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Lightness induction revisited

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Abstract. Lightness induction is the classical visual phenomenon whereby the lightness of an object is shown to depend on its immediate surround. Despite the long history of its study, lightness induction has not yet been coherently and satisfactorily explained in all its variety. The two main theories that compete to explain it descend (i) from H von Helmholtz, who believed that lightness induction originates from some central mechanisms that take into account the whole viewing situation, with particular stress upon the apparent illumination of the object; and (ii) E Hering who argued in favour of more peripheral sensory mechanisms based on local luminance contrast. The balance between these theories has recently been shifted towards Helmholtz's position by E H Adelson who has provided additional evidence that lightness induction depends on perceptual interpretation and, particularly, on apparent transparency.

I challenge Adelson's conclusions by introducing modified versions of his tile pattern that use luminance gradients. In the first of these new demonstrations there is a strong lightness induction even though no apparent transparency is experienced. In the second there is a clear impression of transparent strips, yet no lightness induction is present. And the third shows that breaking up the Adelson tile pattern, while it affects neither the impression of transparency nor the type of grey-level junctions, makes the lightness-induction effect vanish. This implies that Adelson's illusion can be accounted for by neither local contrast, nor the apparent transparency, nor the type of grey-level junctions. Presented here is an alternative look at lightness induction as a phenomenon of the pictorial (as contrasted to natural) vision, which rests on the lightness – shadow invariance, much as Gregory's 'inappropriate constancy scaling' theory of geometrical illusions rests on the apparent size – distance invariance.

One of the patterns designed by Adelson (1993) to demonstrate the dependence of achromatic colour induction on the perceptual interpretation is presented in figure 1a. All the horizontal diamonds in this figure are physically the same, ie their reflectance is the same, but the diamonds on the bright strips 1 look darker than those on the dark strips 2. Such an apparent difference in lightness, caused by the surround, is usually referred to as lightness induction, or lightness contrast.[(1)] The point made by Adelson is that if the lightness induction could have been caused by low-level mechanisms driven by local contrast,[(2)] then in figure 1b the same rows of diamonds embedded in a similar, though rearranged, spatial context should have exhibited the same lightness shift as in figure 1a. However, it can be seen that the lightness difference between the diamonds in different rows (1 and 2) almost disappears in figure 1b.

As Adelson (1993) pointed out, figure 1 seems to lend itself to Helmholtz's explanation of the lightness induction. Indeed, the difference in the lightness-induction effect produced by the patterns in figures 1a and 1b can be accounted for by the fact that these patterns are seen in two different ways. Although both patterns are perceived as arrays of 3-D blocks with differently painted sides, the blocks in figure 1b look equally lit whereas those in figure 1a look differently lit. More specifically, the pattern 1a looks

(1) I prefer the term 'lightness induction' since the term 'contrast' has at least a two-fold meaning in visual literature, namely, contrast as a visual phenomenon (which is referred to here as lightness induction), and contrast as a normalised measure of light intensity (eg ratio of luminances). I will use the term contrast here only in the latter sense.

(2) Like those considered by Cornsweet (1970), and recently advocated by Kingdom et al (1997).

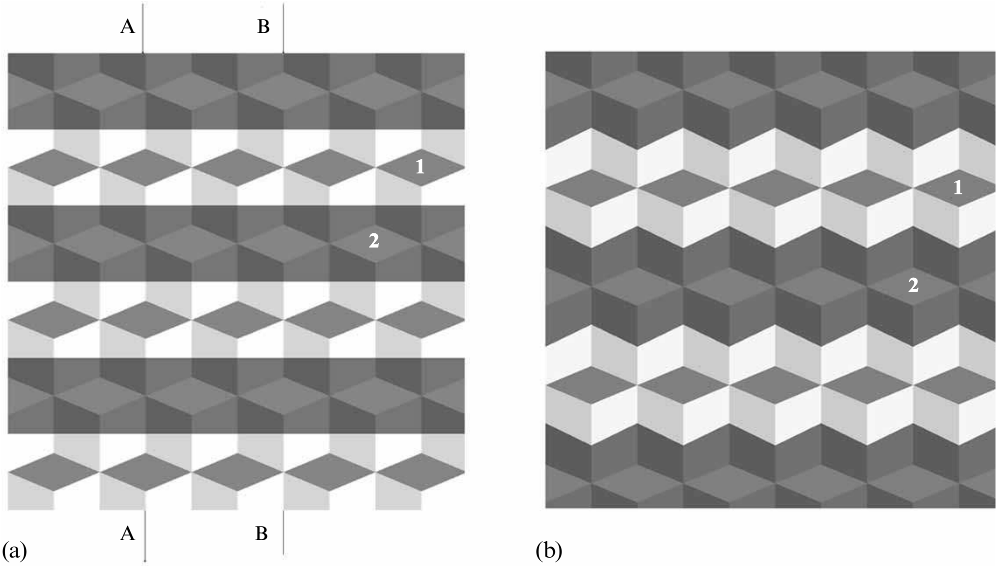


Figure 1. An effect of the mode of perceiving on lightness induction as demonstrated by Adelson (1993). Although the rows of diamonds 1 and 2 have been printed with the same ink in both patterns (a) and (b), they appear of different lightness in pattern (a), whereas there is almost no difference between them in pattern (b). The luminance profiles along two vertical dimensions (A and B) for pattern (a) are depicted in figure 5.

as if the wall of blocks is seen behind alternating 'dark' transparent filters; or as if a striped shadow is cast on it. At any rate, this pattern makes us perceive a difference in apparent illumination between adjacent strips, whereas the blocks in pattern 1b appear homogeneously illuminated. Given that, first, the retinal signals from all the diamonds are the same [following the Helmholtzian line of thinking it is assumed here that the retinal input relevant to the diamond's lightness is the amount of light reflected from it[(3)]]; and, second, given a perceptual assumption that alternating rows of diamonds are differently lit,[(4)] one cannot but arrive (unconsciously and involuntarily after Helmholtz) at the conclusion that the diamonds 1 and 2 have different lightness. Furthermore, this difference in lightness should be of an opposite sign to the difference in illumination, which is just what we see in figure 1.

Later, Adelson (1994) suggested that while being certainly more sophisticated than simple low-level mechanisms like lateral inhibition, a hypothetical mechanism responsible for lightness induction might be less complicated than that involved in producing an apparent-transparency effect. In particular he claimed that a particular type of grey-level junction might play a critical role in producing lightness induction. Specifically, he suggested that X-junctions, such as in figure 1a, facilitate lightness induction, whereas Y-junctions, such as in figure 1b, degrade it.

However, all these three explanations are seriously undermined by figure 2 where the blocks from figure 1a are presented spatially separated from each other. While the separation seems to change neither the impression of apparent transparency, nor the type of junction, it substantially reduces the lightness difference between diamonds in

(3) The case when one assumes, as do relational theories of lightness perception (eg Wallach 1963; Helson 1964; Gilchrist 1994), that the stimulus correlate of lightness is a luminance ratio in the stimulus pattern, will be discussed later.

(4) The impression of differently illuminated strips includes diamonds too. In other words, we do not see diamond-like holes or shadows; on the contrary, we experience spatially continuous strips of light casting on each even strip of the pattern.

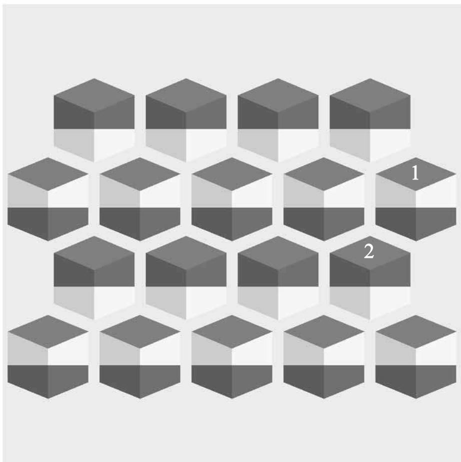


Figure 2. The same pattern as in figure 1a except that the blocks are spatially separated from each other. Such a separation makes the diamonds 1 and 2 look the way they really are, namely of the same lightness, thus eliminating the lightness-induction effect which is quite strong in figure 1a.

rows 1 and 2. It proves that mechanisms mediating the Adelson effect are of higher order than those responsible for the classical brightness induction, since it is known that the latter can be induced by not only contiguous but also quite remote surrounds (Shevell et al 1992).

I have measured the lightness of the diamonds for patterns in figures 1 and 2 (as well as for those in figures 4, 6, 7, 8, 10, and 11) using the Munsell grey scale. Fifteen observers, not aware of the purpose of the experiment, were tested. They were asked to pick out one of 31 standard grey chips which matched the diamond under evaluation. Each pattern, printed on a single A4 sheet, was presented to the observer once under conditions of the standard luminescent illumination. The median Munsell neutral-scale values are presented in figure 3.

My results were very much the same as for the original Adelson patterns (figure 1) despite the fact that Adelson measured a different perceptual dimension [brightness

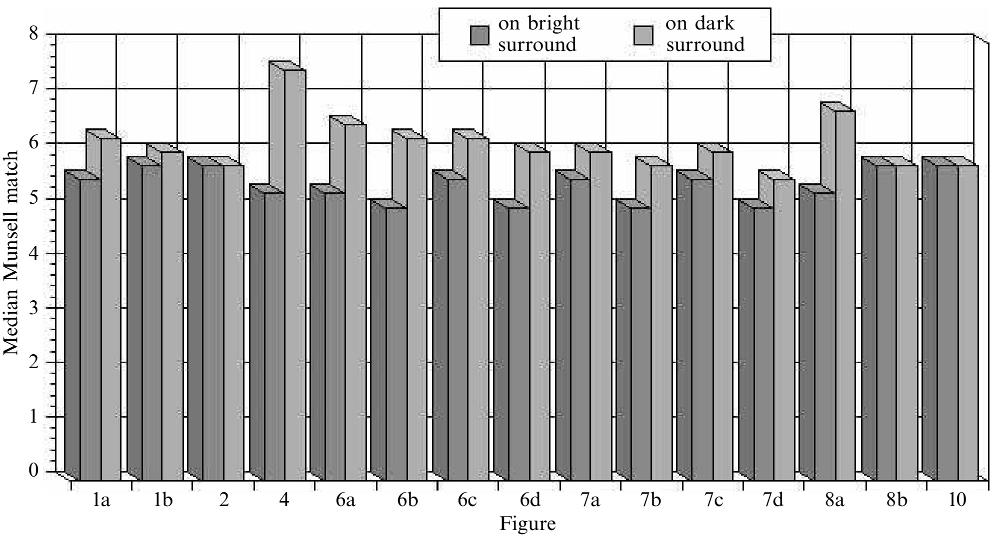


Figure 3. The dependence of diamond lightness on the spatial context for the various patterns. The ordinate unit is the Munsell neutral value. Dark and light columns correspond to the diamonds in the bright (1) and dark (2) surrounds, respectively.

rather than lightness[5]] and used a different procedure (brightness cancellation technique). To be more exact, although the majority (thirteen out of fifteen) of the observers evaluated the diamonds surrounded by the dark tiles (2) as being lighter than those surrounded by the light tiles (1) in figure 1b (one of the remaining two observers saw them equal in lightness, and the other saw diamonds 2 darker than 1), the median difference between the lightness of diamonds 1 and 2 in figure 1b is much less than in figure 1a, as one can see in figure 3. The lightness-induction effect in figure 2 was even less than in figure 1b. Only eight observers saw diamonds 2 as lighter than 1 (six observers saw diamonds 2 darker than 1, and one saw no difference). The median lightness difference for figure 2 is zero.

Therefore, experiencing an apparent-transparency effect is not in itself sufficient to produce lightness induction. On the other hand, figure 4 shows that apparent transparency is not necessary for patterns spatially configured as in figure 1 to give rise to lightness induction either (see also Adelson 1994). In figure 4, blurring the borders between the strips (a luminance profile for the pattern in figure 4 is presented in figure 5) eliminates the apparent transparency and considerably reduces the impression of an apparent illumination difference between the alternating strips (especially when this pattern is viewed from close up). However, the strength of the lightness-induction effect in figure 4 is by no means reduced. On the contrary, the row of diamonds 1 appears remarkably darker than 2 despite the fact that in reality they have the same reflectance. At any rate, the lightness-induction effect in figure 4 (at about two units on the Munsell scale) is much higher than in classical textbook demonstrations.[6]

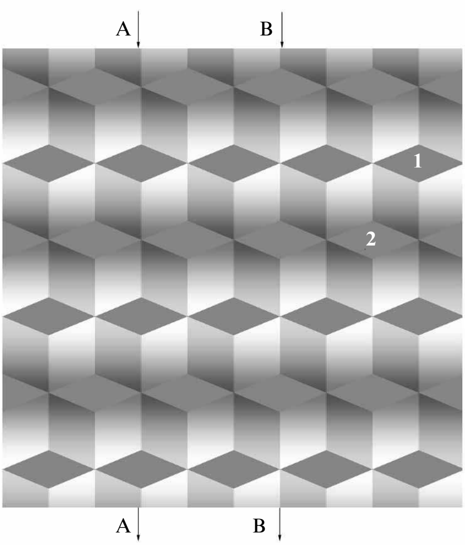


Figure 4. The pattern in this figure was produced from the tile pattern in figure 1a by blurring the contrast at the border between the dark and bright strips. (See figure 5 which shows how luminance varies across the verticals A and B.) As in figure 1a, the diamonds 1 and 2 are physically the same but look rather different because of lightness induction caused by the vertical luminance ramp.

[5] It should be noted that the effect of perceptual organisation on the achromatic colour induction demonstrated by Adelson (1993) can be observed for both perceptual dimensions—brightness (when the tile pattern is presented on a display screen) and lightness (when the pattern is printed on paper). (Brightness is a subjective intensity of light, whereas lightness refers to a perceptual dimension of an object colour which mainly depends on the object reflectance.) Adelson restricted himself to the brightness rather than lightness induction. Here, I am dealing with the lightness version of the effect.

[6] By the way, it undermines the point made by some authors (eg Whittle 1994) that there is a substantial difference between the effect of lightness induction, which is very weak, and that of brightness induction which is considerably stronger. It turns out that the lightness-induction effect can be much stronger than it was once thought.

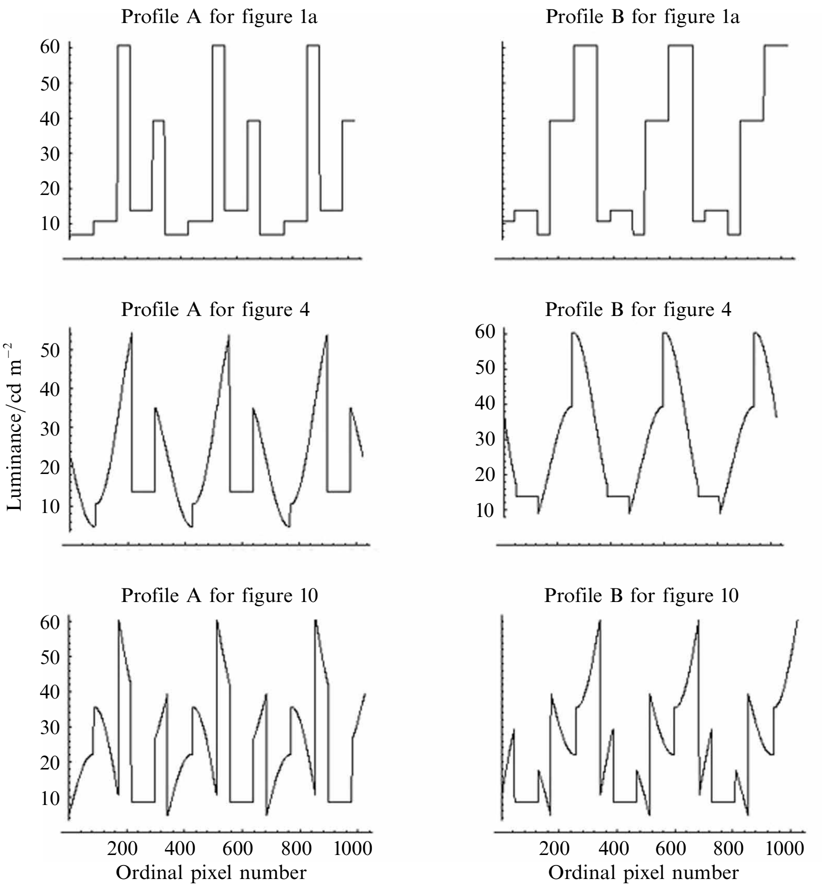


Figure 5. Luminance profiles for the patterns displayed in figures 1a, 4, and 10 when presented on the screen of the display. Each graph shows the luminance distribution in the corresponding pattern across the vertical direction A (Profile A) or B (Profile B). Luminance of all the diamonds (85 pixels high) was set at 13.6 cd m^{-2}. So in each graph multiple, 85 pixels wide plateaux at the level 13.6 cd m^{-2} correspond to the diamonds.

Hence, it seems that both classical theories, Helmholtz's (1867) as well as Hering's (1874/1964), present an oversimplified account of lightness induction. An alternative approach to lightness induction can be found within the context of the Gestalt theory (Koffka 1935). Gestalt psychologists have emphasised that the lightness-induction effect can be dramatically altered by manipulating perceptual organisation. For example, Benary (1924/1938) demonstrated that lightness induction can be based only on perceptual belongingness. More recently Agostini and Proffitt (1993) have shown that lightness induction can be evoked by using the gestaltist law of 'common fate'. It is the gestaltist concept of belongingness that plays a central role in a new theory of lightness which has recently been developed by Alan Gilchrist and his collaborators (Gilchrist et al, in press). It seems to provide a satisfactory explanation of (i) the dependence of lightness induction on the pattern configuration in figure 1; (ii) the separation effect observed in figure 2; and (iii) the facilitating effect of the luminance gradient on the lightness induction in figure 4.

This theory hypothesises in some detail a so-called anchoring process to convert the luminance into lightness. It starts with parsing a pattern into frameworks. There is supposed to be an anchor within each framework. For simple patterns the anchoring is equivalent to the maximum luminance rule as applied to the framework. More specifically, the lightness of any area in the framework is derived from the luminance ratio between that area and that having the highest luminance in the framework.[7] Since the same area may belong to more than one framework, the resultant lightness value of the area is evaluated as a weighted average of all the lightness values for that area derived for each framework to which the area in question belongs.

The anchoring theory predicts that the diamonds in figure 1a will have a different lightness because they are assumed to be anchored within different local frameworks. There are two different groups of local frameworks in figure 1a—around apparently dark and light diamond rows, respectively. As the maximum luminance within these frameworks is different, the anchoring process yields different lightnesses. Since the anchoring theory suggests that a luminance gradient has a further segregating effect, it also predicts the facilitation effect of the luminance gradient on the lightness induction in figure 4.

By breaking up Adelson's tile pattern into isolated blocks (figure 2) we presumably change the local frameworks. While it is, generally, not always clear into what frameworks a given picture can be parsed according to the anchoring theory, it seems that figure 2 is most likely to be parsed as an array whose local frameworks are the single blocks. Each block consists of three sides. The upper side is completely identical for both types of blocks. The lateral sides are also the same except for the rotation by 180°. So, both the local and global anchors for the diamonds are the same for figure 2. Therefore, the lightness of the diamonds in figure 2 should be the same according to the anchoring theory. The results of my experiment for figure 2 are in line with this prediction (figure 3).

Still, it should be noted that the anchoring theory predicts the same insulation effect not only for the pattern in figure 1a but also for that in figure 4. However, contrary to this prediction, the pattern with blurred borders (figure 4) has proved to be quite robust to breaking up, as can be seen in figure 6. While the separation somewhat reduces the lightness induction in figure 6, the difference between the lightnesses of diamonds 1 and 2 in all four patterns in figure 6 is still not less than in figure 1a (0.75 Munsell unit). Surprisingly, the background luminance (6a versus 6b and 6c versus 6d) was found to have no significant effect on the lightness induction.[8]

Although the display in figure 6 reveals that the luminance gradient makes a substantial contribution to lightness induction, it is not clear how it does this.[9] In particular, does introducing a luminance ramp across the vertical dimension in figure 4 only facilitate the effect produced by the local luminance contrast at the borders of the diamonds, or does it make its own independent contribution?

[7] For complex patterns an area effect and a scale normalisation effect are taken into account during anchoring.

[8] A two-factor ANOVA was performed on the data obtained for the patterns in figure 6. The dependent variable was the lightness difference between the diamonds 1 and 2. The two factors were spatial separation and background luminance. Only spatial separation was significant beyond 1% level ($F_{1,14} = 10.91$, $p = 0.005$). Background luminance was not significant ($p = 0.108$).

[9] That the luminance gradient plays an important role in achromatic colour perception has been well established for a long time. A classical example is another lightness illusion—Mach bands. It is known that a linear luminance gradient is required for Mach bands to be observed, a sharp luminance step producing no illusory bands (see eg Fiorentini 1972). Interestingly, while the Mach bands illusion has been known for a long time, a systematical study of facilitating effect of the luminance gradient on the lightness induction has only recently been reported (Agostini and Galmonte 1997, 1998). Though, if we accept that grating induction (McCourt 1982) is a particular case of achromatic colour induction, as it has been recently claimed by Blakeslee and McCourt (1997), then we have to admit that the study of achromatic colour induction caused by the sinusoidal luminance gradient has begun as far back as 1982.

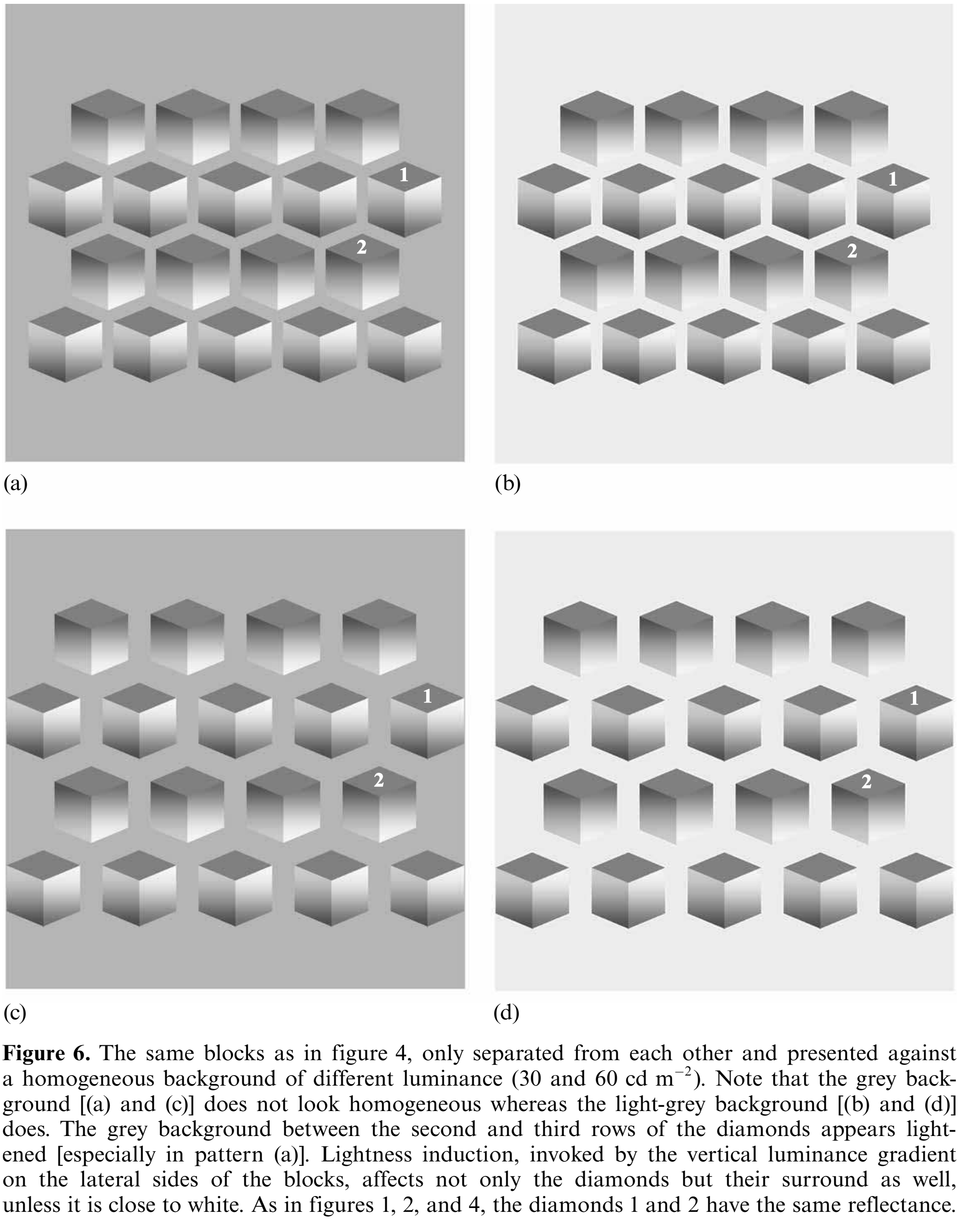


Figure 6. The same blocks as in figure 4, only separated from each other and presented against a homogeneous background of different luminance (30 and 60 cd m^{-2}). Note that the grey background [(a) and (c)] does not look homogeneous whereas the light-grey background [(b) and (d)] does. The grey background between the second and third rows of the diamonds appears lightened [especially in pattern (a)]. Lightness induction, invoked by the vertical luminance gradient on the lateral sides of the blocks, affects not only the diamonds but their surround as well, unless it is close to white. As in figures 1, 2, and 4, the diamonds 1 and 2 have the same reflectance.

A clue to an answer to this question can be found in figure 7 which shows that, although separation of the diamonds from the lateral sides reduces the lightness-induction effect, it does not eliminate it completely. For instance, the median lightness difference between diamonds in rows 1 and 2 in figure 7b is the same as in figure 1a (0.75 Munsell unit) even though, because of the separation, in figure 7b the local luminance contrast at the diamonds' border in row 1 is exactly the same as that in row 2. For the rest of the three patterns in figure 7, the median lightness difference was found to be only slightly less (0.5 Munsell unit). Even if luminance contrast, rather than luminance values, would be encoded at the retinal level, the retinal signals from the diamonds in

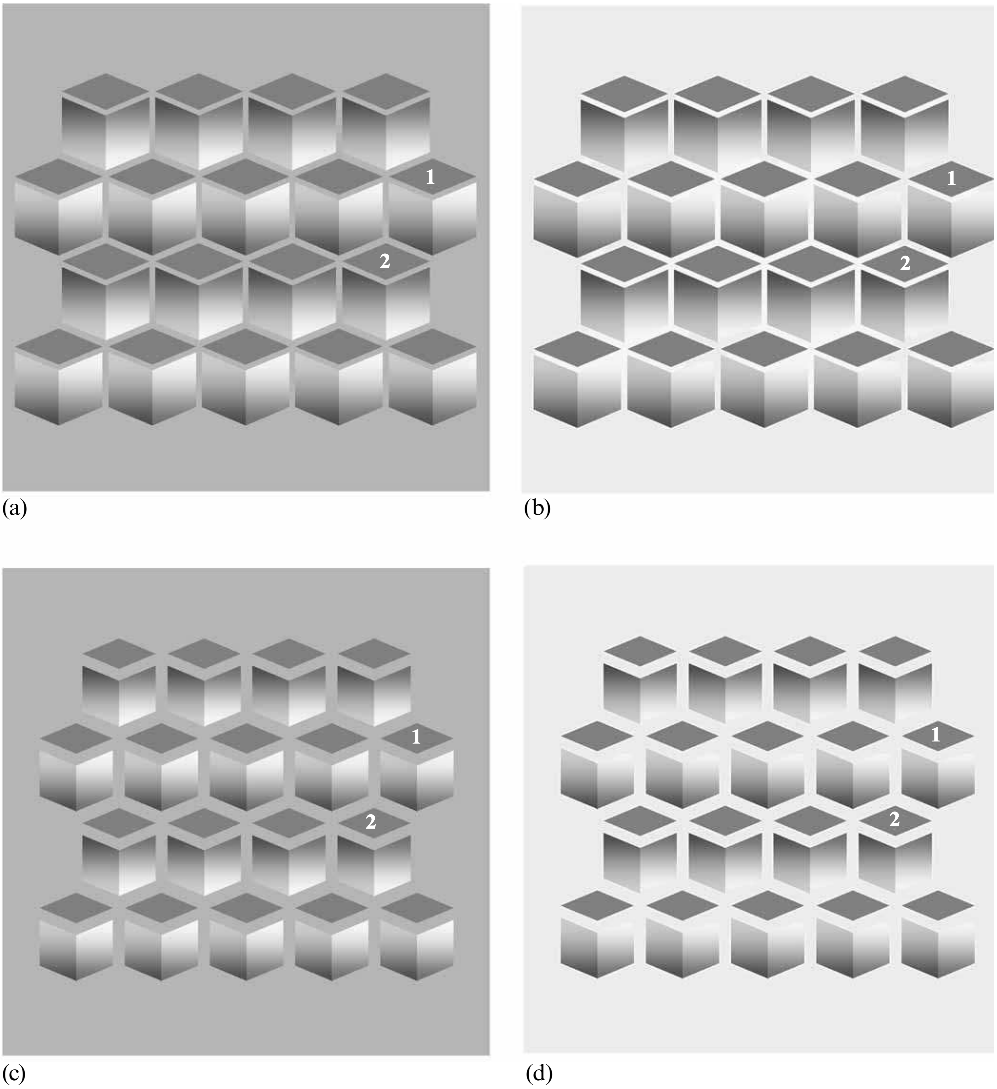


Figure 7. Same as figure 6, except that the diamonds (which all are identical) are detached and shifted up from the lateral sides. As a result the diamonds look outlined. Because of the same effect of illusory lightening of the background due to the luminance gradient as in figure 6, the outlining contours seem different for diamonds 1 and 2.

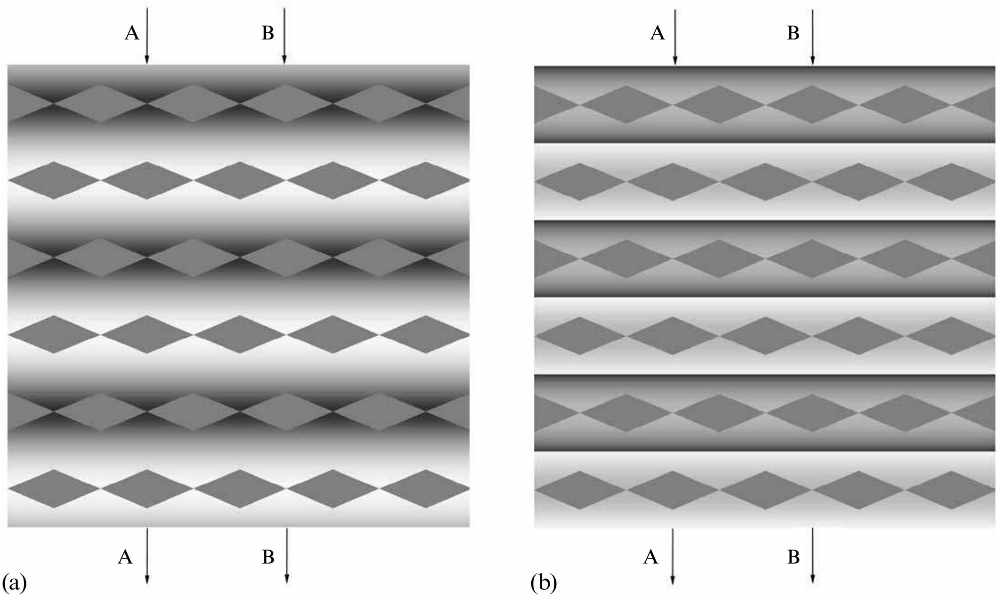
rows 1 and 2 in figure 7 should be the same. Nevertheless, the lightness of the diamonds in rows 1 and 2 in figure 7 is still rather different.[10]

Thus, the luminance gradient itself can be a determinant of the lightness induction. Although at this stage I have no complete explanation of this fact, it should be mentioned that the visual system is widely believed to tend to interpret gradual luminance transitions as illumination changes, whereas it interprets stepwise luminance transitions

[10] The data for figures 6 and 7 were analysed together by using a three-factor ANOVA. In addition to spatial separation of the blocks and background luminance, the third independent variable was the spatial separation of the top side (diamond) from the lateral sides of the blocks. Both separation factors were found to be significant ($p < 0.01$). Background luminance and all the interactions were insignificant.

as reflectance borders.[11] Such a tendency, together with the assumption that there is an invariant relationship between lightness and apparent illumination (shadow),[12] would, in principle, account for the facilitating effect of the luminance gradient on the lightness induction. However, such an account drives us into at least two problems.

First of all, it should be noted that not every luminance gradient produces lightness induction. For example, there is a gradual transition of luminance along the vertical dimension in both patterns presented in figure 8. Each of these patterns was made from the same horizontal square-wave grating. To be more specific, pattern 8a is a horizontal sinusoidal grating whereas pattern 8b is a square-wave grating of the same spatial frequency with missing fundamental (luminance profiles for these patterns are depicted in figure 9). The same diamonds are imposed on each strip of both gratings. Nevertheless, the effect of the sinusoidal luminance gradient on the diamonds is very different for patterns 8a and 8b. There is quite a difference in lightness (1.5 Munsell units) between the diamonds imposed on the peaks and troughs of the sinusoidal grating in figure 8a. On the contrary, in figure 8b all the diamonds look of the same lightness. To be more precise, only three of fifteen observers judged diamonds in adjacent strips



(a) (b)

Figure 8. The same rows of diamonds imposed on a sine-wave grating (a) and a square-wave grating with missing fundamental (b). (See figure 9 where two vertical luminance profiles, A and B, for this pattern are presented.) See explanation in the text.

[11] This difference between gradual and abrupt luminance changes is the basis of the Retinex algorithm which attenuates gradual luminance transitions and integrates abrupt luminance changes across the pattern (Land and McCann 1971). Attenuation of gradual changes results in enhancement of the lightness induction effect by the shallow luminance gradient; integration of abrupt changes secures robustness to the insulation.

[12] In quantitative terms, the lightness – shadow invariance was first formulated as a so-called albedo hypothesis (eg Koffka 1935; Beck 1972). It should be noted, however, that, as shown recently, it is unlikely that the albedo hypothesis in its original form is correct (Logvinenko 1996). Nevertheless, after some modification it can be brought in line with experimental evidence (Logvinenko and Menshikova 1994; Logvinenko 1996).

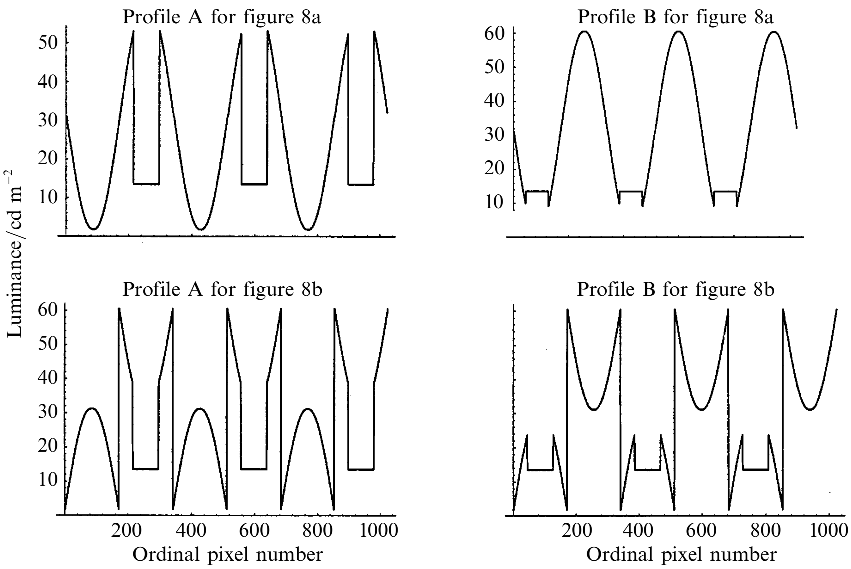


Figure 9. Luminance profiles for figure 8.

in figure 8b unequal in lightness (two found the diamonds on apparently dark strips brighter than those on apparently light strips; and one the other way round).[13]

A similar technique was also used to sinusoidally enhance the contrast at the strip borders in the Adelson tile pattern (see figure 10, and figure 5 where the luminance distributions in figure 10 are presented). As distinct from figure 4 where the luminance gradient facilitates the lightness-induction effect, the luminance gradient in figure 10 eliminates it completely. (Only two observers judged the diamonds on apparently dark strips brighter, and one judged them darker, than the diamonds on the apparently light strips.)

It seems as if for the human visual system some luminance gradients are more compatible with the hypothesis that they are produced by the variation in the surface illumination (ie shadows) and others are more compatible with the hypothesis about variations in surface reflectance. I believe that only shadow-compatible luminance gradients can bring about lightness induction. The array of blocks in figure 11b is made up of the same blocks as the array in figure 11a. Nevertheless, the lightness-induction effect, which is quite noticeable for the array 11a, almost vanishes in the array 11b. (Only four out of fifteen observers noticed a difference in lightness between the diamonds in row 11b.)

The difference in lightness between arrays 11a and 11b cannot be explained by any model of brightness (lightness) perception employing a set of linear shift-invariant spatial filters at the first stage (eg Grossberg and Todorovic 1988; Kingdom and

[13] The display in figure 8b is similar to that used to create the well-known Craik – O'Brien visual illusion (Craik 1966; O'Brien 1958). Arend et al (1971) reported that an apparent difference in brightness, of the opposite sign relative to the lightness-induction effect, between the physically identical tests was observed as a consequence of the Craik – O'Brien illusion produced by a rotating disc. It is obviously not what the observers found in this study for figure 8b. The discrepancy is probably due to the difference in the displays used. Note that the luminance of the strips in the nearest neighbourhood of the diamonds in figure 8b is not the same (the vertical luminance profiles for the pattern displayed in figure 8b are presented in figure 9). Therefore, it is not an illusion that the strips look different in brightness. There is a physical difference in mean luminance between the alternating strips. Nevertheless, this physical difference between strips produces no lightness difference between the diamonds in the alternate strips. So, one cannot exclude that had the luminance around the diamonds in both kinds of strips been completely equated, as classical Craik – O'Brien illusion implies, the result of Arend and collaborators would have been reproduced in this study.

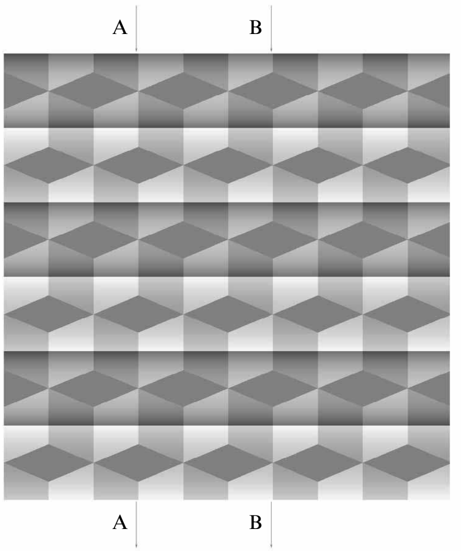


Figure 10. The pattern in this figure was produced from the tile pattern in figure 1a by sinusoidal enhancement of the contrast at the border between the dark and bright strips. (See figure 5 which shows how luminance varies across the verticals A and B.) Such contrast enhancing does not substantially change the appearance of the diamonds.

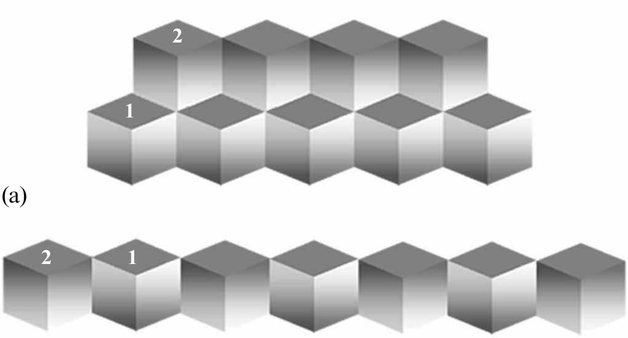


Figure 11. The upper set of blocks (a) is a fragment of the array in figure 4. Although physically identical, the diamonds 1 and 2 look different because of lightness induction. However, the lightness-induction effect is essentially reduced in the array (b), which is made up from the same blocks as (a), but put in different order. (See explanation in the text.)

Moulden 1992; Pessoa et al 1995; McArthur and Moulden 1999). Being shift-invariant, such filters would produce identical outputs in response to any block in figure 11 irrespective of its orientation. Therefore, their predictions, which are based on 'interpretation' of the filters' outputs combined in a certain way, would depend neither on block orientation, nor on block position in the array. Nor can the lightness difference between arrays 11a and 11b be explained within the context of the anchoring theory. I assume that it is observed because the luminance distribution in the latter array is shadow-incompatible. Indeed, it is very unlikely to expect the illumination gradient to be different for adjacent blocks as is the case in the array 11b.

The second problem, which a lightness/shadow-invariance-based explanation of lightness induction has to face, is related to the fact that lightness induction is usually demonstrated by using pictures rather than real objects. However, pictures are special, dual objects for the human visual perception (see Gibson 1979, pages 267–291). On the one hand, a picture is an object among the others in the physical world. In this respect all pictures are nothing more than painted sheets of paper. On the other hand, a picture renders special, pictorial objects which may have, in particular, a pictorial shape, pictorial colour, and pictorial apparent illumination (shadows). So there are two different kinds of the content to be perceived in pictures—objective and pictorial ones.

It is therefore necessary to specify whether it is objective or pictorial apparent illumination that is referred to in this lightness–shadow invariance explanation. It is by no means an easy question to answer. It is certainly not an apparent illumination of a picture considered as a real object because my observers had no doubt that all the pictures presented to them during the experiment were always homogeneously illuminated. On the other hand, there is no evidence that pictorial apparent illumination and pictorial achromatic colour are related to each other the way the albedo hypothesis implies. It has simply not been a matter of experimental investigation. All the data in favour of the lightness – shadow invariance (ie the albedo hypothesis) have been obtained in experiments with real objects and real illuminants (eg Gelb 1929; Logvinenko and Menshikova 1994). Furthermore, some demonstrations used here (eg figures 2 and 4) point out clearly that the pictorial lightness and apparent illumination do not closely depend on each other.[14]

Nevertheless, although shadow-compatible luminance gradients do not always induce pictorial shadows, and these latter are not always perceptually coupled[15] with pictorial shadows, I believe that they are somehow taken into account by the human visual system when it processes a picture with such gradients, to compute lightness. One can assume that, given the invariant relationship between the lightness and shadow (apparent illumination) as suggested by the albedo hypothesis (at the level of natural vision), the shadow-compatible luminance gradient triggers the hypothetical perceptual mechanism, securing this invariant relationship without producing the apparent illumination gradient. Gregory's 'inappropriate constancy scaling' theory of geometrical illusions (Gregory 1974) can be drawn as a helpful analogy here. According to this theory, we see the outgoing Müller-Lyer arrow longer than the corresponding ingoing arrow because the perspective cues of distance supposedly trigger the perceptual mechanism (primary constancy scaling in Gregory's terms) maintaining the size – distance invariant relationship without producing the apparent distance shift. I believe that the same line of reasoning can be applied to lightness.[16]

Hence, the displays presented above (particularly figures 8b and 10) not only do not undermine the lightness – shadow invariance, as it may seem at the first glance,[17] but, on the contrary, the invariant relationship between lightness and apparent illumination of real objects is a presumption necessary for these displays to be accounted for. However, it should be stressed that, although I resort to the lightness – shadow invariance in my explanation of lightness induction, I consider the lightness – shadow invariance as a relationship at the level of the natural perception, whereas lightness induction is considered as a phenomenon of the pictorial rather than natural perception.

(14) For example, the impression of the vertical wave of apparent illumination in figure 4 seems to depend on the viewing distance whereas the diamonds, lightness does not.

(15) Regarding a concept of percept – percept coupling (see eg Hochberg 1974; Epstein 1982).

(16) Some time ago Gilchrist made an argument against reducing the lightness-induction effect to the same perceptual mechanisms as those which implement the lightness – shadow invariance. It might be the difference in the strength of the lightness-induction effect and the lightness constancy (which can be considered as a particular case of the lightness – shadow invariance — see eg Logvinenko 1996). "If the effect were equal in strength to the kind of ratio effects typical of constancy experiments, the gray squares would appear almost white and black ..." (Gilchrist 1988, page 415). Admittedly, the diamonds 1 and 2 in figure 4 do not look completely white and black, but they manifest much stronger lightness-induction effect than that to which Gilchrist referred.

(17) In particular, the demonstrations reported here can, by no means, be considered as evidence against the theories which are often referred to as the intrinsic image theories of lightness (for review see eg Arend 1994; Gilchrist et al, in press) as far as they are devoted to the perception of real objects. For example, figures 8b and 10, where there is a clear impression of apparent brightness difference between strips, yet no lightness induction is present, do not undermine the albedo hypothesis, because the albedo hypothesis suggests that it is an apparent illumination rather than brightness of the strips that is related to the lightness. However, the strips in figures 8b and 10, as well as the whole pattern considered as a real object, are perceived undoubtedly equally illuminated.

Thus I conclude that lightness induction, as emerged from observing arrays presented here, is probably a sort of visual illusion which results from the lightness – shadow invariance acting in a reduced, inappropriate form at the level of pictorial perception.

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