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Global shape integration and illusory form perception in the absence of awareness

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ABSTRACT

Previous research on perceptual organization operations still provides contradictory evidence on whether the integration of sparse local elements into coherently unified shapes and the construction of the illusory form are accomplished without the need of awareness. In the present study, three experiments were conducted in which participants were presented with masked (Experiment 1, SOA = 27 ms; Experiment 2; SOA = 53 ms) and unmasked (Experiment 3) *primes* consisting of geometric shapes (a square or a diamond) that could be congruent or incongruent with subsequent *probe* stimuli (square vs. diamond). Furthermore, the primes were divided into: a *grouping condition* (where local elements may group together into global shapes), an *illusory condition* (where the arrangement of local elements produced illusory shapes) and a *hybrid condition* (where both operations were presented simultaneously). While no priming effects were found for the shortest SOA (27 ms), both *grouping* and *illusory primes* produced significant priming effects in the longer SOA (53 ms). On the other hand, results in Experiment 3 (unmasked) showed strong priming effects for the grouping of the inducers in both the *grouping* and the *hybrid conditions*, and also a significant but weaker priming effect for the *illusory condition*. Overall, our results support the possibility of the integration of local visual features into a global shape in the absence of awareness and, likewise, they suggest an early –subliminal– construction of the illusory shape, implying that feedback projections from higher to lower visual areas are not crucial in the construction of the illusory form.

1. Introduction

Perceptual organization operations (i.e. contour processing, grouping operations, figure-ground segmentation or modal/amodal completions) are responsible for the structuring of pieces of visual information into larger units of perceived objects and their interrelations (Palmer, 1999, pp. 255). This structuring, however, is a complex task better explained as a hierarchy of visual processes divided into different perceptual stages (Marr, 1982; Palmer, 2015), where different perceptual organization operations might be accomplished at different processing levels: some rapidly in early perceptual stages, others involving later processing in higher tier visual areas of the ventral stream (Behrmann & Kimchi, 2003).

Furthermore, studies investigating the perceptual organization process at the mid-level stage often confront one of the most fascinating phenomena in visual perception: the emergence of visual consciousness. Thus, while it is commonly assumed that low-level visual operations are mostly accomplished in the absence of awareness, studies involving mid-level visual processes (such as form perception) are often focused on determining the extent of the involvement of visual consciousness on its completion.

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Not surprisingly, previous studies on mid-level perceptual operations have tried to understand how and when unified global shape percepts arise from the integration of separate local elements, yet results still provide contradictory evidence on whether these operations are accomplished with or without the need of perceptual awareness. Montoro, Luna, and Ortells (2014) recently showed that arrays of local elements could be grouped together by Gestalt proximity and similarity principles in the absence of participants' awareness. The authors used a visual masking paradigm where subliminally presented primes defined by Gestalt principles of proximity and similarity primed the orientation of subsequent probe stimuli. Schwarzkopf and Rees (2011), on the other hand, studied the integration of separate local elements into global shapes in the absence of awareness by presenting participants with primes defined by position (including corner information) or orientation (with no corner information) cues, which generated square or diamond shapes. Interestingly, the probe could either be defined by the same (within-cue) or different (cross-cue) cues as the prime. Their results showed robust priming effects for both prime types in the visible condition, yet rendering the primes invisible (by counter-phase contrast flickering) produced mixed results: position-defined primes yielded only within-cue priming (suggesting that the local features produced the effect), whereas orientation-defined primes showed only cross-cue priming (which would suggest that the integration of the local elements into a global shape was taking place). The authors, however, introduced a further control condition for position-defined primes, varying the probe size with the aim to avoid intrinsic lateral connections in a retinotopic level, which might be responsible for the priming effect found with the orientation-defined primes. In this case, only a strong within-cue priming effect was found in the visible condition and no priming effect at all in the invisible condition. Even though these results seem contradictory, Schwarzkopf and Rees concluded that, in the absence of awareness, separate visual stimuli constructed of a small number of local elements did not activate abstract representations of geometric shapes. Interestingly, a previous study using metacontrast masking (Breitmeyer, Ogmen, Ramon, & Chen, 2005) showed that square or diamond primes defined only by their corners (the sides of the shapes were removed) would subliminally prime subsequent targets (whole square or diamonds) yet, crucially, square or diamond primes defined only by the sides of the geometric shapes (with no corner information) would produce no priming effects. In sum, the question on whether the integration of local elements into global shapes occurs in the absence of awareness still remains unanswered.

Likewise, the construction of the illusory form under subliminal presentations has originated some controversy among researchers. Illusory form perception -which is often studied using Kanizsa-like stimuli- is a striking example of perceptual organization mechanisms and comprises both modal (i.e. the perception of borders and surfaces across homogeneous luminance regions, usually referred as *illusory contours*) and amodal (i.e. the ability of the visual system to determine which surfaces are hidden behind others, perceiving objects as single continuous entities) completion operations (Spillmann & Dresp, 1995). While behavioral studies on modal and amodal completions show that, when presented in isolation, they can be completed under the threshold of awareness (Emmanouil & Ro, 2014; Seydell-Greenwald & Schmidt, 2012), a great debate exists, however, on whether the illusory form construction is accomplished early within the visual system hierarchies or, on the contrary, is dependent on higher areas in the visual ventral stream and/or the need of conscious scrutiny for its perception.

Traditionally, Kanizsa configurations have been regarded as examples of perceptual inference, a process that is linked to conscious processing (Vandenbroucke, Fahrenfort, Sligte, & Lamme, 2014). Consistent with that view, early behavioral research using Kanizsa-like stimuli suggested a late processing of the illusory form (Reynolds, 1981; Ringach & Shapley, 1996), yet more recent studies have introduced a variety of subliminal techniques to provide contradictory evidence on the rapid-late processing debate of the illusory form. Using breaking-continuous flash suppression (b-CFS), Wang, Weng, and He (2012) showed that the Kanizsa triangle was significantly faster breaking the suppression time compared to the control stimuli, suggesting that a grouping process leading to the perception of the illusory form was occurring unconsciously. In addition, Lau and Cheung (2012) found that the perception of illusory squares survived the crowding of the inducers, while Poscoliero, Marzi, and Girelli (2013), using meta-contrast visual masking, provided evidence of the illusory salient region – the approximate region without detailed contours that creates a first impression of global surface- being processed unconsciously. In contrast, Harris, Schwarzkopf, Song, Bahrami, and Rees (2011) used continuous flash suppression (CFS) to find that illusory shapes were not perceived in the absence of the awareness of the local inducers. Interestingly, Moors, Wagemans, van Ee, and de-Wit (2016) replicated Wang et al.'s (2012) study including further control conditions, finding that the advantage on breaking interocular suppression was not specific to the Kanizsa configuration, which suggests that the Kanizsa surface percept played no role in breakthrough times. It is noteworthy that the use of different techniques to render the stimuli unconscious often influences the results, as some of them allow very little perceptual processing while others use less restrictive masking of the stimuli (Breitmeyer, 2015; Peremen & Lamy, 2014).

In addition to the behavioral results, physiological and neuroimaging data have provided further contradictory evidence to the debate. While neuronal activations to modal completions (illusory contours) are usually found early within lower-tier cortices (~70 ms, V2 and V1) (Grosof, Shapley, & Hawken, 1993; Ohtani et al., 2002; Ramsden, Hung, & Roe, 2001; von der Heydt, Peterhans, & Baumgartner, 1984), neuroimaging and physiological data on Kanizsa-like illusory form perception produces a complicated picture regarding the *when* – but also the *where* – debate in the illusory form perception (Seghier & Vuilleumier, 2006). Some studies show evidence of early processing of the illusory form within lower visual cortices (Brodeur et al., 2008; Ffytche & Zeki, 1996; Larsson et al., 1999; Lee & Nguyen, 2001), but others argue for a later initial processing of the illusory form within higher visual lateral occipital complex (LOC) (Brighina et al., 2003; Halgren, Mendola, Chonag, & Dale, 2003; Knebel & Murray, 2012; Mendola, Dale, Fischl, Liu, & Tootell, 1999; Murray et al., 2002; Shpaner, Murray, & Foxe, 2009). Moreover, some authors suggest a first rough processing of the illusory form (by grouping of the inducers, possibly) in LOC, from which this form segregation may be afterwards

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