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When figure-ground segmentation modulates brightness: The case of phantom illumination

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ABSTRACT

In the phantom illumination illusion, luminance ramps ranging from black to white induce a brightness enhancement on an otherwise homogeneous dark background. The strength of the illusion was tested with regard to the extension of the brightness inducing perimeter, surrounding the target area by manipulating the number of inducers (exp. 1) and the size of the inducers (exp. 2). Participants' task was to rate the difference in brightness between the target area and the background. Results show that the illusion occurs only when the target area is not completely segregated from the background by luminance ramps; vice versa, when the target area is delimited by a continuous gradient, it appears darker than the background. These findings suggest a major role of figure-ground organization in the appearance of the illusion. This hypothesis was tested in a rating task experiment with three types of target area shapes circumscribed by four types of edges: luminance contours, illusory contours, no contours, and ambiguous contours. Illusory contours, just as luminance contours, hinder the illusion and produce a darkening of the target area. A control experiment measured the brightness of the previous stimuli without luminance ramps: all configurations resulted in a darkening of the target area. Results from all experiments suggest that figure-ground segmentation plays a major role in the determination of both illumination and lightness in stimuli with luminance gradients.

0. Introduction

The phantom illumination (PI) illusion (Zavagno, 2005) consists in a brightness enhancement perceived on a photometrically homogeneous dark background (Fig. 1). The brightness enhancement is induced on a certain area of the background by quasi-linear luminance ramps ranging from black to white. Some naïve observers report that the central area appears to be illuminated by a spotlight, while others report that the target area is more illuminated; hence the name "phantom illumination". Observers never mention the darkening of the rest of the background, although this would also be a plausible effect, as shown in a previous study (Zavagno, 1999).

A study conducted with centre-surround displays evidenced that the illusion is highly dependent on the interaction between the luminance of the background and the luminance range of the ramps (Zavagno, 2005). In particular, it emerged that the illusion is clearly perceived with full-range luminance ramps, ranging from black (outwards) to white (inwards) on a dark background (Fig. 1). Despite its apparent relationship with traditional assimilation effects (Bezold, 1876; Burnham, 1953; Helson & Rohles, 1959; Musatti, 1953; Newhall, 1942), the previous study also concluded that the illusion relies on different photo-geometrical constraints. In particular, it was observed that the illusion requires a certain spatial organization of the inducing elements: the brightness ends of the luminance ramps should all face a common point or direction.

Spatial organization as a crucial factor is common to many brightness illusions. In anomalous figures, for example, the Gestalt principle of good continuation and amodal completion determine perception of an opaque surface of different brightness with respect to a background of the same luminance: the illusory surface appears darker or brighter in contrast with the brightness of the inducers (Kanizsa, 1955, 1979). Neon colour spreading also affects an illusory surface, which shows transparency and whose colour is assimilated (or spreads) from the inducers (Van Tuijl, 1975; Varin, 1971). Spatial organization is also a requirement of Fuchs' colour assimilation effect (1923): the colour of a relatively small surface can change its appearance on the basis of how it is perceptually grouped with other surfaces. This particular phenomenon is so compelling that it has been used to study the strength of different grouping principles (Van Lier & Wagemans, 1997), and it has become evidence for supporting more general perceptual and cognitive theories based on the concept of assimilation (King, 2001;

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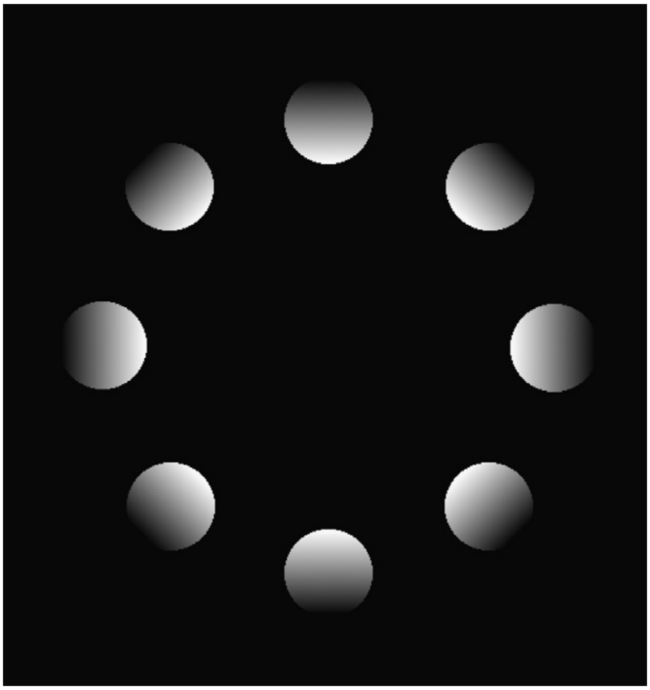

Fig. 1. The phantom illumination illusion: naïve observers report the circumscribed area as more illuminated and some mention also the presence of a spotlight (Zavagno, 2005).

Purdy, 1936). Along with spatial organization, the above listed phenomena share a common perceptual status: they concern surfaces and surface colours. The PI illusion, on the other hand, seems to affect the level of perceived illumination of a background and not surface colour *per se* (Zavagno, 2005).

The present study focuses on two aspects: the effect of the inducing perimeter (i.e. the extension of the contact perimeter between the bright ends of the luminance ramps and the target area) on the strength of the PI illusion and the effect of figure-ground segmentation. We employed full-range luminance ramps because these produce strong brightness effects (Zavagno, 2005; Zavagno & Caputo, 2001).

If we consider configurations as illustrated in Fig. 1, there are two ways to test how the inducing perimeter affects the appearance of the PI illusion: (1) by increasing or decreasing the number of inducers (Experiment 1, Fig. 2a); (2) by increasing or decreasing the size of the inducers (Experiment 2, Fig. 2b). The common feature in both situations is that the upper end of the continuum leads to ring configurations in which the target area (*T*) (i.e. the region circumscribed by the bright ends of the ramps) is completely surrounded by a bright luminance contour. Manipulation of either the number or the size of the inducers has different effects on the slope of the luminance ramps and on the shape of *T*. With reference to the slopes of the ramps, these are constant with increments in the number of inducers, but vary considerably as the size of the inducers increases or decreases. Using luminance ramps that approximate well enough to a linear function, the slopes of the ramps can be described by the ratio $\Delta l/\Delta s$, where Δl stands for luminance changes (the actual range of the ramps) and Δs stands for spatial changes (the size of the inducers): since Δl is a constant range in all our experiments, as the size of an inducer increases the slope of the ramp decreases. As regards the shape of the target area, as the number of inducers is increased, *T* is more and more clearly defined as circular; when the size of the inducers is increased, the shape of *T* changes, looking more and more like a six-point star. Finally, both manipulations result in different figure-ground segmentation outcomes for *T*: in ring configurations *T* should appear as a surface segregated from the background.

1. Experiment 1

In experiment 1, inducers were ramp-discs (discs with a full-range linear luminance ramp), the number of which was manipulated while their size was kept constant. There is no specific literature as to what should happen when we modulate the amount of contact perimeter between the bright ends of inducing gradients and the target area. However, given the photometric features in play and the effect they have on the target area of the standard PI configuration (Fig. 1), we can consider two competing hypotheses derived from the classic contrast and assimilation literature: (1) an increment in the amount of inducing perimeter may determine a brightness depression (the target area should look darker than the background), as a result of a lateral inhibition mechanism (Diamond, 1953; Heinemann, 1972); (2) an increment in

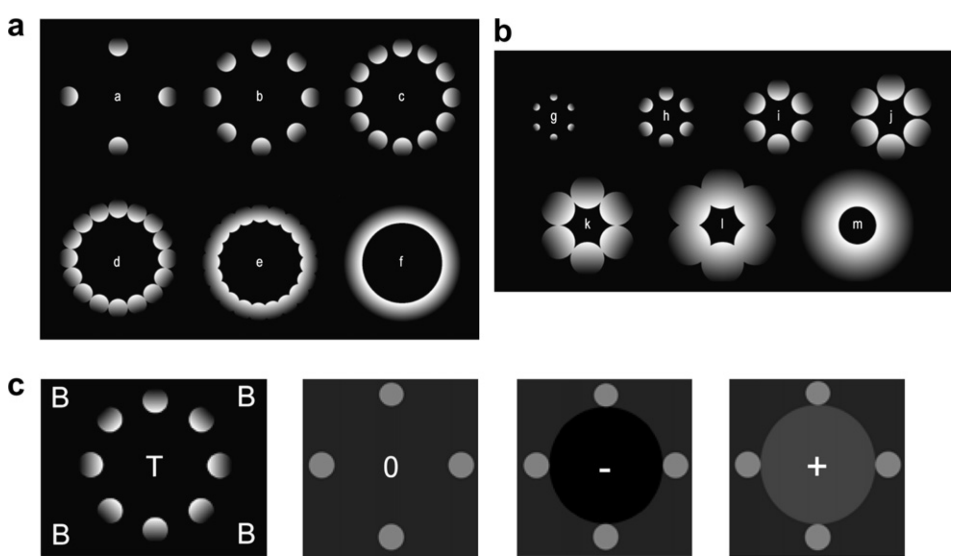

Fig. 2. (a) Stimuli for exp. 1; (b) stimuli for exp. 2. Actual stimuli presented no lettering; (c) left: graphic definitions of *T* (target area) and *B* (backround). Ratings were expressed for the brightness of *T* with respect to the brightness of *B*. From centre to right: examples used to illustrate the rating procedure to the participants.