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Brain structure links everyday creativity to creative achievement

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ABSTRACT

Although creativity is commonly considered to be a cornerstone of human progress and vital to all realms of our lives, its neural basis remains elusive, partly due to the different tasks and measurement methods applied in research. In particular, the neural correlates of everyday creativity that can be experienced by everyone, to some extent, are still unexplored. The present study was designed to investigate the brain structure underlying individual differences in everyday creativity, as measured by the Creative Behavioral Inventory (CBI) ($N = 163$). The results revealed that more creative activities were significantly and positively associated with larger gray matter volume (GMV) in the regional premotor cortex (PMC), which is a motor planning area involved in the creation and selection of novel actions and inhibition. In addition, the gray volume of the PMC had a significant positive relationship with creative achievement and Art scores, which supports the notion that training and practice may induce changes in brain structures. These results indicate that everyday creativity is linked to the PMC and that PMC volume can predict creative achievement, supporting the view that motor planning may play a crucial role in creative behavior.

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1. Introduction

Creativity is commonly considered to be a cornerstone of human progress and it is vital to all realms of our lives, such as Art, Science, Pedagogy, and Education. Although creativity plays a crucial role in almost all areas of our everyday life, its neural basis remains elusive, largely due to the different tasks and measurement methods used in studies (Chávez-Eakle, Graff-Guerrero, García-Reyna, Vaugier, & Cruz-Fuentes, 2007; Dietrich & Kanso, 2010; Jung et al., 2010). Generally, creativity research tends to focus on two facets: eminent real-life creativity and creative cognitive processes (called "big-C" versus "little-C") (Kaufman & Beghetto, 2009). Everyday creativity, which is an important part of "little-C," is necessary to develop the processes for someone to reach the big-C level (Kaufman & Beghetto, 2009). It is a fundamental ability for human survival and penetrates all aspects of life, including gardening, decorating, dancing, and farming (Richards, 2010). In addition, everyday creativity is viewed as being a behavioral requirement for actual creative achievement (Jauk, Benedek, & Neubauer, 2014; Richards, 2010). However, previous neuroimaging studies have focused on the brain mechanisms of creative thinking processes (divergent thinking, insight, etc.) as well as creative individuals in specific areas (painters, musicians, scientists, etc.). Research on the neurocognitive mechanisms of real-life creative activities, in which the general public may take part each day (e.g., painting an original picture; designing your own greeting cards) is sparse and, thus, little is known about its neural correlates. Therefore, the present study aims to investigate the brain structures underlying individual differences in everyday creativity, as measured by the Creative Behavioral Inventory (CBI; Dollinger, 2003; Hocevar, 1979).

The concept of everyday creativity, which focuses on human originality in everyday activities, including work and leisure, stems from the study of real-life creative activities among the general (non-eminent) population (Richards, 2010). It can play an important role in human life and be experienced by everyone (Richards, Kinney, Benet, & Merzel, 1988). The revised CBI has been used widely to measure everyday creativity (Dollinger, 2003), including many kinds of everyday creative activities (e.g., painting an original picture, preparing an original floral arrangement, etc.) in the literary, performing, and visual arts, and crafts (Dollinger, 2011). Kaufman thought everyday creativity was an important part of little-C and a necessary process to reach creative achievement (Kaufman & Beghetto, 2009). Richards also believed everyday creativity was the basis of creative achievements and a behavior essential for actual creative achievement (Richards, 2010). However, as of yet, there are only a few studies that have examined

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the relationship between everyday creative activities and creative achievements empirically (Dollinger, 2003; Jauk et al., 2014; Silvia & Kimbrel, 2010) and, thus, little is known about whether the same processes that lead to everyday creativity also may contribute to creative achievement. Here, we attempt to investigate the associations between brain anatomy and individual differences in everyday creativity and creative achievement.

Although recent studies on creativity have applied brain imaging techniques, such as structural magnetic resonance imaging (sMRI) and functional magnetic resonance imaging (fMRI), to examine the neural basis of creative cognition (Arden, Chavez, Grazioplene, & Jung, 2010; Dietrich & Kanso, 2010; Jung et al., 2010), to date, many inconsistent results have been reported because of the different measures and tasks of creativity employed (Arden et al., 2010; Dietrich & Kanso, 2010; Piffer, 2012). For example, some studies of artistic creativity (musical improvisation) generally support the notion that frontal and premotor regions, such as the inferior frontal gyrus (IFG), dorsolateral prefrontal cortex (DLPFC), premotor cortex (PMC), anterior cingulate cortex (ACC), parietal association areas, supplementary (SMA), and pre-supplementary motor areas (pre-SMA) play a key role in musical improvisation (Bengtsson, Csíkszentmihályi, & Ullén, 2007; Berkowitz & Ansari, 2008; Brown, Martinez, & Parsons, 2006; Dreu et al., 2012; Limb & Braun, 2008). Furthermore, when the ordinary individual performs a visual creativity task, such as visuospatial creativity problems and product design, there is strong activation of the posterior parietal cortex, the premotor cortex (PMC), the dorsolateral prefrontal cortex (DLPFC), the medial PFC, and the right inferior frontal gyrus (IFG), which might be involved in sustained attention, cognitive flexibility, working memory, and goal-directed planning (Aziz-Zadeh, Liew, & Dandekar, 2013; Kowatari et al., 2009). Despite these studies, the neurocognitive mechanisms of creativity remain elusive, largely due to the complex cognitive processes and neural networks that are likely to be involved in creative behavior.

Further evidence comes from sMRI studies that have explored the association between brain anatomy and creative cognition. For example, research on divergent thinking revealed that brain structure volumes that were positively related to creative thinking were observed in regions corresponding to the right cuneus, right and left precuneus, left striatum, right posterior cingulate, right dorsolateral prefrontal cortex (DLPFC), right parietal lobe, the default mode network, right midbrain regions, and the bilateral caudate and IFG(Fink et al., 2014; Gansler et al., 2011; Jauk, Neubauer, Dunst, Fink, & Benedek, 2015; Jung et al., 2010; Moore et al., 2009; Takeuchi et al., 2010; Zhu, Zhang, & Qiu, 2013), whereas brain structure volumes that were inversely related to creative thinking were observed in regions corresponding to the left lateral orbitofrontal gyrus, lingual gyrus, inferior parietal gyrus, and fusiform gyrus (Jung et al., 2010). Moreover, research on eminent real-life creativity found that creative achievement, as measured by Creative Achievement Questionnaire (CAQ), was negatively correlated with the left lateral orbitofrontal gyrus, and positively correlated with the right angular gyrus (Jung et al., 2010). In another study, CAQ scores were positively related to the gray matter volume (GMV) of the left superior frontal gyrus and negatively related to the GMV of the bilateral dorsal ACC (Chen et al., 2014). However, the relationships between the brain anatomy and the creative activities in which many people take part in everyday life remain unexplored.

Everyday creativity, as a creative ability, is likely to be relatively reliable and stable, as opposed to creative thinking. In addition, sMRI is considered to be a highly reliable and reproducible methodology (Jung, Mead, Carrasco, & Flores, 2013). The investigation of anatomical features using sMRI may be more effective than functional MRI for examining stable creative ability (Li et al., 2014). The present study attempted to investigate the neuroanatomical correlates of individual everyday creativity (measured by the revised CBI) by using VBM, which was used to link inter-individual variation in behavioral performance to individual variations in regional brain structures to define the anatomical correlates of behavioral expression across participants (Ashburner & Friston, 2000). In terms of cognitive processes, everyday creativity activities, such as musical performance, may include the following processes: "action planning" – generating possible actions based on available information, "action selection" – inhibiting task-irrelevant actions and selecting appropriate actions from multiple options, and "execution" – applying the decided-upon action to solve problems (Berkowitz & Ansari, 2008). Thus, we hypothesized that individual differences in everyday creativity would be associated with: (1) the DLPFC and IFG, which have been linked to monitoring responses and inhibiting task-irrelevant stimuli (Jahanshahi & Dirnberger, 1998; Jahanshahi, Dirnberger, Fuller, & Frith, 2000; Nachev, Kennard, & Husain, 2008; Petrides, 2000); (2) the volume in the premotor cortex, which has been implicated in the creation and selection of novel action(Aziz-Zadeh et al., 2013; Bengtsson et al., 2007; Brown et al., 2006; Fink, Graif, & Neubauer, 2009; Hoshi & Tanji, 2002, 2007); and (3) the anterior cingulate, supplementary motor area, and pre-SMA, which might be involved in selecting among behaviors and deciding what behaviors to execute. In addition, as above research findings suggested, everyday creativity and creative achievement were closely related (Dollinger, 2003; Jauk et al., 2014; Silvia & Kimbrel, 2010). Nevertheless, there is no empirical evidence available to support the premise that the structures of these brain regions are correlated with everyday creativity, which, in turn, might be associated with creative achievement. Thus, the second aim of the current study was to examine whether the brain structures associated with everyday creativity can predict self-rating creative achievement.

2. Methods

2.1. Participants

A total of 167 healthy undergraduate students from the local community of Southwest University in China participated in this study as a part of our ongoing project investigating the associations among brain imaging, mental health, and creativity. The intelligence of subjects was measured by the Combined Raven's Test-Rural (mean intelligence = 65.73; *SD* = 3.76). Four subjects were excluded because of problems with the imaging data (two subjects with excessive artifacts) and incomplete behavioral data (2 subjects). Consequently, a total of 163 participants (70 males; mean age = 19.95; *SD* = 1.017) were included in the analyses. All participants were right-handed and had no history of neurological or psychiatric diseases. The experimental protocol was approved by the Institutional Review Board of the Southwest University Brain Imaging Center. All participants provided informed consent prior to engaging in the experiment and received payment for their participation.

2.2. Assessment of divergent thinking

The visual TTCT was used to measure divergent thinking, which is an important aspect of creativity (Wu, Gao, Wang, & Ding, 1981). The verbal TTCT test can be confounded with IQ (Kershner & Ledger, 1985) and higher educational level (Bornstein, Suga, & Prifitera, 1987); therefore, we used the visual TTCT to avoid these sources of confounding (Bornstein et al., 1987). Participants were asked to draw pictures using shapes, and to title their drawings. The pictures were scored on four dimensions: fluency, abstractness