NeuroImage 105 (2015) 440–451

Contents lists available at ScienceDirect

NeuroImage

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

The artist emerges: Visual art learning alters neural structure and function

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ARTICLE INFO

Article history:
Accepted 7 November 2014
Available online 15 November 2014

Keywords:
Art
Creative cognition
Perception
Perception-to-action
Plasticity
White matter
Cerebellum
Motor cortex
DTI
fMRI
MVPA

ABSTRACT

How does the brain mediate visual artistic creativity? Here we studied behavioral and neural changes in drawing and painting students compared to students who did not study art. We investigated three aspects of cognition vital to many visual artists: creative cognition, perception, and perception-to-action. We found that the art students became more creative via the reorganization of prefrontal white matter but did not find any significant changes in perceptual ability or related neural activity in the art students relative to the control group. Moreover, the art students improved in their ability to sketch human figures from observation, and multivariate patterns of cortical and cerebellar activity evoked by this drawing task became increasingly separable between art and non-art students. Our findings suggest that the emergence of visual artistic skills is supported by plasticity in neural pathways that enable creative cognition and mediate perceptuomotor integration.

Introduction

Art is a complex and uniquely human phenomenon. The creation of artistic work has historically been a mysterious and poorly understood process, often even by artists themselves (Stiles and Selz, 2012). However, according to central tenets of neuroscience, the work of an artist must be mediated by the brain. How does the brain support the cognitive skills necessary to create art?

Art has appeared in many forms throughout human history. The qualities that distinguish artistic work are thus often difficult to define. For example, while some *trompe l'oeil* painters such as William Harnett (Frankenstein, 1953) attain an astounding ability to recreate visual scenes accurately, representation for other painters such as abstract expressionist Barnett Newman (Shiff, 2004) is less important than the concepts or processes that their works communicate. Nonetheless, most artists, regardless of their motivation or medium, spend years developing patterns of thought and behavior that lead ultimately to expression in a work of art. Here, we focused narrowly on a single type of artwork: representational, two-dimensional visual depictions created from observation. We necessarily ignored many important factors such as social, cultural, and affective contexts that are vital to the work of many artists (cf. Stiles and Selz, 2012). No single study can address every factor that influences artistic skill. However, the results presented here may provide a window into some of the neural processes that endow humans with a seemingly limitless ability to create new objects, ideas, and processes.

In the current study we investigated how artistic behaviors are learned, focusing on representational visual art and on three areas of cognition that are relevant to many visual artists: creative cognition, visual perception, and perception-to-action (Fig. 1A). We asked how skills associated with each of these three cognitive domains change and how the brain reorganizes as students learn to create visual art. We recruited 35 undergraduate college students for monthly testing; 17 of these participants took a 3-month-long introductory observational drawing or painting course offered by the Studio Art Department at Dartmouth College, while 18 control participants did not study art. All participants attended monthly MRI scanning sessions. Below we introduce the three areas of cognition that we studied and their potential relevance to visual art.

Creative cognition

Artists are distinguished by the ability to think in new ways, developing new patterns of and connections between ideas to imagine and

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http://dx.doi.org/10.1016/j.neuroimage.2014.11.014
1053-8119/

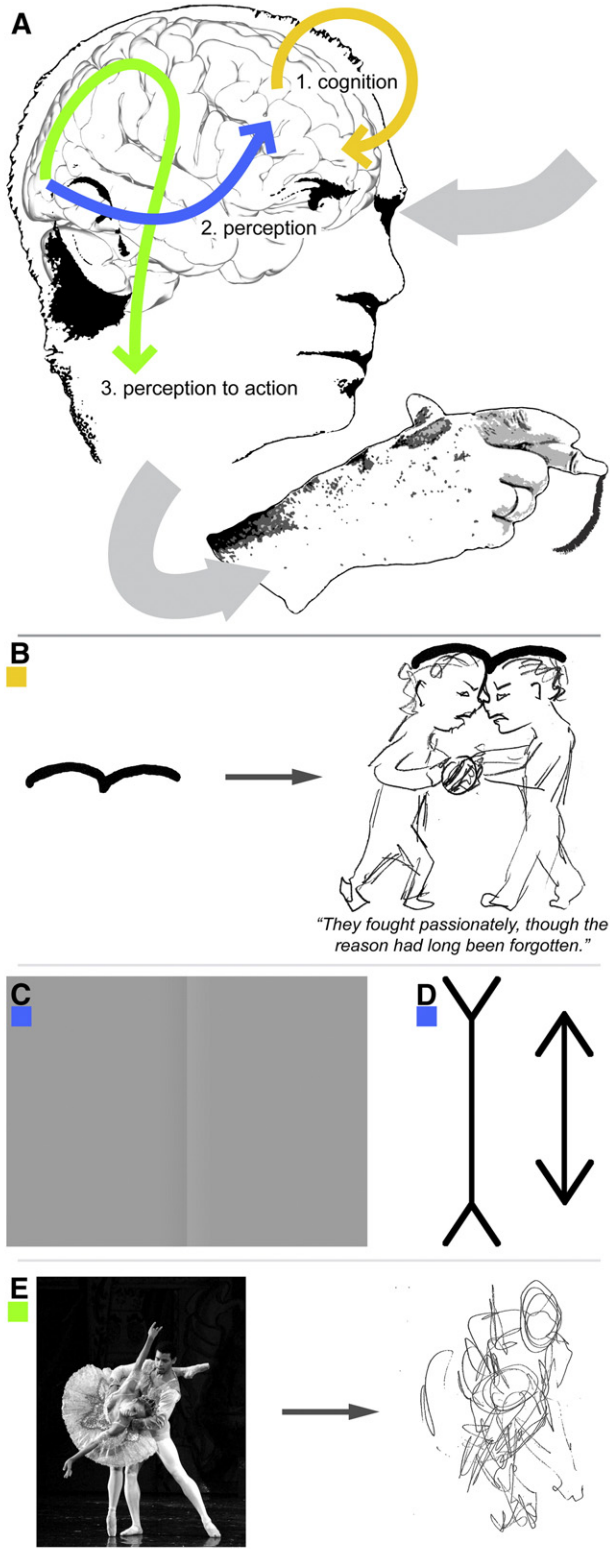

Fig. 1. Experimental design. A. Areas of cognition important to the production of representational visual art: creative cognition, perception, and perception-to-action pathways. B. Example prompt and participant response from the TTCT. Participants were instructed to draw something that no one else would think of, to tell as rich and complete a story as possible, and to give each response a creative title. C. The Craik–O'Brien–Cornsweet illusion, in which a dark-to-light gradient heading left of center and a light-to-dark gradient heading right of center cause a uniform gray rectangle to appear darker on the left side than on the right side. D. The Müller–Lyer illusion, in which a line segment with outward facing arrow ends appears longer than an identical-length line segment with inward facing arrow ends. E. Example stimulus and participant response from the gesture drawing task. Participants had 30 s to complete a gesture drawing of the observed human figures.

create artifacts and processes that have never existed previously. The sources of this creativity are among the least understood and most mythologized aspects of art production (Milbrandt and Milbrandt, 2011; Taylor, 1976). Creative cognition is notoriously difficult to define within a scientific context, partly because creativity can be manifested in myriad domains such as artistic and scientific fields, verbal and visual modalities, and divergent and convergent thought (Dietrich and Kanso, 2010). Many questions about what makes artists creative remain open, especially with respect to the brain's role in these creative processes. Previous neuroscientific studies have used a range of approaches to study the neural basis of creativity in artists, but little consensus about this basis has emerged. For example, Bhattacharya and Petsche (2005) used EEG to study differences in cortical activity between artists and non-artists as both produced drawings of their own choice and found differences in short and long range neural synchronization patterns between the two groups. Kowatari et al. (2009) asked design experts and novice participants to invent a new type of pen while undergoing functional MRI (fMRI) scans and found that creative output was correlated with the degree of dominance of right over left prefrontal cortical activity. Limb and Braun (2008) used fMRI to show that jazz pianists experienced extensive deactivation of prefrontal cortex when they played improvised compared to over-learned musical pieces. Solso (2001), on the other hand, found reduced activity in the parietal cortex in a skilled portrait artist compared to a novice participant as both produced drawings of faces. While little consensus has emerged from such studies, the many emerging findings about both artists and creative cognition more generally have shown that creativity is a complex rather than monolithic process and that researchers must therefore avoid the tendency to reduce creativity to simple conceptual constructs (Arden et al., 2010; Dietrich and Kanso, 2010; Hee Kim, 2006). Thus, in this study we chose assessments of creativity (described below) that measured many aspects of creative ability.

A recent study by Jung et al. (2010) investigated the relationship between white matter organization and creative cognitive ability using diffusion tensor imaging (DTI). They found an inverse correlation in the frontal lobes between fractional anisotropy (FA; a measure of the directionality of water diffusion in white matter) and both divergent thinking and openness, such that more creative individuals as measured by these traits tended to have lower frontal white matter FA. While FA is often associated with myelination of axons, several other properties such as axon count, axon packing, and crossing fibers can affect the anisotropy of water diffusion in the brain as well. While the exact neural correlates of FA are not determined precisely, DTI nonetheless provides a non-invasive means of investigating longitudinal changes in the structure of white matter. Several recent studies have shown that diffusion tensor imaging (DTI) is an effective tool for tracking learning-related changes in the white matter organization of the brain in as little as six weeks or as long as nine months (May, 2011; Schlegel et al., 2012; Scholz et al., 2009). Even shorter term changes (in as little as five days) have been observed in brain structure using other imaging modalities (Ditye et al., 2013; Driemeyer et al., 2008).

Visual perception

The visual system is organized to recover intrinsic properties of perceived objects such as size and reflectance. It therefore often counteracts context-dependent aspects of objects such as distance from the observer and ambient luminance (Todorović, 2002). In other words, the brain constructs our perception of the world not necessarily in accordance with the physical stimulation, but rather as it infers things to be intrinsically. For instance, a white flower still appears white in a blue-lit room, even though the flower reflects only blue light in such a room. While such inferences on the part of the visual system permit us to perceive intrinsic properties of objects (e.g. size, shape, or pigment), they can also lead to illusory percepts such as the Craik-O'Brien-Cornsweet and Müller-Lyer illusions (Figs. 1C & D) (Müller-Lyer, 1889; Todorović, 1987).