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Variations on the Hermann grid: an extinction illusion

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Abstract. When the white disks in a scintillating grid are reduced in size, and outlined in black, they tend to disappear. One sees only a few of them at a time, in clusters which move erratically on the page. Where they are not seen, the grey alleys seem to be continuous, generating grey crossings that are not actually present. Some black sparkling can be seen at those crossings where no disk is seen. The illusion also works in reverse contrast.

The Hermann grid (Brewster 1844; Hermann 1870) is a robust illusion. It is classically presented as a two-dimensional array of black squares, separated by rectilinear alleys. It is thought to be caused by processes of local brightness computation in arrays of neurons (eg Baumgartner 1960).

As reviewed by Spillmann (1994) the illusion is tolerant to many geometrical variations. The alleys need not be orthogonal; the corners of the squares may be rounded. Various ratios of alley width to square size were explored by Vasarely in his artwork (eg Supernovae, reproduced in Thurston and Carraher 1966, page 35). The Hermann grid illusion is also resistant to many manipulations of local contrast. For instance, it works with opposite contrast (white squares, black alleys), and the usual filled squares may be replaced with thin outline squares, or even with graphic patterns without explicit edges (see, eg, left panels in figure 1). Furthermore, careful examination of the variants reveal, alongside with the well-known grey spot, other phenomena, mainly the presence of a faint dark canal running in the middle of the alleys (Dombrowsky 1942), sets of diagonal dark lines passing through the corners of the squares, seen after a 45° rotation (Prandtl 1927), or without rotation either in squeezed tilings (Motokawa 1950) or in the 'pincushion grid' variant (Schachar 1976). When an outlined square is posted at the junction of the black squares, this square seems uniformly filled with illusory darkness (Jung 1973). When the blocks are slightly offset, the illusory grey patches may take on an elongated shape (see figure 3c in Spillmann 1994, or bottom right panel in figure 1).

In Baumgartner's analysis the local brightness computation is carried out at an early processing stage, by neurons having circularly symmetric receptive fields with a Mexican hat profile, which would produce more lateral inhibition at the crossings than elsewhere (Baumgartner 1960). Several aspects of the Hermann grid phenomenology and several consequences of the model inspired a wealth of experiments, usually revolving around the following issues, in addition to the frustrating one of partitioning the responsibility for the effect among various stages of processing:

(i) *Retinal receptors.* To induce the illusory spots, which are most apparent parafoveally, "bar width must be matched to the mean size of receptive field centres at any given retinal eccentricity" (Spillmann 1994, page 691).

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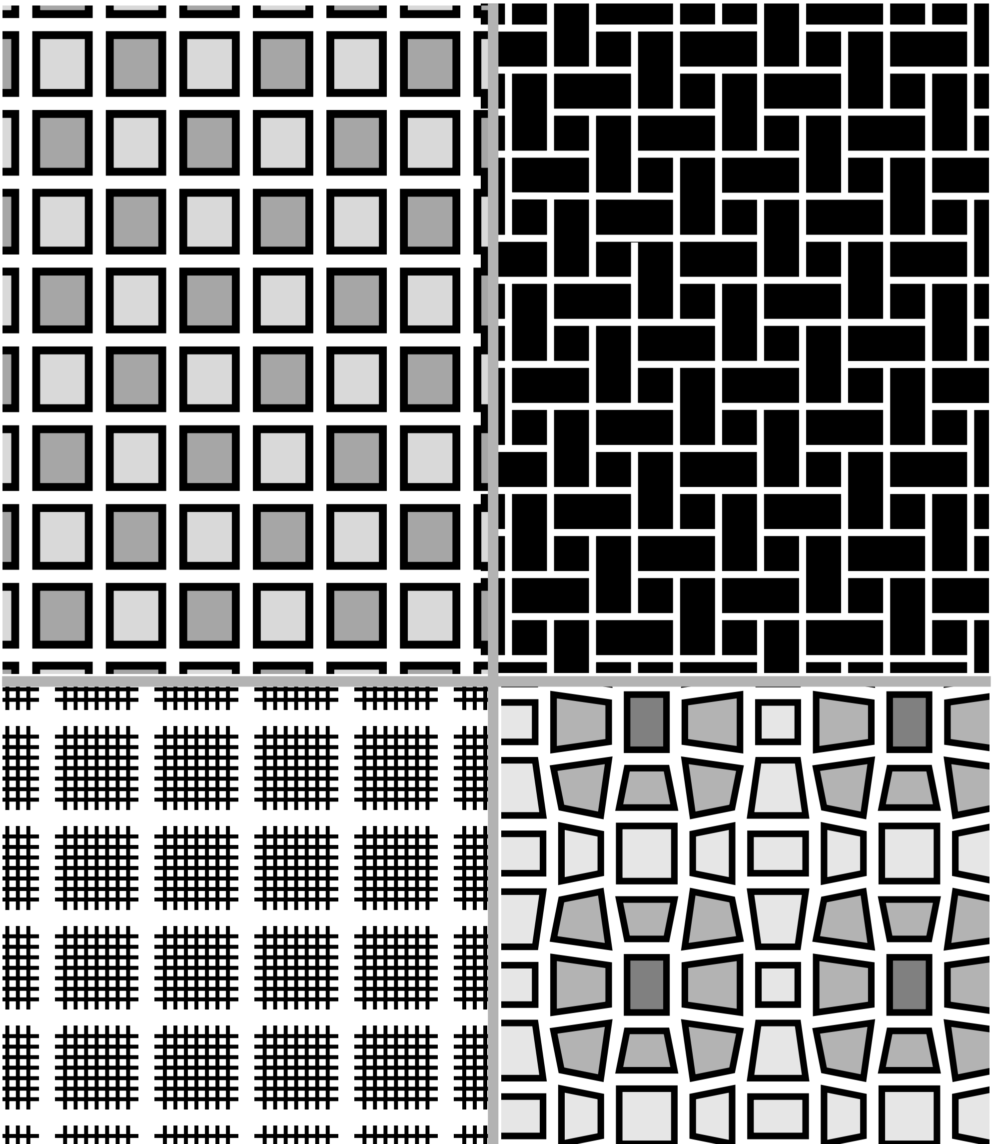

Figure 1. Usually, the Hermann grid is presented as a regular array of solid black squares. Illusory grey disks appear at alley crossings situated away from the fixation point. The squares need not be solid black (top left)—their outline is sufficient; or they may be defined by linear texture (bottom left). In the bottom-right panel, faint elongated patches of grey may be seen instead of disks. In the top-right panel, the grey disks are only seen at alley crossings, but not at corners or T-junctions.

The Hermann grid illusion disappears under conditions of dark adaptation, during which lateral inhibition is diminished, consistent with the presumed role of centre–surround processing in creating the illusion.

(ii) *Locality.* Does the illusion require some form of mutual facilitation across spatially separated elements? Wolfe (1984) showed that the illusion is lost when the squares are jittered such that the alleys no longer form cross-shaped intersections. He also showed that an irregular pattern of crosses produced a weaker illusion than a regular grid (figure 4 in Wolfe 1984). In figure 1, top right panel, observe that the grey spots are conspicuous at the cross-junctions but not at the T-junctions or corners. In this peculiar configuration, crossings in which the illusory spots appear are separated, along the horizontal or vertical directions, by four nonproductive crossings. On the other hand, this geometry allows the branches of the productive crossings to be quite long. The persistence of the illusion, under these conditions, suggests that the facilitatory effect of alignments, reported by Wolfe (1984), may be mainly mediated through the local lengthening of the branches of the crosses.

The illusory spots cannot be simply a matter of local contrast processing in which four corners surround a cross of opposite contrast; outline squares are also effective, as are alleys defined by texture boundaries (figure 1, left panels). Further evidence that the illusory spots do not merely arise from local contrast processing is given in (iii) below.

(iii) *Orientation dependence.* The Hermann grid has been found to be subject to orientation effects (eg Spillmann and Levine 1971), which is usually taken to implicate a cortical stage of visual processing. (However, orientation-dependent long-distance interactions at the retinal level cannot be excluded at the present stage of knowledge.) Whether the observed orientation dependence relates to the oblique effect (Appelle 1972) or processes of Gestalt organisation, it is significant that the salience of the illusory spots varies as the Hermann grid is rotated in the frontal plane.

A striking phenomenon was discovered by Bergen in 1985, giving a new dimension to the domain. Bergen blurred a Hermann grid "by low-pass filtering the standard grid stimulus and passing the result through an accelerating nonlinearity, such as squaring" (Bergen 1985, page 280; see figure 2b in Spillmann 1994). He reported that "as in the original version, the spots do not appear near the point of fixation. The spots grow more intense when the eyes are moved, creating a scintillation effect" (Bergen 1985, page 280). The scintillation is better seen on screen than in print, and it is seen only within a certain range of blur, the optimum varying from one observer to another. For this reason, we show here a printed version that uses a gradient of blur, from right to left, making the phenomenon accessible to most viewers (figure 2). Once the scintillation catches the eye, it does not seem necessary to make voluntary eye movements to retain it. We noticed that scintillation is more conspicuous when the stimuli are viewed binocularly.

Building upon Bergen's initial observation, Schrauf et al (1997) constructed a family of illusory patterns, which they named 'the scintillating grid illusion'. Starting with a standard Hermann grid, they darkened the alleys, and posted white disks at their intersections. They observed, as in Bergen's stimulus, dark patches sparkling within the disks. This is most obvious upon shifting the gaze from one part to another in the figure (figure 3, rotated by 45°). The optimum size ratio between disk diameter and alley width is around 1.4 (Schrauf et al 1997). Both the Hermann grid and the scintillating grid effects are reduced when bright diagonals are added within the squares, even when the diagonals are reduced to small tips near the grid intersections (Schrauf and Wist 1997). Surrounding the white disks, as in figure 3, with black circles is slightly detrimental, but not fatal to the scintillation effect. The illusion is more compelling when viewed on the monitor screen. For printed stimuli that induce light spots, the effect is best when viewed under good illumination, while the opposite contrast versions, which induce dark spots, work better in dim light. The asymmetry is less noticeable when viewed on a computer display.

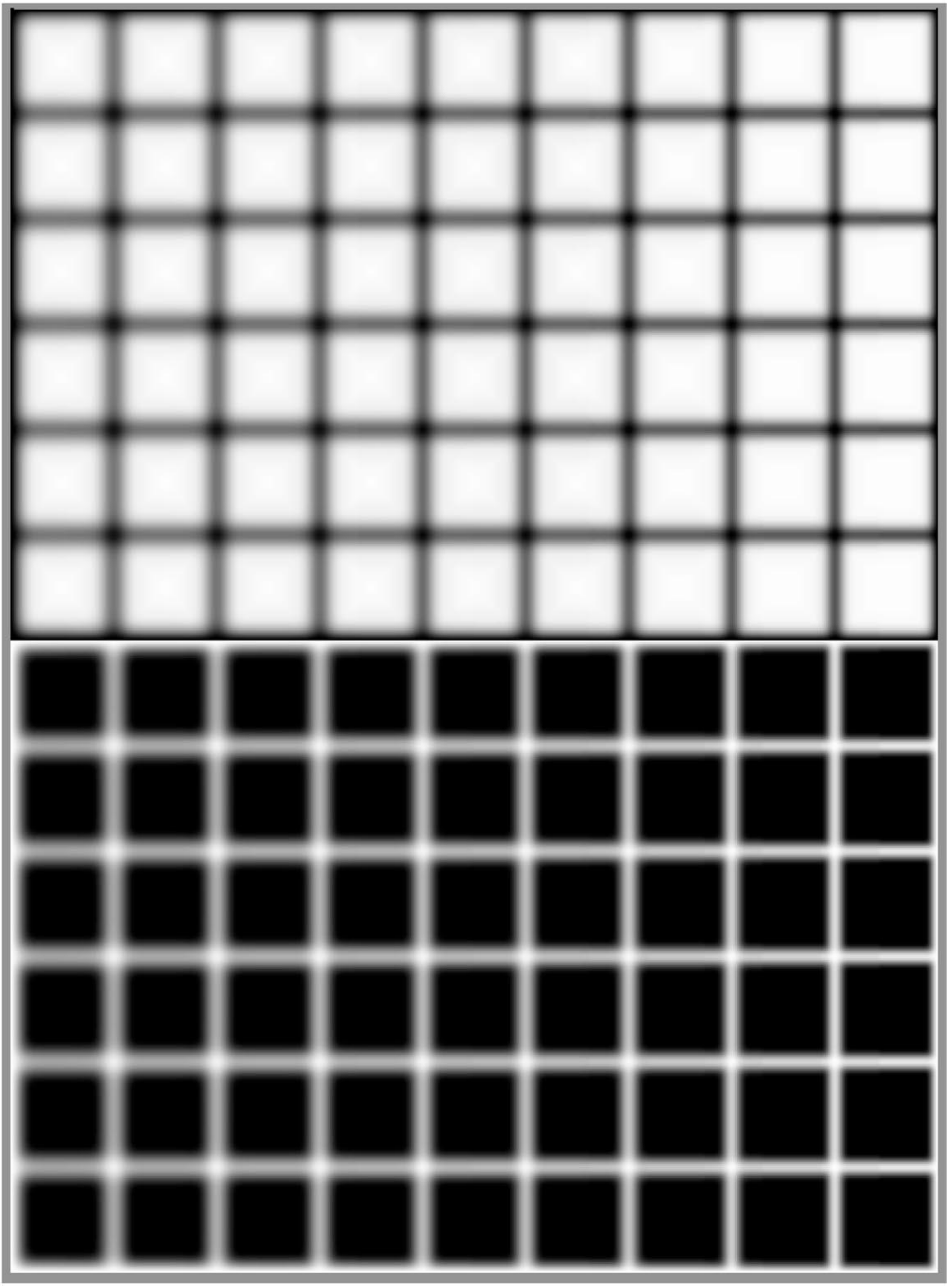

Figure 2. Blurred Hermann grids produce, as found by Bergen (1985), a scintillation effect. Brilliant spots appear to flash at the crossings of dark alleys in the top panel, and dark matter scintillates at the crossings of the light alleys in the bottom panel. Blurring was produced by replacing the grey-level values at each pixel by the average grey-level value over a neighbourhood, and iterating as many times as necessary to reach a degree of blur creating a satisfactory scintillation effect. The number of iterations was varied linearly from the rightmost to the leftmost pixel columns, and the range of grey-level values was rescaled at each iteration so that the minimum and maximum values corresponded to black and white.

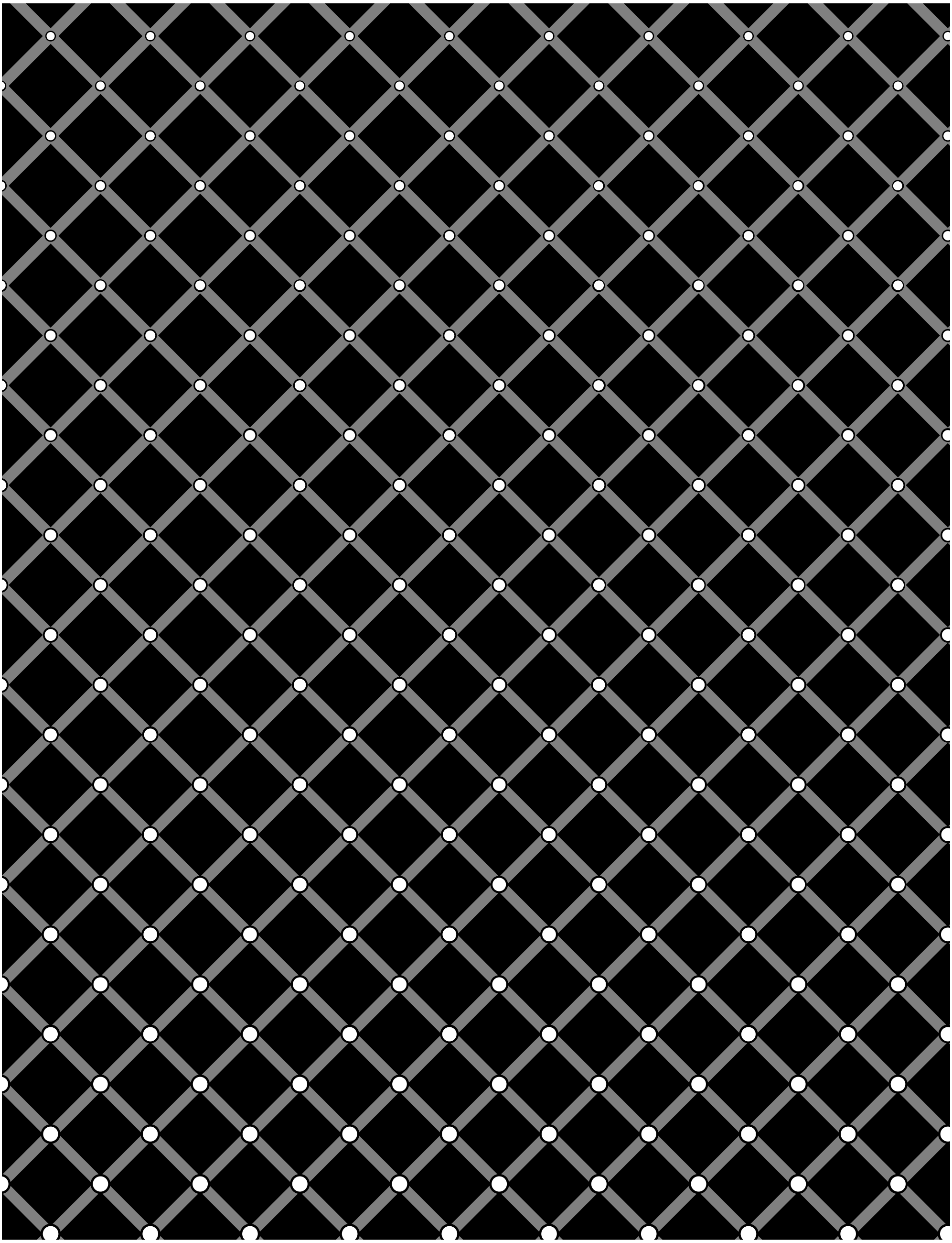

Figure 3. Scintillation and extinction effect. Turning the page by 45° one gets the 'scintillating grid' configuration, developed by Schrauf et al (1997). Upon shifts of fixation from one point to another, black matter seems to scintillate within the white disks. The phenomenon is mostly visible where the disks are the largest. In the case of difficulty, the reader may try to increase the viewing distance. When the image is viewed at its normal orientation, one obtains an extinction effect. Only a few clustered elements are simultaneously visible, the grey alleys being otherwise completed by a kind of filling-in. The phenomenon requires sharp vision and good illumination, and it is best seen where the disks are the smallest. The extinction effect works equally well when the disks are replaced with squares or diamonds. Outside the clusters of white disks, some observers also notice scintillation in the form of black sparkles that appear at many locations at alleys crossings, but as though these crossings were grey, and did not contain the white disks.

While attempting to systematically vary the geometrical design of the Hermann and scintillating grid illusions, we noticed an intriguing phenomenon. As the diameter of the disks is reduced to the width of the alleys or smaller, the scintillation effect yields ground to an extinction effect. On shifting the eyes then holding fixation, all but a very few disks, generally in the vicinity of the point of gaze, disappear; elsewhere, the alleys appear uniform in brightness, as though they had been completed by a filling-in process. Different clusters of disks pop into visibility as the eyes fixate across the pattern, and within seconds only a few remain other than the given disk under fixation.

The extinction illusion works particularly well at the intersections of a triangular tiling pattern (figure 4). The first thing one usually notices in figure 4 is that the large disks are unequally spaced in the top alleys (numbered 2, 4, 6). On closer inspection, one can verify that, in alleys containing disks half-way from the intersections, the disks are all lit, whether large or small, and that extinction occurs in the other alleys, in which the disks, whether large or small, are located at crossings. The illusion also works in reverse contrast (figure 5). A minority of observers also notice a residual scintillation effect: in figure 3, some black sparkling may be seen at crossings, without a concomitant awareness of the white disks.

The grey-level contrast between the disks and their surround is smaller when the disks are posted at the crossings in figures 4 and 5 than when they are posted in-between crossings. One may then think that extinction here is a pure effect of local grey-level values, much in the way that texture loses grain when viewed at a distance (see, in particular, Carlson et al 1980). However, in Carlson et al's figures all detail disappears simultaneously beyond a certain distance, whereas here the elements appear erratically in clusters. The phenomenon described here is also clearly distinct from classical fading effects (Troxler 1804; Babington-Smith 1961). In relation to filling-in processes in the blind spot or in artificial scotomas (Ramachandran and Gregory 1991), one can argue that, although a visual scene appears well-defined everywhere, one sees in detail only the portion which is really attended to (see, eg, O'Regan 1992; Rensink et al 1997), so that a good deal of filling-in may be used without being noticed.

On the other hand, there may be an ecological antecedent to our observations. A 'moving ants extinction effect', in natural settings was previously described by Nelson (1974) (we thank Nicholas Wade for drawing our attention to this work). Here, the observer's "awareness of a few bits of gravel was replaced by an awareness of all the moving ants over a surprisingly wide area". Grounding his arguments on what was known of cat's neurophysiology, Nelson suggested that separate, mutually antagonistic, perceptions arise from the sustained and transient (X and Y) retinal ganglion cells. This concept, in fact, makes a scintillation phenomenon quite intuitive, under circumstances that (i) would make the X and Y cells generate rather different local grey levels, and (ii) would favour a rapid alternation between the two interpretations.

In our extinction patterns, the brain might gather information using different contrast thresholds in different parts of the visual field. At the point of fixation, the finest available spatial resolution would be used and rather slight local contrast values would give rise to a signal. Far from the fixation point, the small disks of figures 4 and 5 would not be seen, owing to the low spatial resolution. In an intermediate range, spatial resolution would not be a problem, but awareness of a feature would require that a grey-level contrast be detected by the cells with the largest receptive fields (the Y cells). Then the larger disks of figures 4 and 5 would be seen or not, depending on whether there are two grey connecting segments in their immediate neighbourhood (as in alleys 9, 11, 13) or six connecting segments (as in alleys 2, 4, 6), making the local grey-level contrast smaller than in the first case.

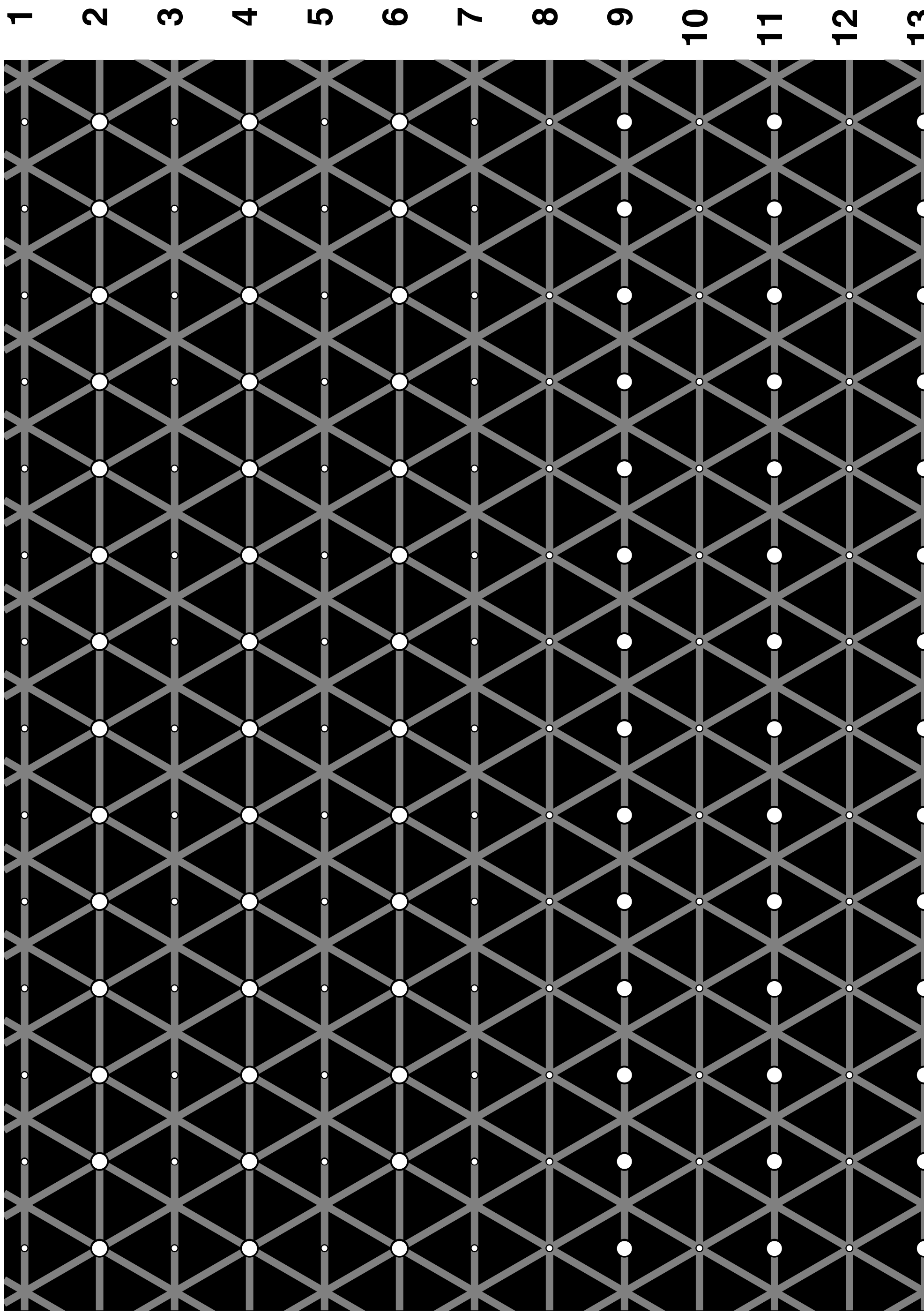

Figure 4. On odd-numbered lines, containing disks half-way from alley crossings, all disks are seen, while many of them are extinguished on even-numbered lines, irrespective of their size, when they are situated at the crossings. At first, if the page is turned by 90°, one perceives a difference in the spacing of the disks, according to their supporting line. Parenthetically, notice the motion of the small disks in-between crossings when the page is moved back and forth in the direction of the alleys.

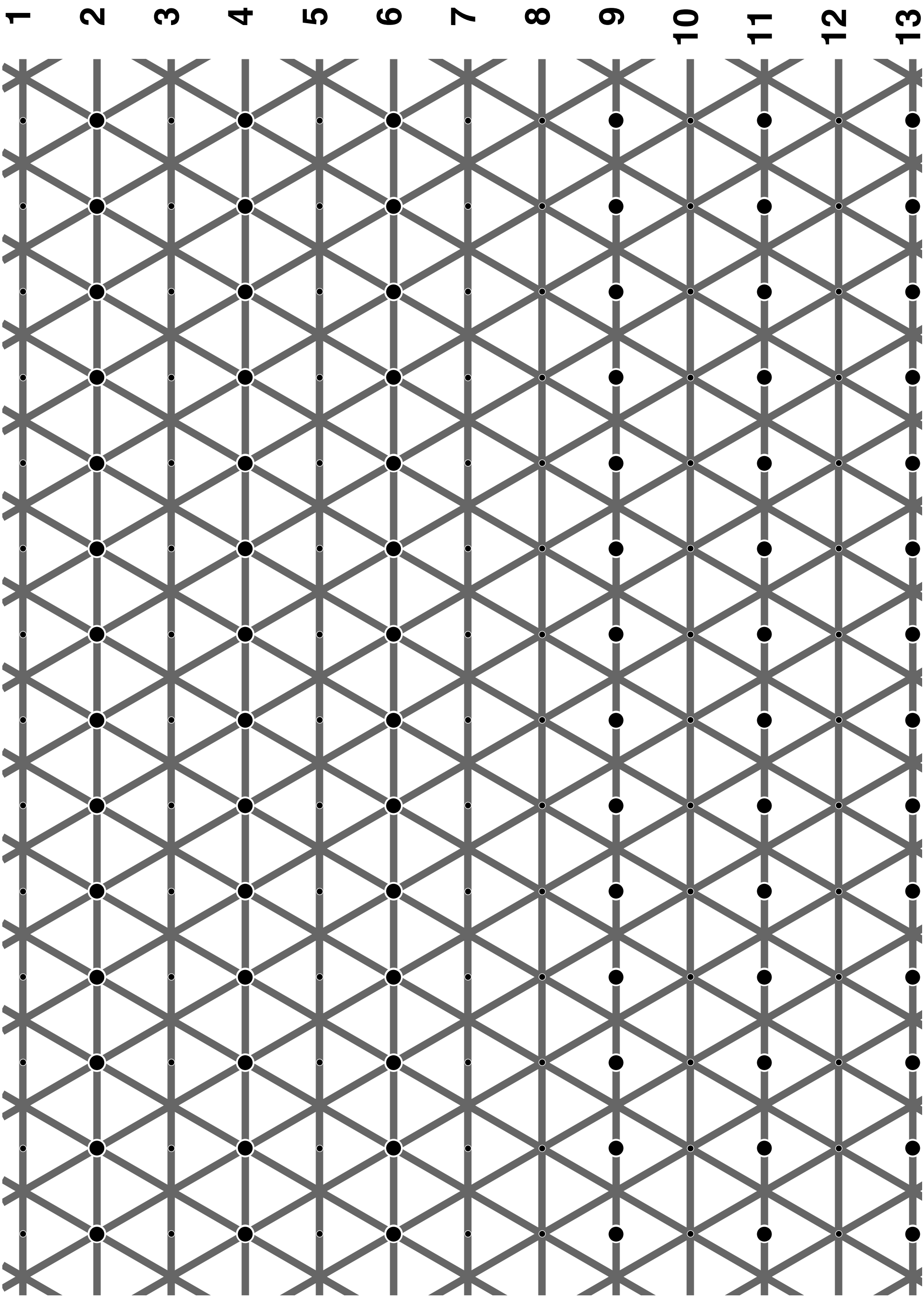

Figure 5. The extinction effect shown in figure 4 also works, as shown here, in reverse contrast. It is very effective on a monitor screen.

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