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Can perceptual grouping unfold in the absence of awareness? Comparing grouping during continuous flash suppression and sandwich masking

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ABSTRACT

In this study we examined whether grouping by luminance similarity and grouping by connectedness can occur in the absence of visual awareness, using a priming paradigm and two methods to render the prime invisible, CFS and sandwich masking under matched conditions. For both groupings, significant response priming effects were observed when the prime was reported invisible under sandwich masking, but none were obtained under CFS. These results provide evidence for unconscious grouping, converging with previous findings showing that visual awareness is not essential for certain perceptual organization processes to occur. They are also consistent with findings indicating that processing during CFS is limited, and suggest the involvement of higher visual areas in perceptual organization. Moreover, these results demonstrate that whether a process can occur without awareness is dependent on the level at which the suppression induced by the method used for rendering the stimulus inaccessible to awareness takes place.

1. Introduction

Our conscious perception is of a seamless whole rather than of bits of obscured, colored blobs of light. Perceptual organization is the process by which the disjoint bits of visual information are structured into a meaningful scene composed of objects and their interrelations. The Gestalt psychologists, who were the first to study perceptual organization, suggested that perceptual organization occurs in accordance to a set of grouping and segregation principles. These include classic principles such as proximity, similarity, good continuation, common fate, and closure (Wertheimer, 1923), and new principles such as generalized common fate (Sekuler & Bennett, 2001), synchrony (Alais, Blake, & Lee, 1998), common region (Palmer, 1992), and element connectedness (Palmer & Rock, 1994) (for reviews see, Peterson & Kimchi, 2013; Wagemans et al., 2012).

An important issue concerns the role of consciousness in perceptual organization: Can perceptual organization unfold in the absence of visual awareness[1] of the stimulus? A number of studies have addressed this question, and the picture that emerges is far from being consistent. The inconsistency in the findings may not be so surprising in light of the evidence that perceptual organization is a multiplicity of processes (Behrmann & Kimchi, 2003; Kimchi, 2003), which vary in their time course (e.g., Hadad & Kimchi, 2008; Kimchi, 1998, 2000; Kurylo, 1997; Razpurker-Apfeld & Kimchi, 2007), developmental trajectory (e.g., Hadad, Maurer, & Lewis, 2010; Kimchi, Hadad, Behrmann, & Palmer, 2005; Quinn & Bhatt, 2006), and attentional demands (e.g., Freeman, Sagi, & Driver,

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[1] In this article, we use the terms “consciousness” and “awareness” interchangeably.

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2001; Kimchi & Razpurker-Apfeld, 2004; Mack, Tang, Tuma, & Kahn, 1992; Moore, Grosjean, & Lleras, 2003; Rashal, Yeshurun, & Kimchi, 2017a), and may operate both early and late in the course of visual processing (e.g., Palmer, Brooks, & Nelson, 2003) (for reviews see, Gillebert & Humphreys, 2015; Kimchi, 2009, 2012; Quinn & Bhatt, 2015).

It is possible, then, that visual consciousness of the stimulus is essential for some perceptual organization processes, but not for others. For example, Montoro, Luna, and Ortells (2014), using a masked priming procedure, showed that grouping elements by proximity and by luminance similarity into horizontally or vertically oriented patterns can take place in the absence of visual consciousness. Schwarzkopf and Rees (2011), on the other hand, failed to find evidence for the grouping of local elements into a global shape in the absence of awareness. Recently, however, Jimenez, Montoro, and Luna (2017) found that elements can group into a global shape for prime-mask SOA of 53 ms, but not for SOA of 27 ms. Sweeny, Grabowecky, and Suzuki (2011) found that closed-curvature aftereffects, in contrast to open-curvature aftereffects, occurred only when observers were aware of the adaptor. Interestingly, even when the same organization process was examined – the formation of illusory Kanizsa configuration – the findings are mixed, presumably due to different methods used to suppress the stimulus from awareness. Sobel and Blake (2003) showed that binocular rivalry suppression prevented the formation of subjective contours. Similarly, Harris, Schwarzkopf, Song, Bahrami, and Rees (2011), using continuous flash suppression (CFS, an interocular masking technique in which a high contrast rapidly changing stimulus presented to one eye suppresses perception of a stimulus presented to the other eye; Tsuchiya & Koch, 2005), showed that awareness of inducers was necessary for perception of illusory contours. Similar findings were reported by Banica and Schwarzkopf (2016) using masking. In contrast, Wang, Weng, and He (2012), using breaking continuous flash suppression (b-CFS, a variant of CFS that entails measuring the time it takes stimuli to break suppression), found that a Kanizsa triangle emerged from suppression significantly faster than a control stimulus in which the local pacmen were randomly or 180° rotated, presumably suggesting formation of illusory contours without awareness (but see Moors, Wagemans, van Ee, & de-Wit, 2016). Also, Poscoliero, Marzi, & Girelli (2013), using metacontrast masking, and Jimenez et al. (2017), using sandwich masking (a combination of forward and backward masking), showed that masked Kanizsa configurations can have an influence on a subsequent shape discrimination, and Lau and Cheung (2012), demonstrated that illusory contour formation survives crowding of the inducers.

Hence, the question is which perceptual organization processes can occur without awareness of the stimulus, and to what extent does the answer to this question depend on the method used to suppress the stimulus from awareness (see Moors et al., 2016).

This study aimed to examine whether perceptual grouping can occur in the absence of visual awareness, using two different methods to suppress the stimuli from awareness. We focused on two basic grouping principles, the classic principle of grouping by luminance similarity (Experiments 1 and 3), and the new principle of grouping by element connectedness (Experiments 2 and 4). The similarity principle states that the most similar elements (in this case in luminance) tend to be grouped together. The principle of element connectedness states that elements that are connected tend to be grouped together.

Each grouping process was examined with two invisibility-inducing methods: CFS and sandwich masking (a combination of forward and backward masking). In all experiments, participants were presented with a liminal prime – dots grouped by luminance similarity or by connectedness into columns/rows – followed by a clearly visible target consisted of lines, the orientation of which was either congruent or incongruent with the prime's orientation. For each process under examination, the stimuli and the task were identical across the two methods. This is important because it can help to disentangle the limits of the method used to render the stimulus invisible and the limits of unconscious processing per se (Faivre, Berthet, & Kouider, 2012; Peremen & Lamy, 2014a).

Awareness of the prime was assessed on each trial using a sensitive subjective visibility scale akin to the Perceptual Awareness Scale (e.g., Ramsøy & Overgaard, 2004). Previous research has suggested that subjective reports of conscious perception can be as sensitive as measures relying on objective discrimination performance, provided that the subjective measure employed is not dichotomous (e.g., Peremen & Lamy, 2014b). The trial-by-trial measure of awareness allowed us to compare the influence of the prime on behavior when it is consciously perceived and when it is not, under identical stimulus conditions. Unconscious processing of the prime was measured as the performance difference between the congruent and incongruent conditions (i.e., a response priming effect) on trials in which participants report no visibility.

If awareness of the stimulus is not essential for grouping to occur, then response priming is expected to be observed regardless of the stimulus visibility. If, on the other hand, awareness is essential for grouping to be accomplished, then response priming should be observed when the prime is visible, but not when the prime is reported invisible. Dependency of the results on the method used to render the prime invisible (CFS vs. visual masking), can tell us both about the level of suppression induced by each method, and about the level of processing of each of these groupings.

2. Experiment 1: Grouping by luminance similarity during CFS

In this experiment we examined whether grouping elements by luminance similarity into columns/rows can take place in the absence of awareness, by testing for response priming effects when the prime is rendered invisible by CFS. As noted earlier, grouping by luminance similarity in absence of conscious perception was examined by Montoro et al. (2014), using sandwich masking to render the stimulus invisible. In the present study we not only employed a different method to induce stimulus invisibility, but we also used a trial-by-trial subjective measure of prime visibility, unlike Montoro et al. (2014) who used a forced-choice prime discrimination task in a separate block and a forced-choice prime detection task on a separate sample of participants to obtain objective indices of prime visibility.