cortex 50 (2014) 162–173

Available online at www.sciencedirect.com

ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex

Research report

Neural representations for the generation of inventive conceptions inspired by adaptive feature optimization of biological species

Hao Zhang [a], *Jia Liu* [b] and *Qinglin Zhang* [a,*]

[a] *Key Laboratory of Cognition and Personality, Ministry of Education, School of Psychology, Southwest University, Chongqing, China*
[b] *State Key Laboratory of Cognitive Neuroscience and Learning, Imaging Center for Brain Research, Beijing Normal University, Beijing, China*

ARTICLE INFO

Article history:
Received 21 March 2012
Reviewed 7 June 2012
Revised 22 November 2012
Accepted 28 January 2013
Action editor Jordan Grafman
Published online 7 March 2013

Keywords:
Creativity
Invention
BA 47
Inferior frontal gyrus
Functional MRI (fMRI)

ABSTRACT

Inventive conceptions amount to creative ideas for designing devices that are both original and useful. The generation of inventive conceptions is a key element of the inventive process. However, neural mechanisms of the inventive process remain poorly understood. Here we employed functional feature association tasks and event-related functional magnetic resonance imaging (MRI) to investigate neural substrates for the generation of inventive conceptions. The functional MRI (fMRI) data revealed significant activations at Brodmann area (BA) 47 in the left inferior frontal gyrus and at BA 18 in the left lingual gyrus, when participants performed biological functional feature association tasks compared with non-biological functional feature association tasks. Our results suggest that the left inferior frontal gyrus (BA 47) is associated with novelty-based representations formed by the generation and selection of semantic relatedness, and the left lingual gyrus (BA 18) is involved in relevant visual imagery in processing of semantic relatedness. The findings might shed light on neural mechanisms underlying the inventive process.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

As the source of human civilizations, creativity has brought forth science, technology, art, music and so on. At the same time, creativity is the most complex phenomenon in the mind. Mainly because there are a great number of creative products in multiple realms, such as Vincent Van Gogh's paintings, Albert Einstein's theory of relativity, fashion designs, and technical inventions. The issue has arisen whether the generation of these creative products shares the same mechanisms (Baer, 1998; Sternberg, 2005). An influential theory states that creativity depends on divergent (numerous and varied responses) and convergent (one correct or conventional response) processing, especially its divergence (Guilford, 1967). Earlier studies of the neural substrates have found that damages in frontal cortex impair word or semantic fluency, particularly the left prefrontal cortex (Laine and Niemi, 1988; Luria, 1966; Perret, 1974). Recent neuroimaging studies have further reported that divergent thinking with different tasks involves prefrontal (e.g., Fink et al., 2009; Gibson et al., 2009; Goel and Vartanian, 2005; Green et al., 2010), parietal (Fink et al., 2009; Sieborger et al., 2007),

* *Corresponding author*. Key Laboratory of Cognition and Personality, Ministry of Education, School of Psychology, Southwest University, Chongqing 400715, China.
E-mail address: qrlzhang@gmail.com (Q. Zhang).
0010-9452/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cortex.2013.01.015

temporal (Chavez-Eakle et al., 2007; Fink et al., 2009; Jung-Beeman et al., 2004), and visual regions (e.g., Howard-Jones et al., 2005). In the case of music, while trained pianists conduct improvisation with a piano, neural activity is different from studies of divergent thinking. Significant activation occurs in motor and pre-motor regions, dorsolateral prefrontal (Bengtsson et al., 2007; Berkowits and Ansari, 2008), middle frontal polar cortex (Limb and Braun, 2008), temporoparietal (Limb and Braun, 2008), and fusiform (Bengtsson et al., 2007). However, neuroimaging studies of artists exhibit another different picture. For example, Kowatari et al. (2009) have found that creativity in designing a pen is correlated with the degree of dominance of the right prefrontal over that the left one. In these studies, the task diversity makes it impossible to have an overlap of activation regions of the brain across studies of creativity (Arden et al., 2010). "To make creativity tractable in the brain, it must be further subdivided into different types that can be meaningfully associated with specific neurocognitive processes" (Dietrich and Kanso, 2010). That is, a best way to investigate creativity is to capture a facet of creative cognition and separate neural components from the brain, rather than creativity writ large.

Invention refers to the creation of a device that did not exist before, which helps humankind to live better or easier (Britannica encyclopedia, 2012; The world book encyclopedia, 1990). The inventive product is about physical objects or devices created in a novel way for practical uses. It is different from scientific, artistic, or literary creativity. Generally, inventive conception of the inventive product means creative ideas for designing devices in the category of technical inventions, rather than a broad category like creativity. It is obvious that the emphasis of inventive conceptions is conducive to elucidate neural mechanisms of the inventive process. Moreover, such exploration may extend the body of knowledge on neuroscience of creativity.

Inventive conceptions involve creative ideas for designing devices that are both original and useful. The generation of inventive conceptions relies on the formation of novelty-based representations in the mind for inventive devices or machines (Finke, 1990; Henderson, 2004; Royce, 1898; Simon, 1983). That a blade with sharp teeth along one edge could cut wood, for example, must have been generated in one's mind for invention of a saw. Such novelty-based representation has been considered to be essential to the inventive process, although physical objectification is subsequently conducted (Fagerberg, 2004; Wiener, 1993). Previous studies of invention have focused on cognitive mechanisms and computational models of novelty-based representations in the inventive process (Dyer and Hodges, 1986; Hampton, 1997; Ward et al., 1999). However, there has been no study aimed at neural substrates of the inventive process. Are there specific regions of the brain that mediate novelty-based representations in the inventive process? The purpose of the present study is to elucidate whether and what regions of the brain are specialized for the generation of inventive conceptions.

Many significant inventions in history are inspired by adaptive feature optimization of biological species (Argentina et al., 2007; Bar-Cohen, 2005; Dickinson, 1999; Vogel, 1998). In nature, these diverse features of living beings are highly optimized, which are efficiently acquired from million years of evolution (Darwin, 1859). It has sparked our novelty-based representations for artificial devices and machines in the inventive process, such as an oar based on fins of a fish, a fishnet based on the spider's web, and an early flying machine based on the bird (Chanute, 1997). Even in modern times, inventions have still been inspired by adaptive optimization. The surface design of some vehicles and buildings with non-stick surfaces was triggered by the lotus effect (Barthlott and Neinhuis, 1997), and the development of robot scientist "Adam" was based on thinking and reasoning (King et al., 2009). Much evidence demonstrates that enlightenment from adaptive feature optimization of biological species is one of the most important paradigms in inventions.

A functional feature association approach restricted to adaptive feature optimization of biological species inspires the generation of inventive conceptions for new devices (Bar-Cohen, 2005; Dickinson, 1999; Vogel, 1998), because the essential core of this paradigm for inventions is involving novelty-based representations formed by novel semantic relatedness. In such tasks biological features and artificial devices are not related semantically and never connected before. To establish their connection, a concept related to biological features at a node activates and spreads in various directions so that a novel idea related to a non-existent device is found among different associations (Estes and Ward, 2002; Guilford, 1967; Koestler, 1964; Mobley et al., 1992; Torrance, 1962). In other words, these unusual links can initiate original representation and novelty response for new devices in the inventive process (Beeman and Bowden, 2000; Mednick, 1962; Razumnikova, 2007). Conversely, processing of familiar semantic relatedness mainly involves retrieval of information about prior semantic relatedness in long-term memory. Thus, this one or very few specific connection drives automatic response among few alternatives, making it harder to find an original idea or solution. Therefore, in the present experiment we employed two types of functional feature association tasks to investigate neural activity underlying the generation of invention conceptions: biological functional feature association tasks (BFFAT) embodying novel semantic relatedness to stimulate the generation of inventive ideas, and non-biological functional feature association tasks (NBFFAT) embodying familiar semantic relatedness to stimulate the generation of ordinary ideas.

BFFAT and NBFFAT might be represented in different regions of the brain, and the neural activity pattern from direct contrast between the two types of tasks might be a measure for crucial components of neural networks underlying novelty-based representations in the generation of inventive conceptions. Previous patient studies have revealed the generation of ideas in divergent thinking is impaired with the left ventral prefrontal lesions (Janowsky et al., 1989; Laine and Niemi, 1988; Luria, 1966; Perret, 1974; Stuss et al., 1998). Neuroimaging data have revealed further that not only generation of ideas but also selection of a certain idea are associated with the left inferior frontal gyrus (Chavez-Eakle et al., 2007; Dapretto and Bookheimer, 1999; Fink et al., 2009; Goldberg et al., 2007; Jung-Beeman, 2005). Based on these studies, we hypothesized that the left ventral prefrontal cortex might be

Download English Version:

https://daneshyari.com/en/article/7316109

Download Persian Version:

https://daneshyari.com/article/7316109

Daneshyari.com