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Hemispheric asymmetry in the influence of language on visual perception

Yanliang Sun, Yongchun Cai *, Shena Lu *

Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, China

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ABSTRACT

Many studies have shown that language can affect visual perception; however, our understanding of the neural basis of linguistic influence is inadequate. This can be investigated by examining the hemispheric asymmetry of linguistic influence. The left and right hemispheres are dominant in close and distant semantic processing, respectively. In this study, we investigated whether the hemispheric asymmetry of semantic processing led to hemispheric asymmetry for concept priming on the detection of objects degraded by continuous flash suppression. We combined a priming paradigm with the divided visual field paradigm and used continuous flash suppression, which renders objects invisible. The results indicated that the hemispheric asymmetry of semantic processing led to a right lateralization in the influence of more abstract concepts on visual perception. The lateralization of brain connectomes may be the underlying neural basis of this effect.

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1. Introduction

There has been sustained interest into whether language affects our visual perception of the world (Gumperz & Levinson, 1996; Lucy, 1997; Wolff & Holmes, 2011). Much research has shown that language exerts rapid and pervasive effects on visual processing, such as color perception (Gilbert, Regier, Kay, & Ivry, 2006; Kay & Kempton, 1984; Roberson & Davidoff, 2000; Winawer et al., 2007; Witthoft et al., 2003), motion perception (Dils & Boroditsky, 2010; Meteyard, Bahrami, & Vigliocco, 2007), face processing (Landau, Aziz-Zadeh, & Ivry, 2010), visual search (Lupyan, 2008; Lupyan & Spivey, 2010b; Lupyan & Swingley, 2012), and simple visual detection (Lupyan & Spivey, 2010a; Pelekanos & Moutoussis, 2011). However, it is argued that the influence of non-visual factors such as language, may occur at the pre-perceptual attention-allocation stage or post-perceptual decision stage, rather than the perceptual stage (Pylyshyn, 1999). One way to circumvent this alternative interpretation is to explore whether language can make unseen objects visible. This can be done by using a task that does not require a visual search process, explicit identification, or categorization of the stimulus (Lupyan & Spivey, 2010a).

Recently, Lupyan and Ward (2013) conducted pioneering research exploring whether linguistic concepts can make unseen objects visible by combining a priming paradigm and continuous flash suppression (CFS). CFS is a version of binocular rivalry where an image presented to one eye is continuously degraded from awareness by successive 10-Hz flashes of high-contrast, contour-rich patterns viewed by the other eye (Tsuchiya & Koch, 2005). Participants are asked to indicate whether

* Corresponding authors at: Department of Psychology and Behavioral Sciences, Xixi Campus, Zhejiang University, 148 Tianmushan Road, Hangzhou 310028, China.

E-mail addresses: yccai@zju.edu.cn (Y. Cai), snlu@zju.edu.cn (S. Lu).

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they see any image (e.g., a picture of a pumpkin) after hearing a basic verbal concept (e.g., a word "pumpkin" or "kangaroo"). The results showed that the presentation of the valid concept improved performance relative to the invalid concept, both in sensitivity (d') and response times. Lupyan and Ward (2013) argue that the underlying neural basis for this effect involves top-down feedback that activates the object-selective regions of cortex, such as the inferotemporal cortex, producing a predictive signal to the forthcoming visual processing. Although there have been some insights into the neural basis of the linguistic influence, as shown in Lupyan and Ward's study (2013), our understanding is currently inadequate. An additional way to investigate the neural basis of the linguistic influence on visual perception is to examine its hemispheric asymmetries.

The functional organization of semantic processing differs between the two hemispheres. The left hemisphere is predominantly associated with rapid interpretation and close semantic processing and the right hemisphere with maintaining broad semantic activation and distant semantic processing (Hutsler & Galuske, 2003; Jung-Beeman, 2005). Based on the cross projection of nerve fibers between left and right visual fields and hemispheres, evidence has shown that semantic priming for target words distantly related to preceding prime words is stronger in the left visual field-right hemisphere (LVF-RH) than in the right visual field-left hemisphere (RVF-LH). Conversely, stronger priming occurs in the RVF-LH when target words are closely related to the preceding prime words (Chiarello, Liu, Shears, Quan, & Kacinik, 2003; Coulson & Williams, 2005; Faust & Lavidor, 2003; Titone, 1998). From a network perspective, the functional interactions are constrained by connectomes in the brain network; therefore, hemispheric asymmetries in semantic processing may arise from the hemispheric asymmetries of connectomes. Increasing evidence has indicated that the RH has a higher ratio of white to gray matter, more synchronous activity across regions, diffuse electrophysiological responses, and functional deficits when compared with similar sized brain lesions in the LH (Beeman, 1998). Gotts et al. (2013) have applied a new hemispheric alignment method with fMRI to evaluate lateralization over the entire cortex. They found that the LH has a greater preference for within-hemisphere interactions whereas the RH interacts more strongly between the two hemispheres. These data suggest that there are more interactive long-range connections in the RH than LH, which may make the RH better at maintaining broad semantic activation and distant semantic processing compared with the LH (Jung-Beeman, 2005).

Based on these observations, we sought to determine whether the hemispheric asymmetry of semantic processing led to hemispheric asymmetry in the influence of linguistic concepts on the detection of objects that are degraded by CFS. We investigated this by manipulating the prediction specificity of object concepts for the degraded objects. The representations of object concepts are hierarchically and interactively organized by sensory features, such as form and color (Humphreys & Forde, 2001); therefore, prediction specificity for the degraded objects can be manipulated by keeping the degraded objects constant and changing the abstractness of object concepts. For example, when a degraded object is a line drawing of a butterfly, the basic object concept "butterfly" is more concrete to the line drawing of a butterfly than the superordinate object concept "insect." Moreover, members of superordinate object concepts share fewer features than basic object concepts (Frederico Marques, 2007; Horton & Markman, 1980; Murphy & Brownell, 1985; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Hence, the diffusibility of the conceptual influence can also be controlled by the abstractness of object concepts. Specifically, the influence of superordinate object concepts would be more diffuse than the basic object concepts.

We adopted the divided visual field paradigm, which is an experimental technique based on the cross projection of optic nerve fibers used to investigate the functional laterality of the brain, combined with CFS to retain visual processing within one hemisphere. CFS can maintain visual information within low-level visual cortex regions, such as V1, over an extended period (Tsuchiya & Koch, 2005). The limited callosal connections of low-level visual cortices are restricted to the vertical meridian representation of the visual field (Berlucchi, 2014). Stimuli presented in the center of one-half of the visual field will be processed predominantly in the contralateral hemisphere. The influence of linguistic concepts on visual perception was measured by the ability to detect objects under CFS. We conducted a pilot experiment that showed that contrast sensitivity under CFS is not symmetric between the two visual fields. Specifically, the contrast sensitivity is weaker when the stimuli are presented in the nasal visual field (see Supplementary Material).

Two predictions can be made from the present experimental design. (1) If the hemispheric asymmetry of semantic processing is the decisive factor that leads to the asymmetry in the influence of object concepts on the detection of degraded objects, the influence of superordinate object concepts will be more right lateralized than the influence of basic object concepts. (2) If the nasal-temporal asymmetry of contrast sensitivity under CFS is the decisive factor of the asymmetrical effect, the impact of object concepts will show a nasal-temporal, and not left–right, asymmetry. Overall, the present study will shed new light on the influence of language on visual perception and its brain mechanism.

2. Methods

2.1. Participants

Fourteen observers (including one author; 8 male, 6 female; mean age, 21 years) participated in Experiment 1a. Fourteen observers (5 male, 9 female; mean age, 22 years; including two observers from Experiment 1a) participated in Experiment 1b. Sixteen new observers (8 male, 8 female; mean age, 23 years) participated in Experiment 2 and the same number of new observers (7 male, 9 female; mean age, 22 years) participated in Experiment 3. Participants were recruited from Zhejiang University and had normal or corrected-to-normal vision. All participants (except the author) were naive to the purpose

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