Neuropsychologia ■ (■■■■) ■■■–■■■

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Emergence of realism: Enhanced visual artistry and high accuracy of visual numerosity representation after left prefrontal damage

Keisuke Takahata [a,b], Fumie Saito [a], Taro Muramatsu [a], Makiko Yamada [b], Joichiro Shirahase [a,c], Hajime Tabuchi [a], Tetsuya Suhara [b], Masaru Mimura [a], Motoichiro Kato [a,c,*]

[a] Department of Neuropsychiatry, Keio University School of Medicine, 35 Shinanomachi, Shinjuku, Tokyo 160-8582, Japan
[b] Clinical Neuroimaging Team, Molecular Neuroimaging Program, Molecular Imaging Center, National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage, Chiba, Chiba 263-8555, Japan
[c] Center for Stress Research (CSR), Keio University, 35 Shinanomachi, Shinjuku, Tokyo 160-8582, Japan

ARTICLE INFO

Article history:
Received 21 October 2013
Received in revised form
1 February 2014
Accepted 24 February 2014

Keywords:
Prefrontal damage
Acquired savant syndrome
Realistic painting
Numerosity
Mental number line

ABSTRACT

Over the last two decades, evidence of enhancement of drawing and painting skills due to focal prefrontal damage has accumulated. It is of special interest that most artworks created by such patients were highly realistic ones, but the mechanism underlying this phenomenon remains to be understood. Our hypothesis is that enhanced tendency of realism was associated with accuracy of visual numerosity representation, which has been shown to be mediated predominantly by right parietal functions. Here, we report a case of left prefrontal stroke, where the patient showed enhancement of artistic skills of realistic painting after the onset of brain damage. We investigated cognitive, functional and esthetic characteristics of the patient's visual artistry and visual numerosity representation. Neuropsychological tests revealed impaired executive function after the stroke. Despite that, the patient's visual artistry related to realism was rather promoted across the onset of brain damage as demonstrated by blind evaluation of the paintings by professional art reviewers. On visual numerical cognition tasks, the patient showed higher performance in comparison with age-matched healthy controls. These results paralleled increased perfusion in the right parietal cortex including the precuneus and intraparietal sulcus. Our data provide new insight into mechanisms underlying change in artistic style due to focal prefrontal lesion.

1. Introduction

The human species is the sole animal that can draw a picture (Matsuzawa, 1991). Paintings are interpreted as indicators of the subject's internal representation of the environment, whether the subject is an artist or not (Clark, 1981; Seeley et al., 2008). Behaviorally, painting depends on various cognitive processes such as object recognition, visual representation, constructive ability, working memory and motor skills. From this viewpoint, it is not surprising that visual artistic skills can be impaired as a result of focal brain damage. One prominent example of a drastic change in artistic style following brain damage is the serial artworks created by the famous professional artist, Willem de Kooning, who had continued to draw after the progression of Alzheimer's disease (Crutch & Rossor, 2006). His artworks began to show a flattening of meaning and decomposition at the initial period of the disease, finally becoming expressions meaningless and disorganized (Crutch, Isaacs, & Rossor, 2001). Change in artistic styles as a consequence of focal brain damage was also reported in patients with a cerebral stroke. The most cited region in relation to visual constructive ability is the right hemisphere (Magnus & Laeng, 2006; Miller & Hou, 2004; Schnider, Regard, Benson, & Landis, 1993). It has been shown that damage in this region can cause a symptom known as constructional apraxia (Kleist, 1934; Piercy, Hecaen, & de Ajuriaguerra, 1960), which refers to the inability to draw or copy figures despite spared motor ability.

Although brain diseases cause various types of impairment in visual artistry, they sometimes give rise to an unexpected emergence or enhancement of visual artistic skills. In 1996, Miller et al.

* Corresponding author at: Department of Neuropsychiatry, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan. Tel.: +81 3 3353 1211; fax: +81 3 5379 0187.
E-mail addresses: ksk-taka@nirs.go.jp (K. Takahata), np-saito@abox3.so-net.ne.jp (F. Saito), mrmtmrmt@fa2.so-net.ne.jp (T. Muramatsu), myamada@nirs.go.jp (M. Yamada), jo_sira@t3.rim.or.jp (J. Shirahase), tabuchi@a8.keio.jp (H. Tabuchi), suhara@nirs.go.jp (T. Suhara), mimura@a7.keio.jp (M. Mimura), motokato@tc4.so-net.ne.jp (M. Kato).

http://dx.doi.org/10.1016/j.neuropsychologia.2014.02.022
0028-3932/

described three cases of a temporal variant of frontotemporal lobar degeneration (FTLD), in which patients obtained savant-like artistic skills and consequently became accomplished painters after onset of the disease (Miller, Ponton, Benson, Cummings, & Mena, 1996). Miller et al. (1998) added two additional cases of patients who might have developed *de novo* artistic skills in the early stage of FTLD. Around the time of Miller's reports, similar cases were reported from non-European countries with different cultural backgrounds. Tanabe et al. (1996) described a case of a Japanese patient with a variant of FTLD, who showed a change in artistic style during the course of the illness. Midorikawa, Fukutake, and Kawamura (2008) also described 2 patients with FTLD who developed skills for realistic drawing without any art education after onset of semantic dementia. These previously reported cases shared important features: (1) almost all patients had left dominant type of FTLD, and (2) the style of the artworks tended to be excessively realistic, as their artistic styles were characterized by strict composition, spatially accurate arrangement of objects, and intensive focus on details. While the paintings created by these patients became more realistic and precise in the reproduction of external objects after onset of disease, they often lacked techniques such as abstraction and accentuation. Recently, Seeley et al. (2008) provided details concerning a professional artist with primary progressive aphasia (PPA) in the left hemisphere. In this case, as PPA began and progressed, the patient's artworks changed "unmistakably toward photographic realism, reproducing the world with high surface fidelity. Symmetry and structural detail were emphasized". These published reports of professional and amateur painters with dementia suggest that artistic skills of realistic painting can be promoted as a result of focal brain dysfunction, and especially with left frontal damage.

Why do patients with left frontal damage often show increased tendency toward realism? At present, detailed mechanisms underlying the paradoxical development of realism in visual artistry are not yet fully understood. This might be due to the heterogeneity of clinical profiles in previously reported cases and a difficulty in isolating a critical component associated with realistic painting. However, recent works in cognitive, neuropsychological and neuroscientific research hint at a plausible biological model that associates disruption of left frontal functions and emergence of visual realism.

Of interest in the current study is why some patients suffering left frontal damage show enhanced skills of realistic painting. Clinical observations that brain lesions not only lead to a functional loss but also manifest unpredicted heightening of cognitive functions in certain conditions have been described for longer than two decades (Kapur, 2011). Enhancement of functioning in people with chronic or acute sensory loss has been one of the most widely reported forms of this phenomenon (Amedi, Raz, Pianka, Malach, & Zohary, 2003; Forster, Eardley, & Eimer, 2007; Muchnik, Efrati, Nemeth, Malin, & Hildesheimer, 1991). Similar phenomena were also cited in relation to psychiatric symptoms, such as sensory hallucinations (Menon, Rahman, Menon, & Dutton, 2003) and mood elevation (Koreki, Takahata, Tabuchi, & Kato, 2012). The neurobiological studies in the past century have shown that cerebral hemispheres are structured by several functional modules, reciprocally interacting through inhibitory and excitatory connections especially between both hemispheres (Hilgetag, Kötter, & Young, 1999). This interhemispheric competition model of brain functions has been looked upon as the basis for the neural mechanism underlying enhanced artistic skills following the occurrence of focal brain damages (Schott, 2012). Consistent with this notion, Miller and his colleagues had previously reported that patients with FTLD on SPECT had shown the highest perfusion in the right posterior parietal cortices (Miller et al., 1996, 1998). Thus, converging evidence has supported the hypothesis that left frontal dysfunction and right parietal facilitation play a key role in emergent visual realism following left frontal damage. However, the exact nature of enhanced visual realism due to left frontal dysfunction, especially in behavioral terms, remains unknown. To answer this question, detailed investigation of cognitive characteristics of patients showing enhanced skill of visual arts following the occurrence of brain damage will be necessary.

Visual realism is characterized by accurate and detailed representation of the scenes and objects in visual space. In primates, visual representation is constructed via hierarchical processing of lower-level perceptual information and higher-level visual representation (Marr, 1982; Riesenhuber & Poggio, 1999; Stoianov & Zorzi, 2012). For realistic drawing, extraction of lower-level perceptual information, such as edge, contour, shape, color, contrast, light and shadow are necessary. This lower-level perceptual information corresponds to the so-called "physical level" in Marr's classical computational model of visual representation (Marr, 1982). Magnus and Laeng (2006) included this perceptual information as necessary components for expert drawing.

However, enhancement of lower-level perceptual processing is not sufficient for improvement of accurate drawing of complex objects and space. As Magnus and Laeng (2006) indicated, precise drawing relies on not only lower-level perceptual processing, but also processing of higher-level information such as spatial relationship of objects and their gestalt. Especially, in visual realism, depiction of accurate spatial relations is critically important, and they are organized in the form of representational metrics such as distance, orientation, angle and size, and are encoded in the parietal cortex. This view was consistent with clinical observations that damage in this region often causes impairments of accurate drawing or disability to arrange objects precisely, known as constructional apraxia (Laeng, 2006). Our view is further supported by the fact that there was minimum change in lower-level perceptual abilities in past-reported patients who showed enhanced realistic painting skills after brain diseases.

Several lines of behavioral evidence have indicated that numerical representations are closely associated with representations of spatial relationship. It has been suggested that different types of numerosity including size, distance and number are coded in common properties as an integrated form of the mental number line (Walsh, 2003). Bulk of evidence suggested that individual differences in properties of mental number line affect visual representation of visual space. One well-known example is SNARC effects (Dehaene, Bossini, & Giraux, 1993). SNARC effects indicate that visual space is represented along with the mental number line: lower numerosity on the left side and higher numerosity on the right side. Other evidence of a tight link between numerical and spatial representations comes from a TMS study that showed that the mental number line and visual spatial representation are co-represented in the right parietal cortex (Cattaneo, Silvanto, Pascual-Leone, & Battelli, 2009). Furthermore, a recent study showed that numerical representation is coded topographically. This finding demonstrates that higher-level perceptual processing including visual numerosity representation shares a common characteristic with lower-level perceptual information (Harvey, Klein, Petridou, & Dumoulin, 2013).

All the above studies together indicate that visual representation of spatial relationship and that of numerosity were inseparable not only at a cognitive but also at a neural level. From this evidence, we hypothesized that a high accuracy of visual numerical representation could refine visual spatial representation via more precise metrics of size, distance, angle and numbers of objects in visual space. Past studies in the field of developmental psychology provide indirect evidence that higher numerical performance (mathematics) is associated with higher drawing skills (Brunswick, Chamberlain, McManus, & Rankin, 2011). Thus, a plausible scenario would be that

Please cite this article as: Takahata, K., et al. Emergence of realism: Enhanced visual artistry and high accuracy of visual numerosity representation after left prefrontal damage. *Neuropsychologia* (2014), http://dx.doi.org/10.1016/j.neuropsychologia.2014.02.022