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Neural and genetic mechanisms of creative potential

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Creative potential exists in everyone and it has pervasively penetrated into our daily life. A series of recently studies have shed new light on the issue of how the brain produces creative potential and how genes affect it. The present study systematically explored the genetic and brain basis of creative potential. In terms of brain level, a wide range of brain regions in the structure and function are involved in creative potential. In terms of heredity level, genes involved in dopamine (DA) transmission such as the catechol-*O*-methyltransferase gene (COMT) and the dopamine D2 receptor gene (DRD2) have been considered as potential candidates for creative potential. Further, some trends of future research are pointed out for advancing our understanding of creative potential.

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Introduction

Kerosene lamps to light bulbs, carriages to cars, kites to planes, every invention is inextricably linked to human creativity. As one of the most fundamental activity of human information processing, the nature and origin of creativity have been troubling researchers in many fields [1]. How to define and measure creativity is in the psychology most basic and one of the most important research questions [2].

Creativity is generally considered to include two core characteristics: novelty (originality) and appropriateness (usefulness) [3–5]. These two core characteristics are the fundamental differences between creativity and other similar concepts, and also the basic criteria for discriminating creativity from the concept. Relying on the basic concept of creativity, researchers have further quantitative research, the first of which is measuring creativity [6–10].

But due to the complexity of creativity, how to measure seems to have confused the academe for a long time, and attracted many researchers to work at it. The lack of a widely accepted definition of creativity brings difficulties to measurems [11]. Further, thanks to the diversity of creativity definition, the measurement is not limited to the standardized tests of creative products, creative process, the performance of creative tasks, the self report of multiple fields, creative personality [12]. Many measurements are faced with the problem of poor predictive validity [13,14], which may even mean that most of them are actually ineffective. The correlation between the scores measured by different measurements is usually around 0.3 [15–17]. As research progressed, researchers have gradually realized that creativity couldn't be fully interpreted if we just considered creativity as creative thinking or a pure psychological process. Then researchers proposed that we should put a systematic perspective on creativity [5,18,19].

Based on this, here we introduce the concept of creative potential. Creative potential is known very well by researchers in the field of creativity, and there is a general agreement that creative potential is a multifaceted phenomenon [20–23].

Creative potential

Creative potential is a complex concept. It is not composed of single cognitive component, nor can it be interpreted by a single cognitive processing. Creative potential was divided into creative cognition and creativity trait [8,24,25]. Creative thinking such as divergent thinking and convergent thinking is the core of creative cognition. Originality came into being with divergent thinking, and originality is the central feature of creativity [26]. Tests of divergent thinking provide useful estimates of the potential for creative thinking, such as Torrance Test of Creative Thinking (TTCT) [27], Alternate Uses Task (AUT) [28], Remote Association Test (RAT) Test of creative Thinking Drawing production (TCT-DP) [29]. These measures/tasks focus on verbal and figure creativity.

Creativity trait has also been widely observable by researchers. Several studies have demonstrated that openness of experience robustly predicted individual creative thinking and creative achievement. Openness of experience is often used as the validity criterion in the compilation of creativity measurement. Besides, characteristics such as tolerance of ambiguity, risk taking,

curiosity are often attributed to creativity trait [30]. Several types of creativity trait measures exist, such as Williams Creative Tendency Test (WCTT) [31] and Gough's Creative Personality Scale (CPS) [8].

It's noteworthy to understand that the creative potential exists in everyone, and individual differences are reflected in a matter of degree of high or low creative potential, rather than all-or-nothing creative potential. Creative potential is not exclusive to genius or scientists. Everyone has creative potential [32].

Gene-brain-behavior based prediction of creative potential

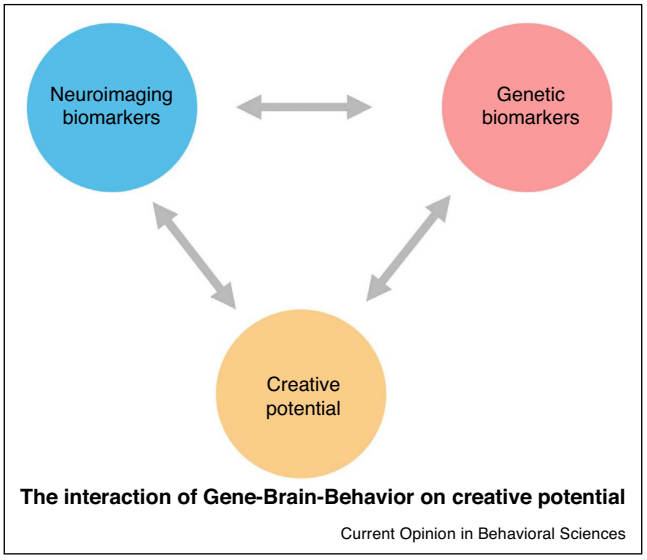
The main goals of scientific psychology are to describe, interpret, predict and control human behavior. In the past few decades, researchers have invested much effort in describing and interpreting human behavior. In the past few years, predicting human behavior has played such an important role in scientific psychology. In the meantime, the research focus has shifted from group averaging to the comparison of individual subjects' statistics. The validity and reliability of behavioral research can be well investigated based on individual differences. Though majority of fMRI studies used correlation analysis on individual differences, it is subject to overfitting. Besides, generalization of findings to other samples is confronted with difficulty. Sometimes even group data can not describe individual participants. Lacking generalizability of group-to-individual and individual-to-group and group-to-group is a threat to human subjects research especially to creative research [33]. The prediction-based approach is used to provide more generalizability than traditional correlation-based analysis at the individual subject level [34•]. Selecting and assessing the biomarkers is crucial for shaping the unique predictive power of fMRI features. Previous neuroimaging studies have explored the relationship between brain regions/networks and creative potential. These studies have revealed that creative thinking may be related to widespread brain regions rather than to a single region of the brain, which provides brain biomarkers of prediction on creative potential.

A great number of prediction programs have been developed that try to transform raw sequence data into knowledge. Previous candidate gene prediction systems have largely been based on keyword similarity to known disease genes or phenotypes. Many genes involved in dopamine (DA) transmission such as the catechol-*O*-methyltransferase gene (COMT) and the dopamine D2 receptor gene (DRD2) were found to be associated with creative potential [35,36,37•,38,39], which provide gene biomarkers of prediction on creative potential (Figure 1).

Brain biomarkers of creative potential

In recent years, neuroimaging techniques have been used more and more widely in the field of psychology and cognitive neuroscience, which greatly improves our understanding of the brain mechanism and individual differences of creativity. Numerous studies showed that creative potential was related to a wide range of brain regions in the structure and function [40–42,43••]. This reflects that creativity depends on multiple-processing and a wide range of brain regions are involved in it.

Figure 1



The interaction of gene-brain-behavior on creative potential.

Studies of meta analysis showed that the lateral prefrontal cortex, inferior parietal lobule (IPL), anterior cingulate cortex (ACC) and fusiform gyrus were involved in the task of divergent thinking [44,45]. Based on different task paradigms including visuospatial creativity problem solving [46], improvisational performance of music [47,48], poetry composition [49], divergent thinking [50–52], insight problem solving [53], the studies of brain structure and function showed that the most consistent finding was the involvement of inferior parietal lobule (IPL) and dorsolateral prefrontal cortex (DLPFC). According to the large-scale brain networks, most of the brain regions activated by creative tasks are located in the default mode network (DMN) and executive control network (ECN) [54–57]. The synergy between these two networks will lead to more creative ideas, and this pattern has the consistency of different tasks in divergent thinking, poetry composition and improvisational performance of music [58•].

As part of creative potential, creativity trait also plays an important role in its development. Researchers regard openness of experience as the main creativity trait. Gray matter volume of right posterior middle temporal gyrus (pMTG) is greater in the individuals of high creativity