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Luminance gradients, perceived illumination, and lightness perception

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Recently, Agostini & Galmonte (1997) showed a new effect of luminance gradient on lightness perception. This short note reports a number of original qualitative observations risen from the basic display. These variations suggest the interpretation of the effect in terms of apparent illumination to be a plausible one.

It is well known that blurred edges modify color appearance. For example, Kanizsa (1954) showed that the color and the texture of a gray disk with a fuzzy edge are quite different from those of an identical disk having a sharp edge (see Figure 1).

By manipulating luminance gradients, Kennedy (1976) and, more recently, Zavagno (1996), gave further evidences of the role of blurred edges on color appearance.

Agostini & Galmonte (1997) observed that, when two identical middle gray squares are placed at the center (white or black respectively) of two crosses, the first cross having arms filled by a linear achromatic gradient from black (outer part) to white (inner part), whereas the second cross is the reverse of the first one, the gray target surrounded by white appears much darker than the same target surrounded by black (see Figure 2). They found this phenomenon to be three times larger than that observed in the Hering's (1874/1964) classical lightness contrast configuration (for a review of the literature about the magnitude of the contrast effect see Agostini & Bruno, 1996).

In this work we report a set of qualitative observations varying a number of factors thought to be responsible for the effect. Figure 3 shows that the effect remains quite robust even when the amount of immediate black and white areas is reduced and the gradient contains only 16 discrete steps. The configurations depicted in Figure 4 and 5 examine more closely the role of the immediate targets' background and the presence of the opposite direction gradients.

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Figure 4 depicts a variant of the display shown in Figure 3, where the gray targets have been enlarged to fill the centers of the crosses. This was done to eliminate the influence of the local background. Therefore, when the only factor affecting the perceived color of the target is the direction of the gradient, the effect seems to be still larger than that observed in the classical simultaneous lightness contrast display.

Randomizing the sequence of the luminances used to build the gradient of the previous displays and therefore

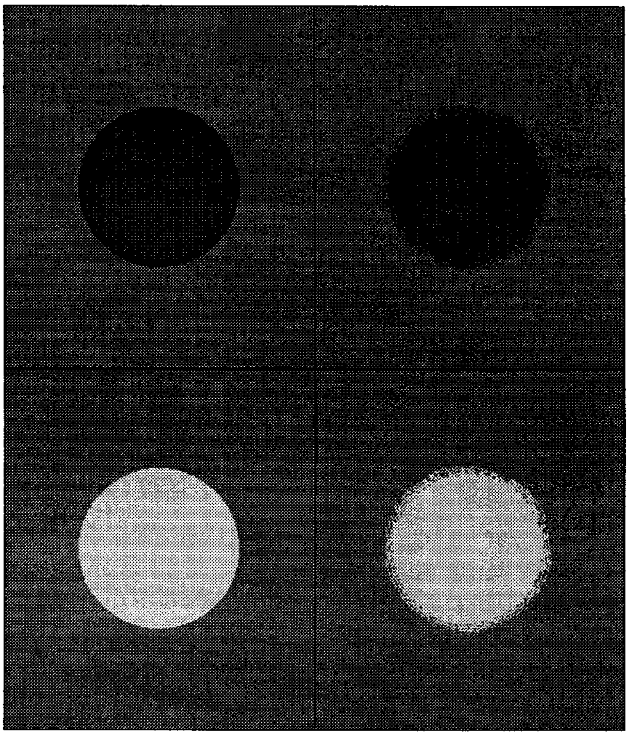

Figure 1. The color and the texture of the gray disk with a fuzzy edge appear different from the other.

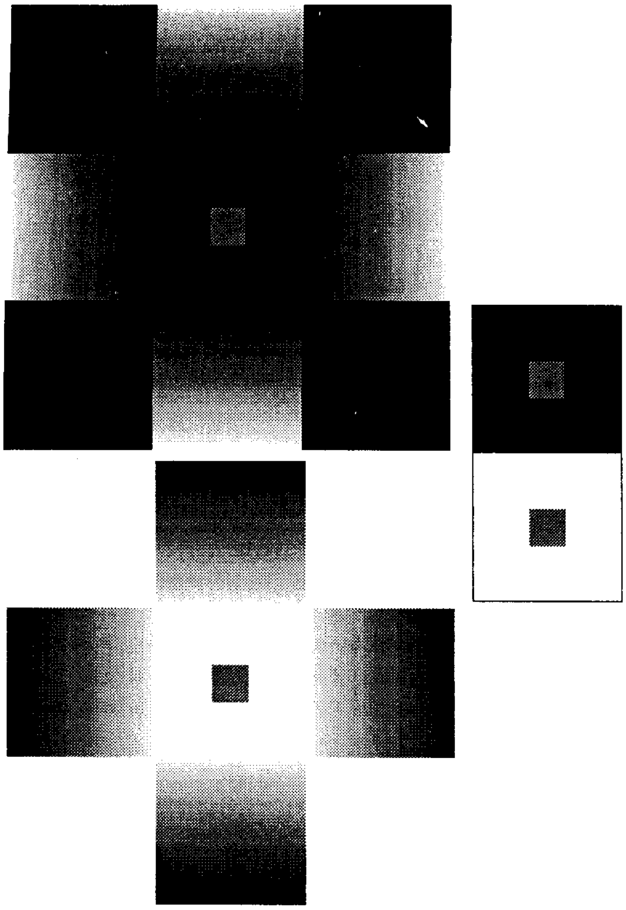

Figure 2. The effect of gradient on lightness. The gray square on the white center of the right cross appears much darker than that on the black center on the left cross, even though their reflectances are the same. When simultaneously compared with the classic lightness contrast effect shown below, the size of the effect is larger.

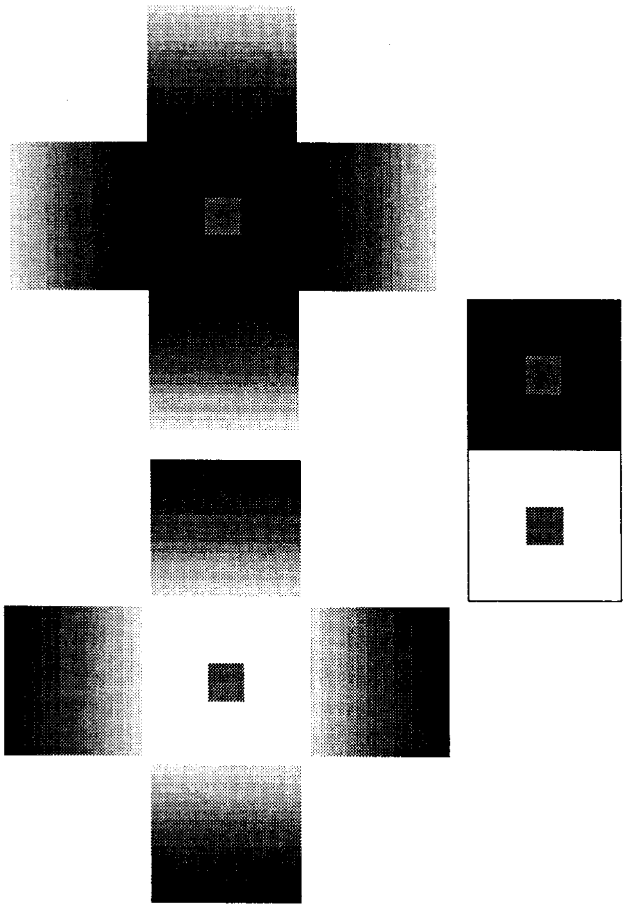

Figure 3. Reducing the black area and introducing a stepwise gradient does not affect the size of the effect.

keeping their average luminance constant, the effect seems to disappear[1] (see Figure 5). It should be pointed out that, in this case, the colors of the areas immediately surrounding the targets are black for one cross and white for the other. In the previous display the colors of these areas are dark gray and light gray. Nevertheless, in Figure 4 the effect is still present.

In Figure 6 a square has been fractalized and filled with a circular linear gradient. The shape of the configuration and that of the gradient do not affect the size of the illusion.

The local structure of Figure 2 and 3 is analogous to that of the classical simultaneous lightness contrast display, that is, two identical gray targets are placed at the center of a white and a black area. Therefore, the difference in the size of the effect between the two types of displays might be due to the gradient, as suggested by the observation of the differences between Figure 4 and 5. It is possible to account for the effect by assuming that the gradient is perceived as an illumination gradient rather than as a reflectance gradient. For instance, the display on the left side of Figure 2 could be seen as a brightly illuminated homogeneous reflectance cross, shadowing off from its center to its periphery, whereas the display on the right side could be perceived as a homogeneous reflectance cross illuminated in its periphery and gradually diminishing towards its center, which is in deep shadow. This means that the main difference between these two configurations, that is, the difference in the direction of the gradients, could be interpreted as a difference in apparent illumination. This interpretation is supported by the conditions determining the

[1] It must be noticed that some observers reported an inversion of the effect. This could be a new assimilation phenomenon.

perception of a shadow according to Kardos (1934), and by the subsequent demonstration of an artificial penumbra showed by Mac Leod (1947). Kardos argued that a shadow is seen when at the borders of a surface appears, even in a small amount, a penumbra zone, and the "jump" in quantity of light (received and/or reflected) is gradual. Mac Leod produced an artificial penumbra by spinning a Maxwell disk having an internal, circular, gray part, an external, annular, white part, and an intermediate annulus with lightness gradually changing from the color of the internal part to the color of the external part. The internal gray shows the phenomenal appearance of penumbra.

Musatti (1953) argued that the light reflected from a surface is split in two components: color of the object and

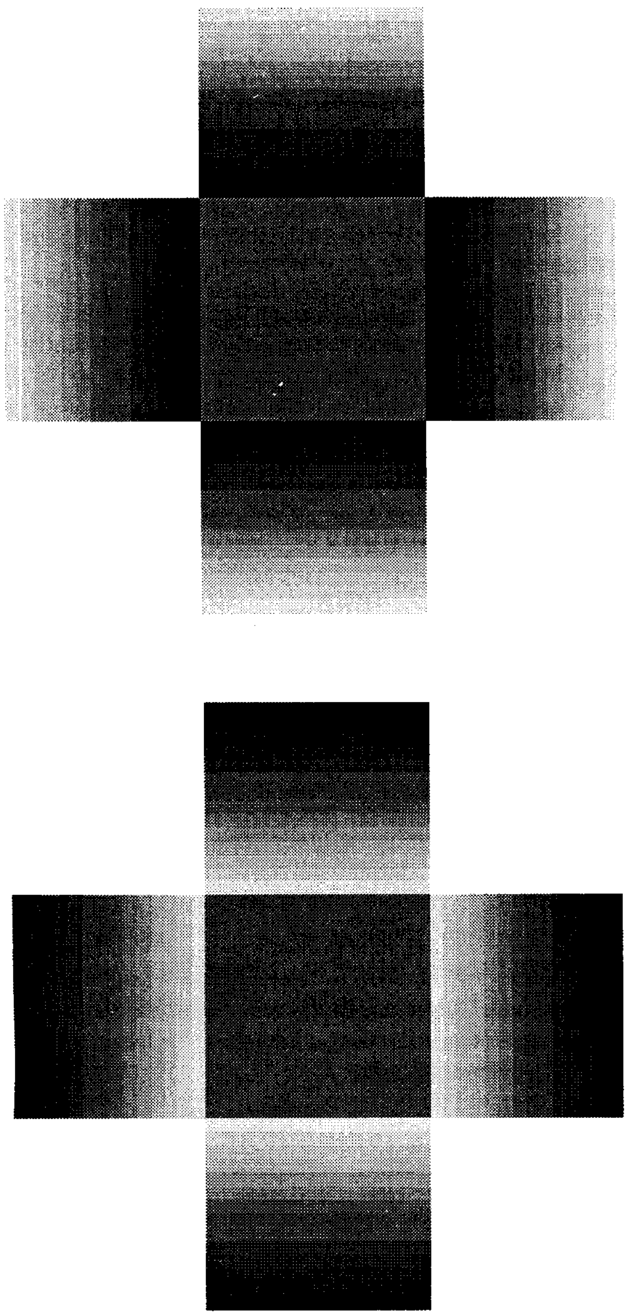

Figure 4. The direction of the gradient by itself is sufficient to produce a contrast effect.

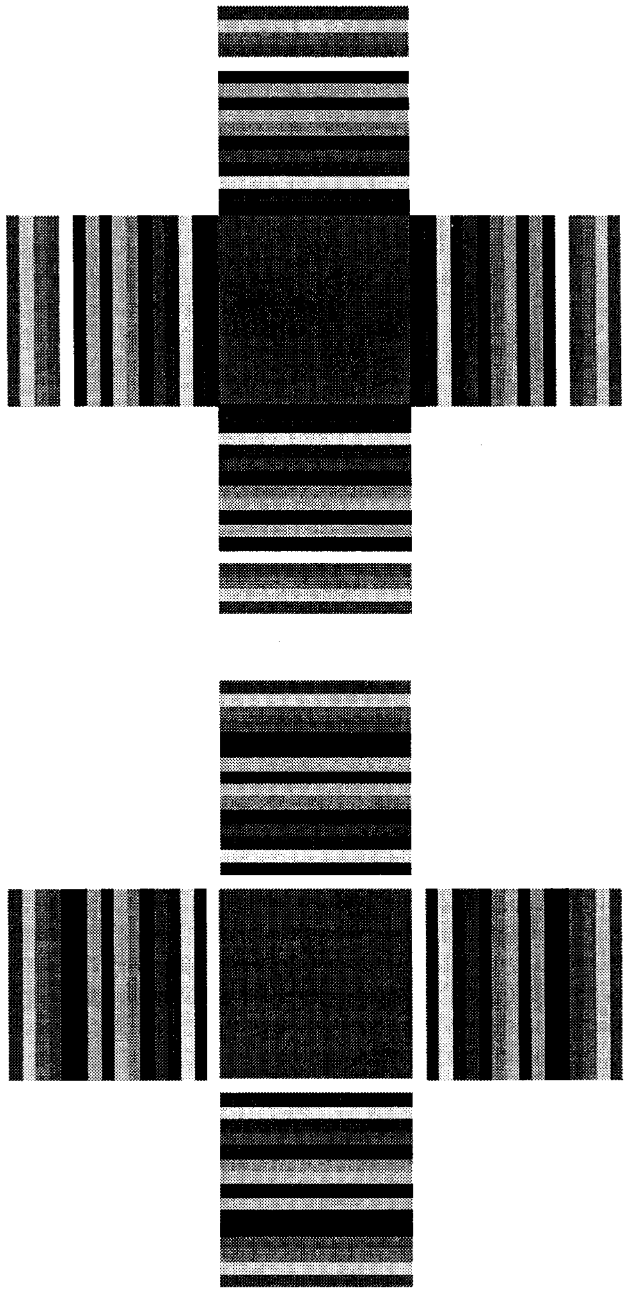

Figure 5. By arranging the stripes in a random order the effect is faint.

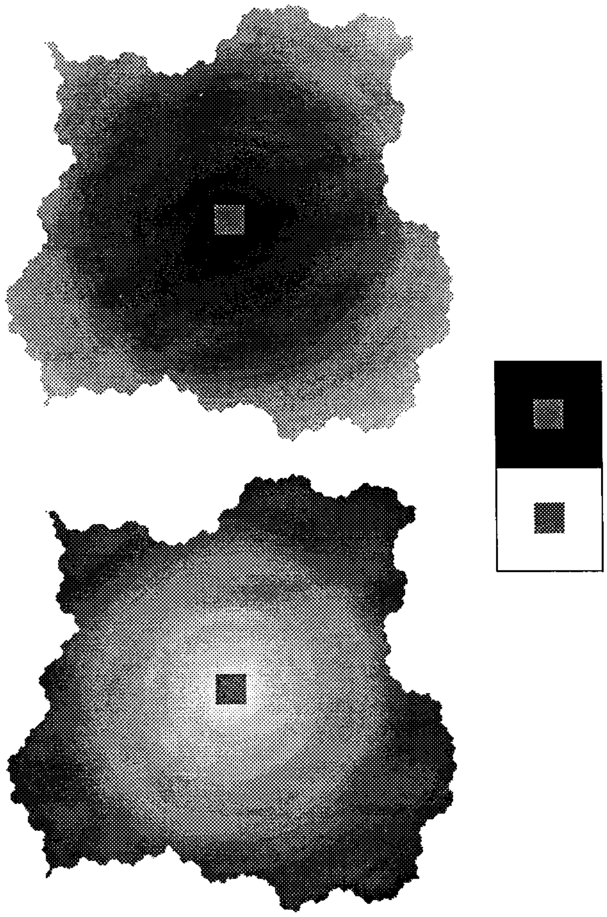

Figure 6. The effect of the gradient on the lightness of the target is independent from the shape of the display and from that of the gradient.

environmental illumination. Since the environmental illumination by itself is not visible, the sensations of luminosity are produced on the basis, and therefore at the expenses, of the lights reflected by the surfaces. In general, a dark surface under high illumination appears even darker since a big amount of its reflected light contributes to the perception of the environmental illumination and therefore the surface color is the result of the little residual light. A light surface under low illumination appears even lighter since a small amount of its reflected light contributes to the environmental illumination and its surface color is determined by the almost total residual light.

One possible way to account for the lightness effect shown above is to assume that what Musatti states for the real changes of the levels of illumination is true also for the apparent changes of the levels of illumination.

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