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No evidence for dorsal-stream-based priming under continuous flash suppression

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ABSTRACT

Previous studies have proposed that potentially action-relevant visual features of masked images are processed along the dorsal visual pathway, and can thus prime responses to images of man-made manipulable objects (tools). According to the "category priming by elongation" hypothesis, (invisible) stimulus elongation is the basis for how the dorsal stream can affect the categorization of tools. In our study, prime stimuli were rendered invisible using continuous flash suppression (CFS) and anaglyphs for dichoptic stimulation. We found that participants' reaction times were only weakly affected by CF-suppressed prime stimuli. If anything, the RT data were more consistent with response priming based on shape. Moreover, when prime visibility was low, participants were not able to infer the prime's category but its shape. We recommend that future CFS priming studies should use crosstalk-free setups for dichoptic stimulation, and that awareness measures should be tailored to the stimulus feature of interest.

1. Introduction

This study brings together two topics that were among Bruce Bridgeman's main research interests: perception-action interactions and consciousness (Bridgeman, 2011; Cooper, Sterling, Bacon, & Bridgeman, 2012). Specifically, we investigated the notion that continuous flash suppression (CFS), a relatively new psychophysical "blinding" technique, selectively disrupts stimulus identification mediated by the ventral "vision-for-perception" pathway, while preserving action-relevant stimulus features processed by the dorsal "vision-for-action" pathway (Lin & He, 2009). CFS is a method of interocular suppression, where dynamic masks shown to one eye suppress the conscious perception of stimuli presented to the other eye (Tsuchiya & Koch, 2005; Tsuchiya, Koch, Gilroy, & Blake, 2006). Early CFS work using functional magnetic resonance imaging (fMRI) suggested that neural activity along the dorsal visual pathway remains largely intact when images of man-made manipulable objects (tools) are rendered invisible by CFS (Fang & He, 2005). More recent neuroimaging studies did not confirm this dorsal-ventral dissociation (Fogelson, Kohler, Miller, Granger, & Tse, 2014; Hesselmann & Malach, 2011; Ludwig, Kathmann, Sterzer, & Hesselmann, 2015). However, the notion that CFS could be used to "isolate" or "bias" dorsal visual processing resonated well with the predictions of the perception-action model (Milner & Goodale, 2006; Milner, 2012), and has significantly contributed to the method's popularity by inspiring various lines of behavioral and neuroimaging research [for a review, (Ludwig & Hesselmann, 2015)].

Based on the results from masked priming experiments, it has been proposed that the "dorsal-stream-based analysis of elongation along a principal axis is the basis for how the dorsal visual object processing stream can affect categorization of manipulable objects" [(Almeida et al., 2014), p.319]. The results from a category discrimination task (tool versus animal) showed that CF-suppressed

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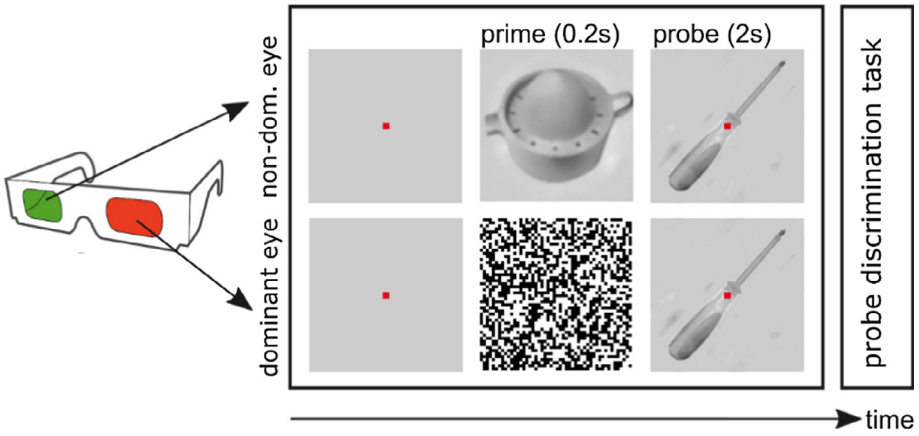

Fig. 1. CFS priming paradigm. Prime stimuli were presented for 0.2 s to the non-dominant eye (via the green anaglyph filter), while random noise pattern masks were flashed at 10 Hz to the dominant eye (via the red anaglyph filter). Probes were presented binocularly for 2 s. On each trial, participants provided a speeded probe discrimination response, either relating to the probe's category (animal, tool) or the probe's shape (elongated, non-elongated). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

elongated prime stimuli yielded shorter response times (RTs) to tool probes, when compared with CF-suppressed non-elongated prime stimuli (Almeida, Mahon, & Caramazza, 2010; Almeida, Mahon, Nakayama, & Caramazza, 2008). RTs to animal probes were less affected by invisible prime stimuli. Given the implications of this "category priming by elongation" hypothesis for our understanding of perception-action interactions and the interplay between the two visual streams, we recently studied its empirical basis in a series of masked priming experiments using CFS (Hesselmann, Darcy, Rothkirch, & Sterzer, in press). We did not find evidence for non-conscious priming of object categorization by stimulus elongation as a potentially action-relevant visual feature. While our previous setups closely resembled the original setups with respect to stimuli and procedures (e.g., the choice of CFS masks and dichoptic stimulation method), our experimental design did not include the shape-category confound present in the original studies (Almeida et al., 2008, 2010, 2014). Shape and category were confounded as all tool probes were elongated, while animal probes were non-elongated. In the current study, we aimed to replicate the "dorsal-stream-based" priming effects under CFS with an experimental design including the shape-category confound. Since participants would be able to solve the category discrimination task based on stimulus shape alone, we included blocks of trials with the same stimuli and conditions but with a shape discrimination task. According to a "shape priming" model, responses should be faster in trials where prime shape and probe shape are congruent. In our analysis, we aimed to directly quantify which model is more consistent with the observed RT data, the "category priming by elongation" hypothesis or a response priming model based on stimulus shape.

2. Methods

2.1. Participants

27 participants took part in the experiment. Data from 25 participants (17 female, mean age: 22, range: 18–33 years) were submitted to statistical analysis after the exclusion criteria were applied (see below). All participants had normal or corrected-to-normal vision, were naïve to the purpose of the study, and provided informed written consent. Nine participants reported that they had participated in previous CFS experiments. The experiment was conducted at the Department of Psychiatry and Psychotherapy, Charité - Universitätsmedizin Berlin, Germany, with ethics approval from the German Association of Psychology (Deutsche Gesellschaft für Psychologie, DGPs). Participants were recruited from student pools via email and were paid 8 €/h for their participation.

2.2. Continuous flash suppression (CFS)

Fig. 1 illustrates the setup of the experiment. Prime stimuli were rendered invisible using CFS (Tsuchiya & Koch, 2005; Tsuchiya et al., 2006). CFS masks consisted of high-contrast random noise patterns, similar to the ones used in the original masked priming studies (Almeida et al., 2008, 2014; Sakuraba, Sakai, Yamanaka, Yokosawa, & Hirayama, 2012).

We used red/green anaglyph glasses (www.3d-brillen.de/) for dichoptic stimulation. The filters were LEE Filters #124 (Dark Green) and #182 (Light Red), respectively (LEE Filters Worldwide, UK).[1] The overall crosstalk across luminance levels was 3.31%, and the luminance attenuation factor was 16.90 (Hesselmann et al., in press). Our measurements indicated larger crosstalk for lower luminance levels. These values are in good agreement with previous reports for anaglyph glasses in CRT setups (Baker, Kaestner, &

[1] Data sheets with transmission spectra can be downloaded at http://leefilters.com/lighting/colour-list.html.