Phenomenal Effects of Microelements' Numerosity on Texture Appearance

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Abstract

This paper describes peculiar qualitative effects occurring in texture appearance, resulting from the manipulation of the amount of textural microelements. Keeping fixed the textural local properties, the increase of microelements' number produces a texture aspect more homogeneous and denser. Conversely, patterns filled by a small number of elements exhibit a more salient subparts' articulation, and the textural microstructures increase in perceived local contrast, size and detailedness. Those effects are discussed in terms of economic principles governing the visual processing.

Keywords: texture appearance; filled-area illusion; microelements' numerosity; density; contrast; detailedness.

Introduction

A texture is a region of the visual field composed by basic microstructures or features (Julesz, 1981), whose combination determines the peculiar aspect of a visual surface (Landy & Graham, 2004). Texture appearance assumes a key role in the ecology of vision, because it provides information about the material properties of an object and it leads to gauge its size and its distance from an observer (Gibson, 1950).

Textural characteristics affect the perceived size of visual objects also when depth indices, like texture gradient or figure-ground stratification, are absent. Giora & Gori (2010) investigated the perceptual overestimation of textures articulated in subparts, as those depicted in figure 1. The illusory area enlargement increased with spatial-frequency and decreased with the filling microelements' numerosity, independently of the stimulus size. The effect diminished when the subparts' articulation weakened, as applying a low-pass filter to the images. While the spatial-frequency effect was explainable in terms of visual spatial channels (Campbell & Robson, 1968), the inhibitory role played by numerosity was supposed to be based on the fact that a greater microelements' number decreased the luminance variance and consequently textures appeared more *homogeneous* (Giora & Gori, 2010; Giora, 2011).

The filled-area effect can be interestingly compared with a classical phenomenon of size estimation reported by Botti (1906). Botti showed that rectangular areas filled by lines perceptually enlarged, until a critical point, with the increase of the lines' numerosity. The illusory effect in fact diminished when the lines became to be densely arranged. Qualitative changes in texture appearance help to understand this effect. Few lines filling a rectangle are perceived as discrete elements, whereas a large amount of lines – although effortlessly distinguishable in terms of optical resolution – perceptually results in a homogeneous texture and then the effect of partition disappeared.

Based on these seminal observations, I aim at investigating the effects of microelements' numerosity on texture appearance.

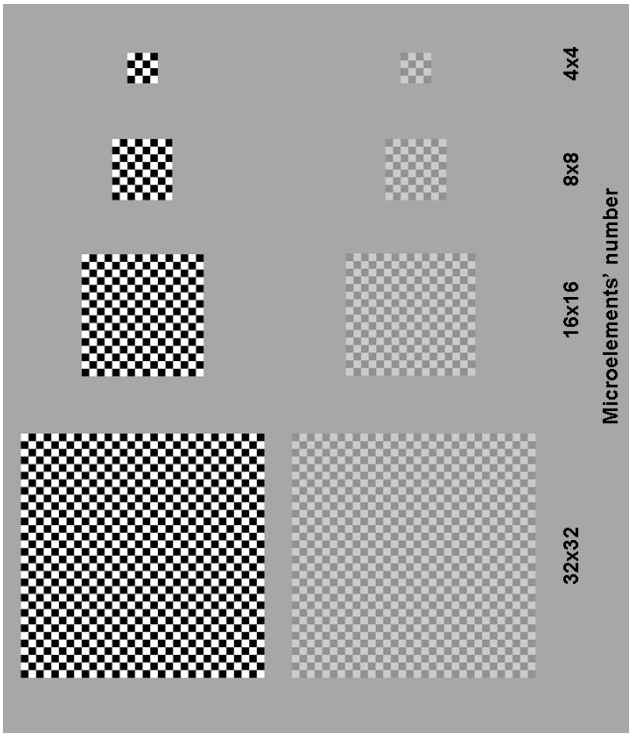

Figure 1: stimuli firstly used by Giora & Gori (2010). Numerous textures appear more homogeneous and denser, whereas textures composed by few elements increase in perceived local contrast, size and detailedness. The effect is shown for two sets of stimuli with different luminance contrasts. An optimal appreciation of the effect requires the textures' side subtending respectively 9.6, 4.8, 2.4 and 1.2 deg of visual angle.

Investigation of the phenomenon

In the Botti's figures the spatial arrangement of lines and their numerosity covaried. In our patterns the local textural properties are instead kept constant and solely the microelements' number is manipulated. Surprisingly, a quantitative variation of texture numerosity produces the *emergence* of qualitative changes in texture appearance.

In the stimuli represented in figure 1 the microelements' spatial-frequency remains constant at 3.2 cycles/deg – i.e.

the value that produced the higher filled-area perceptual increment according to Giora & Gori (2010) – while the numerosity varies with a ratio of 1:4. Keeping fixed the local properties of microelements, the stimulus area increases in function of the microelements' amount. As already pointed out, the manipulation of areas did not affect the filled-area illusory enlargement (Giora & Gori, 2010).

In a new study we have asked twenty subjects to focus on the phenomenal appearance of textures. Observers report that textures composed by a large amount of elements appear more homogeneous and characterized by a weaker subparts' articulation. Interestingly, this effect is more appreciable in the inner texture region than at the texture borders. Differently, less numerous textures show higher subparts' saliency. In this case, microelements exhibit higher local contrast, they look larger and textures appear more detailed and less densely arranged.

Noteworthy, textural numerosity affects the perception of both *holistic* texture appearance (degree of homogeneity) and *local* subparts' characteristics (contrast, detailedness, density). Because in our stimuli the local properties remain constant whereas the whole amount of microstructures varies, a global stimulus processing seems to precede the analysis of textures at a local level. In agreement with the Navon effect (Navon, 1977), in perceiving textures the visual system would see the forest before the trees.

Discussion

A phenomenon that exhibits interesting analogies with the effects on texture appearance above described is the so-called "effect of rarefaction" (Vicario, 1971; 1972). Vicario investigated the appearance of square figures varying in size but constantly filled by equally spaced diagonal lines. In comparison with larger figures, the small squares appeared more spaced, filled by thicker lines and characterized by a higher contrast between lines and background. Masin (1980) further investigated the Vicario's phenomenon and found that it occurred to the greatest extent adopting a short interlinear spacing and square sides shorter than 6-9 deg.

Vicario claimed that the rarefaction phenomenon was essentially based on the stimulus area, disregarding the concurrent role of elements' numerosity. Giora & Gori (2010) found instead that the illusory expansion of filled-areas occurred independently of stimulus size. However, in our study the effect of size overestimation experienced in filled textures was clearly linked to the changes in texture appearance, and both the effects crucially depended on microelements' numerosity. In particular, the increase of microelements' numerosity reduced the illusory size overestimation, while textures appeared more homogeneous and denser. On the contrary, when figures were filled by a small number of subparts, the illusory enlargement became higher, as well as the textural microstructures appeared clearer, more spaced and less dense.

It is therefore reasonable to think that, in spite of the Vicario's conjecture, texture numerosity could play a crucial role also in the rarefaction's phenomenon. Textures depicted in figure 1 allow to test the role of the microelements' numerosity, which cannot be easily controlled when filling square areas by diagonal lines, like in the Vicario's study.

More recent researches can further shed some light on the perceptual rules involved in texture appearance. Other phenomena that seem related to the illusory effects here described are the lower perceived contrast exhibited by a textured spot when it is superimposed on a similar, high-contrast, textured background (Chubb, Sperling, & Solomon, 1989), and the increased brightness- and spatial-contrast experienced when a textured surface is instead viewed through a tube (Spillmann, Hardy, Delahunt, Pinna, & Werner, 2010).

Moreover, the result of lower perceptual density occurring in small textures filled by few high spatial-frequency microelements agrees with the correlation between apparent density and numerosity found by Dakin, Tibber, Greenwood, Kingdom, & Morgan (2011). Interestingly, Heinrich & Bach (2010) demonstrated that image detailedness increases scaling down the image size, but this effect cannot be disentangled from that of varying spatial-frequency and texture density.

All those qualitative effects occurring in texture appearance when microelements' articulation quantitatively changes could be understandable in terms of perceptual processes' economy (Attneave, 1954). One can speculate that subparts' articulation is emphasized in small patterns filled by few microelements, where local properties are strongly informative. On the contrary, when the analysis of highly repeated modularity results significantly expansive, the local characteristics are perceptually weakened and the microstructures appear as interconnected elements belonging to unified textures.

From an evolutionary perspective it is reasonable that the visual system learned to strengthen the detailedness of small objects – like fruits or insects, which can hold particular ecological relevance – and to inhibit the redundant information occurring in numerous patterns, to make more easily available the representation of the overall image properties.

Acknowledgments

I am indebted with dr. Simone Gori for a critical reading of the manuscript. I would like also to thank prof. Baingio Pinna and prof. Giovanni B. Vicario for their insightful suggestions and comments.

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