; whereas divergent thinking, measured by divergent thinking tests which emphasize numerous responses within a limited time, may require selective sensory processing more than previously thought.

1. Introduction

Although numerous papers have claimed that creative thinking is linked with atypical attention, it remains unresolved which types of creativity and which aspects of attention are associated. There are at least two seemingly contradictory proposals, but it is possible that both operate, each on different aspects of creativity.

The first proposal suggests that creative people may have particularly broad or "leaky" attention, or a propensity to deploy attention over a wider focus or a larger range of stimuli at once. Anecdotes indicate that numerous eminent creators, including Richard Wagner, Marcel Proust, and Charles Darwin strongly lamented the distracting nature of noise (Kasof, 1997). More importantly, some empirical evidence supports this putative association between creativity and leaky attention, particularly in dual task situations. For instance, when asked to repeat information presented to one ear, while attempting to remember information presented to the other ear, creative people (creativity assessed with the Pattern Meaning and Similarities subtests from Wallach and Kogan's (1965) battery of creativity tests) make more errors of intrusion from the non-shadowed ear (Rawlings, 1985). Moreover, creative people are more likely to incorporate seemingly irrelevant cues when solving anagrams (creativity assessed with Mednick's (1962) Remote Associate's Test (RAT; Mendelsohn and Griswold, 1964), recalling words and phrases (creativity assessed via RAT; Russell, 1976), and performing auditory discrimination tasks (creativity assessed with a Creative Achievement Questionnaire (CAQ; Carson et al., 2005); Carson et al., 2003).

Leaky attention is akin to reduced latent inhibition, or a reduced ability to screen or inhibit from conscious awareness stimuli previously experienced as irrelevant (Lubow, 1973). Reduced latent inhibition may enhance creativity by enlarging the range of unfiltered stimuli available in conscious awareness, thereby increasing the possibility that novel and useful combinations of stimuli will be synthesized (Carson et al., 2003). Therefore leaky attention may underlie both costs and benefits of creative cognition; noise and other environmental stimuli can serve as distractors for creative people, and lead them to make errors on some tasks. At the same time, leaky attention may help people integrate ideas that are outside the focus of attention into their current information processing, leading to creative thinking.

An alternative proposal of how attention relates to creativity

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suggests that creativity depends on the ability to focus and shift attention, supporting cognitive flexibility. More generally, creativity may rely heavily on executive functions (De Dreu et al., 2012; Gilhooly et al., 2007; Nusbaum and Silvia, 2011; Wiley and Jarosz, 2012), i.e., general-purpose control mechanisms such as the ability of the cognitive system to configure itself for the performance of specific task goals (Botvinick et al., 2001; Miyake and Friedman, 2012). Indeed, in order to create a highly original thought or product, people have to focus and persist on the task at hand. For instance, the preparation stage of creativity involves information gathering, mastering a knowledge base, and identifying the problem (Wallas, 1926). These behaviors surely benefit from focus and persistence. Leonardo da Vinci, for example, one of the most recognized creative polymaths, was said to have "obsessive attention to detail" (Lester, 2012, p. 191). Marie Currie described her focus during schoolwork as "allowing no lapses of attention (p. 72)," as well as concentrating her attention "without even hearing the mounting roar of chatter" (p. 97; Curie and Sheean, 2001).

Emerging neuroscientific literature provides support for cognitive inhibition involved in creative thinking. Inferior frontal gyrus (IFG), a region associated with interference resolution in the left hemisphere (Thomspon-Schill et al., 1999), and cognitive inhibition in the right hemisphere (Aron, 2007), has been implicated in divergent thinking tasks (Abraham et al., 2012; Chrysikou and Thompson-Schill, 2011; Kleibeuker et al., 2013; Vartanian et al., 2013; for review, see Gonen-Yaacovi et al., 2013), which measure the ability to generate many original responses to a given problem within a limited time (Guilford, 1950; Torrance, 1974), and are often used as measures of creative cognition.

The assertion that creative cognition requires focused and persistent attention seems to directly contradict the first hypothesis, that creative thinking is associated with leaky attention. These ideas, however, may not be mutually exclusive. It may be that different measures of creativity are associated with different forms of attention. Our recent series of experiments, using a model task in which people attend to either local or global aspects of attention (e.g., a large S constructed of small Es), suggest that there are distinct attentional components that independently relate to two different measures of creativity: divergent thinking versus real-world creative achievement. We find that divergent thinkers show selective focus and rapid inhibition of attention, thus exhibiting flexible attention: they easily switch their attention from an incorrect attentional focus to a correct one (Zabelina et al., 2015).

Whereas divergent thinking tests are timed laboratory measures of creative cognition, real-world creative achievement is a survey of people's creative achievements over their lifetime. Unlike the flexible attention observed in divergent thinking, we find that real-world creative achievers show leaky attention; When asked to identify a target that competes or is facilitated by other information presented concurrently with the target, real-world creative achievers are more likely to be affected by the competing information (Zabelina et al., 2015).

Here we examine how early in the processing stream these attentional differences between divergent thinkers and real-world creative achievement occur. Specifically, we examine whether different measures of creativity relate to sensory gating (sensory suppression) of meaningless stimuli, in the absence of task goals. Thus we examine specific neural markers of sensory gating, namely the P50 event-related potential (ERP), a neurophysiological response that occurs 50 ms after stimulus onset (for review, Patterson et al., 2008). In this paradigm two auditory clicks are presented to a participant, and the extent to which the second click is suppressed compared to the first click (P50 of the second click/P50 of the first click) is seen as a marker of sensory gating (Patterson et al., 2008). P50 is a very early, automatic, form of sensory gating, influencing which stimuli capture attention (Banich, 2004; Gjini et al., 2011). Some view the P50 marker of sensory gating as a marker to some psychopathology, particularly schizophrenia (Olincy et al., 2010).

With respect to P50 and cognitive functioning, studies have reported inconsistent outcomes. Associations between increased P50 sensory gating and better attention, motor speed, and learning, have been observed, mostly in small samples of patients with schizophrenia (Cullum et al., 1993; Erwin et al., 1998; Hsieh et al., 2004), and in Alzheimer's patients or healthy elderly controls (Thomas et al., 2009). These studies are consistent with reports of the associations between better P50 sensory gating and better orienting of attention, better inhibition of conflicting information (Wan et al., 2008), and fewer commission errors on the Delayed Memory Task (Lijffijt et al., 2009) in healthy participants. However, some studies have failed to find such associations (Cullum et al., 1993; Thoma et al., 2006).

Sensory gating, as measured by the P50, varies in the general population (Patterson et al., 2008). We predicted different relations between sensory processing and the two distinct measures of creativity.

First, given that divergent thinking is associated with the ability for selective focus and rapid inhibition of attention, supporting attenional flexibility (Zabelina et al., 2015; Nusbaum and Silvia, 2011), as well as with neural regions implicated in cognitive inhibition (Gonen-Yaacovi et al., 2013), we predict that divergent thinking will relate to more selective sensory gating.

Second, given that real-world creative achievement is associated with reduced latent inhibition (Carson et al., 2003), and with leaky attention on behavioral tasks (Zabelina et al., 2015), we predict that real-world creative achievement will be related to reduced, or leaky sensory gating.

Thirdly, hypothetically the two measures of creativity combined could better predict sensory gating. However, based on prior research suggesting that divergent thinking and creative achievement are only modestly related (Runco and Acar, 2012; Zabelina et al., 2015), and that only creative achievement related to our behavioral measure of leaky attention (Zabelina et al., 2015), we did not expect divergent thinking and creative achievement to interact in predicting sensory gating.

We also considered academic achievement scores as a proxy for general intelligence and as a control variable, given that academic achievement may relate to divergent thinking through the common component of performance on a cognitive measure, and may relate to creative achievement through the common component of achievement. Additionally, we assessed the specificity of the association between the P50 sensory gating and divergent thinking and creative achievement by examining later attentional ERP components, namely N100 and P200.

2. Method

2.1. Participants

One hundred participants were recruited to participate in the present study. Because data collection failed for 3 participants, we were left with 97 participants ages 18–30 (mean age=20.55, SD=2.51, male/female=32/65). Participants were pre-screened to ensure they had no hearing or head injuries. None of the participants abused alcohol or drugs, and none smoked. None of the participants had been hospitalized for psychiatric or neurologic reasons. Four participants had history of depression or mild anxiety (three in the past, but in remission at the time of the study and not taking medication; one current, treated with Zoloft). All subjects were Caucasian, and right-handed, as assessed by the

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