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The perceptual expansion of a filled area depends on textural characteristics

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ABSTRACT

According to the Oppel–Kundt illusion, a filled space appears larger than an empty one. In the present research we studied how textural characteristics affect the perceived size of two-dimensional patterns. We investigated the perceived extension of square textures by manipulating spatial frequency and filling microelements' numerosity. Subjects compared the test stimuli with a uniform gray square varied in size and performed the task both with the adjustment and the constant stimuli methods. An illusory increment of area extension was generally found with textured stimuli. The illusory effect increased with spatial frequency and decreased with the microelements' number, indicating an independent processing of these two basic properties. Moreover, the smaller effect found when spatial frequency extraction became harder, confirmed that the illusion involves spatial frequency processing. Finally, the reduced overestimation of areas observed with a weaker subparts' articulation confirmed the relevance of clear distinguishable micropatterns at the basis of the phenomenon. Those results demonstrate the influence of textural statistical properties on perceiving the size of a visual object.

1. Introduction

Visual images are identified by means of textural labels. A texture can be defined in terms of structural and statistical characteristics that determine surface appearance (Landy & Graham, 2004). Statistical properties of a texture region are effortlessly processed by the visual system (Baker & Mareschal, 2001; Julesz, 1962, 1965; Julesz, Gilbert, & Victor, 1978; Parkes, Lund, Angelucci, Solomon, & Morgan, 2001; Purpura, Victor, & Katz, 1994; Victor, Chubb, & Conte, 2005) and affect segmentation (Bergen & Adelson, 1988; Caelli, 1985; Giora & Casco, 2007; Grossberg & Mingolla, 1985; Malik & Perona, 1990; Wilson, 1993; Wolfson & Landy, 1998). Properties like surface *granularity* or *grain* provide information about the material characteristics of a visual object (Adelson & Bergen, 1991; Zhang & Tan, 2002) and an observer could take them into account to gauge its size and distance (Gibson, 1950).

Phenomenological observations have pointed out that the subparts' articulation of a space affects its perceived size (for a review: Vicario, 2008). Oppel (1855) reported that the division in subparts of a stripe influenced the perception of its extent. Kundt (1863) investigated how the length of a divided segment was overestimated. Hering (1861), Delboeuf (1865), and Ebbinghaus (1908) called "effect of partition" a similar enlargement occurring in a segment divided by a number of lines. Although Lotze (1852) already observed in a seminal work that filled intervals are seen wider than empty ones, the phenomenon of perceiving a filled space as larger is currently referred to as the "Oppel–Kundt illusion" (Westheimer, 2008). That phenomenon is affected by the filling lines' number. The Oppel–Kundt illusion has been recently investigated in three-dimensional space (Deręgowski & McGeorge, 2006) and an analogous illusory effect has been found also in dynamic touch for a haptic filled space (Sanders & Kappers, 2009).

In the Oppel–Kundt illusion, distance appears to expand only orthogonal to lines orientation. Similarly, Helmholtz (1867) reported that lines, entirely filling a square, perceptually enlarge its width, through the dimension perpendicular to lines orientation. Therefore, both the Oppel–Kundt illusion and Helmholtz' squares effects are mainly the result of the perceptual distortion of an area throughout one dimension, i.e. the same enlargement that makes Helmholtz' squares appear as rectangles.

Although a perceived area enlarges when divided in subparts, that perceived expansion does not depend proportionally on the elements' number. In the Oppel–Kundt illusion an extent perceptually enlarged as function of the filling lines only up to a critical number; after that, the perceived size gradually decreased (Coren & Girgus, 1978). Similarly, Botti (1906) showed that filling a rectangular area with lines densely arranged reduces the effect of illusory expansion. More recently, Verrillo and Graeff (1970) have shown that a surface containing a random distribution of small circles, squares and triangles looked somewhat larger than a uniform one. These authors claimed that only the mixture of large and small compositional elements and the increment of surface complexity increased its estimated area. Testing square stimuli filled

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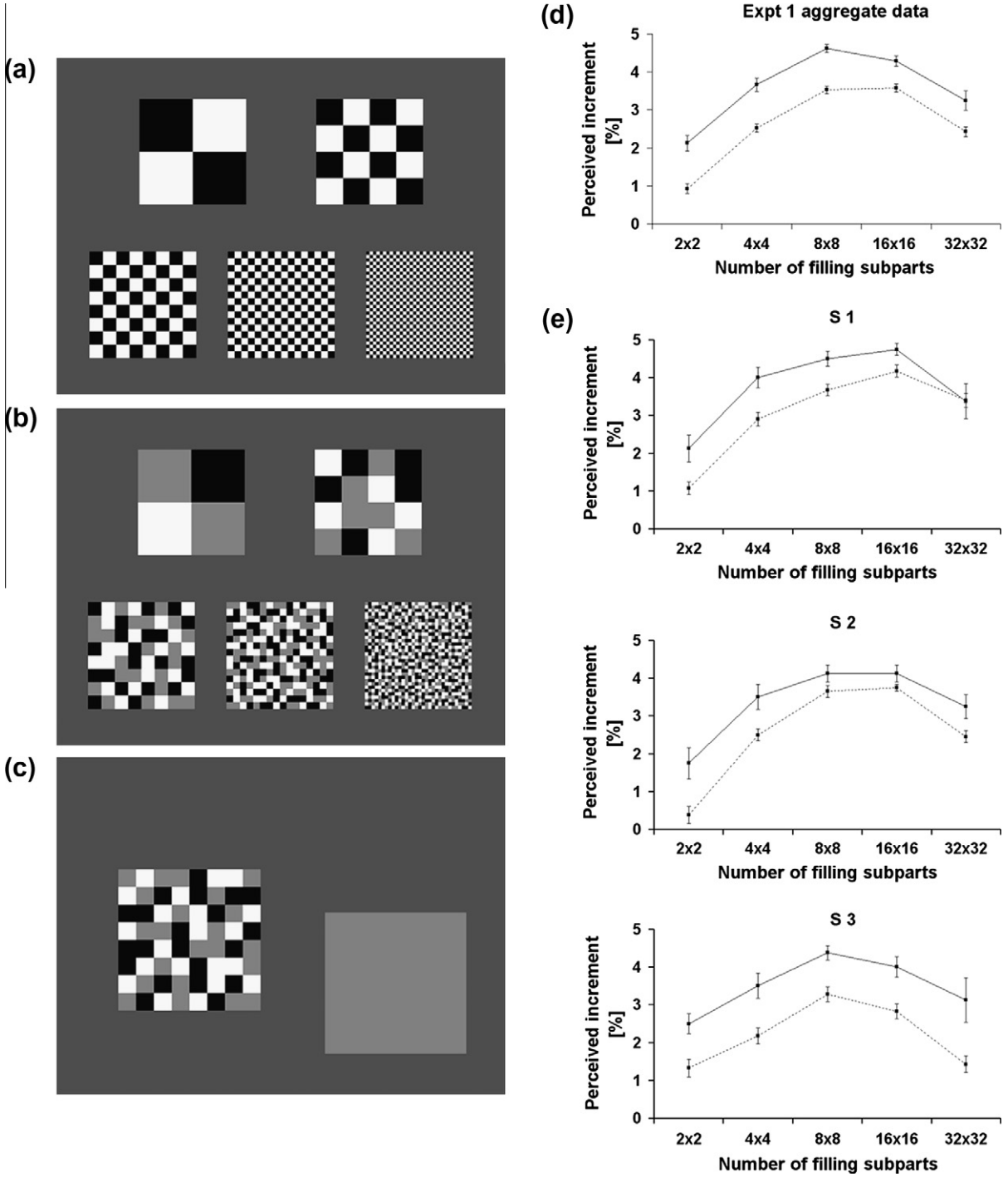

Fig. 1. In panels a and b representative stimuli used in Expt. 1 are depicted: textures with constant size, composed by 2×2, 4×4, 8×8, 16×16, 32×32 subparts, with fundamental spatial frequency respectively of 0.1, 0.2, 0.4, 0.8, 1.6 cycles/deg, articulated either as a 'checkboard' (panel a) or in 'random' (panel b) arrangement. In panel c a trial from an experimental session is represented. For each session, a test stimulus (filled square) had to be compared with a control stimulus (uniform gray square). Note that stimuli where shown on a blue isoluminant background, in figure conventionally represented as gray. Aggregate (panel d) and individual (panel e) data of Expt. 1 are shown. The percentage of perceived increment of area is plotted as a function of textural subparts. Solid lines represent curves for checkboards, while dashed for random patterns. Error bars indicate standard-errors.

by dots, Bazzeo and Zanuttini (1978) reported that areas perceptually expanded when dots' diameter increase and their number diminishes. Considering the phenomenon of filled surfaces dilatation as related to textural appearance, these authors have argued that surfaces expansion was larger with *coarser* textures.

Because textural appearance can be considered in terms of space subparts' articulation, we study how textural properties are involved into perceptual areas estimation. In particular, we will consider the filled area phenomenon as related to a surface grain and therefore to textural statistics. To quantitatively investigate how filling an area affects its perceived size, we manipulate basic textural properties as *spatial frequency*, *microelements' number* and their *arrangement*, either in checkboard or random order. Differently from the investigations previously considered, those variables will be independently taken into account.