

Gating of remote effects on lightness

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In various versions of the dungeon illusion (P. Bressan, 2001), we show that grouping between targets and contextual disks determines whether remote luminances affect target lightness or not. In the dungeon illusion, target disks surrounded by contextual disks contrast with them rather than with the immediate background. We formally establish the existence of this illusion and show that it reverses when the luminance of the targets is either lower (double decrement) or higher (double increment) than the luminances of both the background and the contextual disks rather than in between them. On the basis of the double-anchoring theory of lightness (P. Bressan, 2006a), we predict and show that grouping gates the effects of remote luminances in such a way that they go in opposite directions in the double-decrement and double-increment inverted-dungeon illusions. Our results support the double-anchoring theory and demonstrate that luminances that are far away from the targets are irrelevant in some conditions but critical in others.

Keywords: dungeon illusion, White's effect, reverse contrast, luminance grouping, double-anchoring theory

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Introduction

A region usually looks darker on a high- than on a low-luminance background (simultaneous contrast effect). On a striped background, a target region also looks darker on a high- than on a low-luminance stripe, but this effect can be seen even when the target is flanked by more low than high luminance, as in [Figures 1A and 1C](#), and a simultaneous contrast effect would go in the opposite direction (White's illusion: White, 1979). Various theories have been proposed to account for this particular reverse-contrast effect, based on spatial frequency filtering (Blakeslee & McCourt, 1999; 2004; Dakin & Bex, 2003), geometrical and photometrical cues (Adelson, 2000; Anderson, 1997), light-pattern statistics (Dakin & Bex, 2003; Yang & Purves, 2004), and Gestalt grouping (Bressan, 2006a; Gilchrist et al., 1999; Ross & Pessoa, 2000).

Modifications of the display that gives rise to White's illusion have challenged some of those theories, but one version of it, in particular, seems a real stumbling block. In this version, the luminance of the target patch is not a decrement relative to the high-luminance stripes and an increment relative to the low-luminance stripes ([Figures 1A and 1C](#)), but either a decrement ([Figure 1B](#)) or an increment ([Figure 1D](#)) relative to *both* the high- and low-luminance stripes. These double-decrement and double-increment displays do not give rise to White's illusion but instead to a simultaneous contrast effect (the inverted-White illusion: Ripamonti & Gerbino, 2001; Spehar, Gilchrist, & Arend, 1997).

To date, no theories that account for White's illusion also account for the inverted-White illusion. Ripamonti and Gerbino (2001) suggest that both effects are mediated by T-junctions (which, like other junctions, involve a particular arrangement of abutting luminance regions). However, in the dungeon illusion ([Figure 2A–B](#); Bressan, 2001, 2006a), that does not contain any junctions at all, gray target patches are also perceived as darker on a low-luminance background ([Figure 2A](#)) than on a high-luminance one ([Figure 2B](#)), showing a reversed-contrast effect very similar to White's.

In the present article, we address two questions. The answer to the first paves the way for the second and introduces our main topic, which concerns the gating of remote luminance effects on a region's lightness. This first question is whether the dungeon illusion can be formally established (which hitherto has not been done) and whether it reverses, as White's illusion does, if its targets have a luminance that is either a double decrement ([Figure 2C–D](#)), or a double increment ([Figure 2E–F](#)), relative to the luminances of the inducing regions. If this is indeed the case, then the dungeon and White's illusions are most probably due to just one common underlying mechanism. Only theories of White's illusion that can also explain the dungeon illusion can then still be considered viable.

Our second, and for this article more important, question concerns the gating of remote luminance effects on lightness. Despite the fact that the *potential* relevance of remote luminance has been amply demonstrated (Bressan, 2006a; Gilchrist et al., 1999), many studies

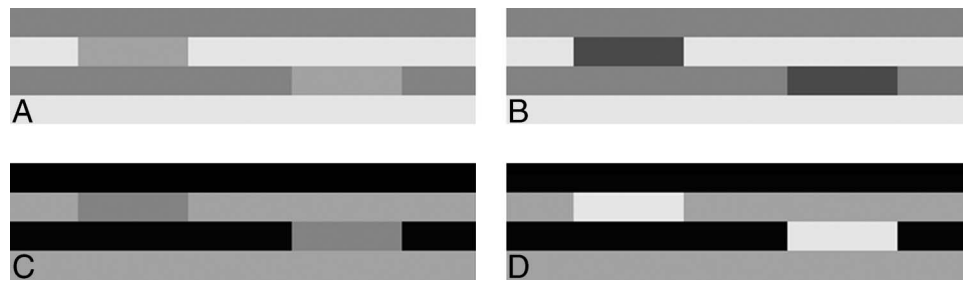


Figure 1. Two examples of White's illusion (A and C): the target (short bar) flanked by dimmer bars, on the left, looks darker than the identical target flanked by brighter ones, on the right. Double-decrement (B) and double-increment (D) inverted-White's illusions: the target flanked by dimmer bars looks lighter than the identical target flanked by brighter ones. Compare A with B, and C with D.

ignore luminances that are considered inconsequential, such as the luminance of the screen around the stimulus and the luminances in the laboratory. On the basis of the double-anchoring theory of lightness (Bressan, 2006a), we predict that remote luminances should have negligible effects under some conditions, but critical ones under others.

Grouping for lightness

According to Bressan's (2006a) double-anchoring theory (a development of the anchoring theory by Gilchrist et al., 1999), lightness determination involves Gestalt grouping. The grouping principles operating in the assessment of lightness (e.g., proximity, good continuation, depth similarity, luminance polarity, and luminance similarity) are the same as those at work in the formation of perceptual objects (Wertheimer, 1923) but have different relative weights to serve a different purpose, namely the estimation of reflectances (see also Bressan, 2007).

Bressan (2006a) provides a quantitative model of how the visual system might determine lightness. In this model, target lightness depends on a weighted average of contrasts of the target with other regions. The weights are relative, while their sum remains constant, and each weight is proportional to the grouping strength between the target and non-target regions. In the current research, we manipulate grouping by luminance polarity and luminance similarity, while keeping all other grouping factors constant (see also Bressan, 2006b).

In Figure 2C, the targets (dark gray) have a lower luminance than the background (midgray), whereas the contextual disks (white) have a higher luminance. That is, targets and contextual disks in Figure 2C have opposite luminance polarities and do not group well (Masin, 2003). The same is true in Figure 2F. In all other panels of Figure 2, targets and contextual disks have luminances that are either both higher, or both lower, than the luminance of the background. That is, in each of these figures, targets and contextual disks have the same

luminance polarity and group well (Masin, 2003). In this article, we show how simple grouping manipulations such as these allow us to derive several different, and in some cases counter-intuitive, predictions.

Inverted-dungeon illusion predictions

Figure 2A–B shows the dungeon illusion (Bressan, 2001, 2006a). The targets are midgray disks on a local background that is black in Figure 2A and white in Figure 2B. These targets are surrounded by contextual disks that, instead, are white in Figure 2A and black in Figure 2B. We will formally establish that the targets are more affected by the contextual disks than by the local background and that the display produces an effect opposite to that of simultaneous contrast, the *dungeon illusion*. The targets are perceived as darker, rather than lighter, in Figure 2A than in Figure 2B. Our predictions in this article, however, do not concern the dungeon illusion itself (Figure 2A–B), but rather the inverted-dungeon illusions (Figures 2C–D and 2E–F).

Compare Figures 2A and 2C. In Figure 2A, the targets and contextual disks are both lighter than the local background. In Figure 2C, instead, the targets are darker and the contextual disks are lighter than the local background. Thus, grouping by luminance polarity between the targets and contextual disks is good in Figure 2A and poor in Figure 2C. Similarly, grouping by luminance similarity between the targets and the contextual disks is stronger in Figure 2A than in Figure 2C (because the luminance of the target disks is lower in 2C than in 2A). Double-anchoring theory therefore predicts that target lightness will be less affected by the contextual disks in Figure 2C than in Figure 2A. That is, Figure 2C should give rise to either a weaker reversed-contrast effect than Figure 2A or to a regular contrast effect.

Compare Figures 2B and 2D. In Figure 2D, unlike in Figure 2B, the local background and the contextual disks both have higher luminances than the targets. Thus, whereas in Figure 2B the local background and the

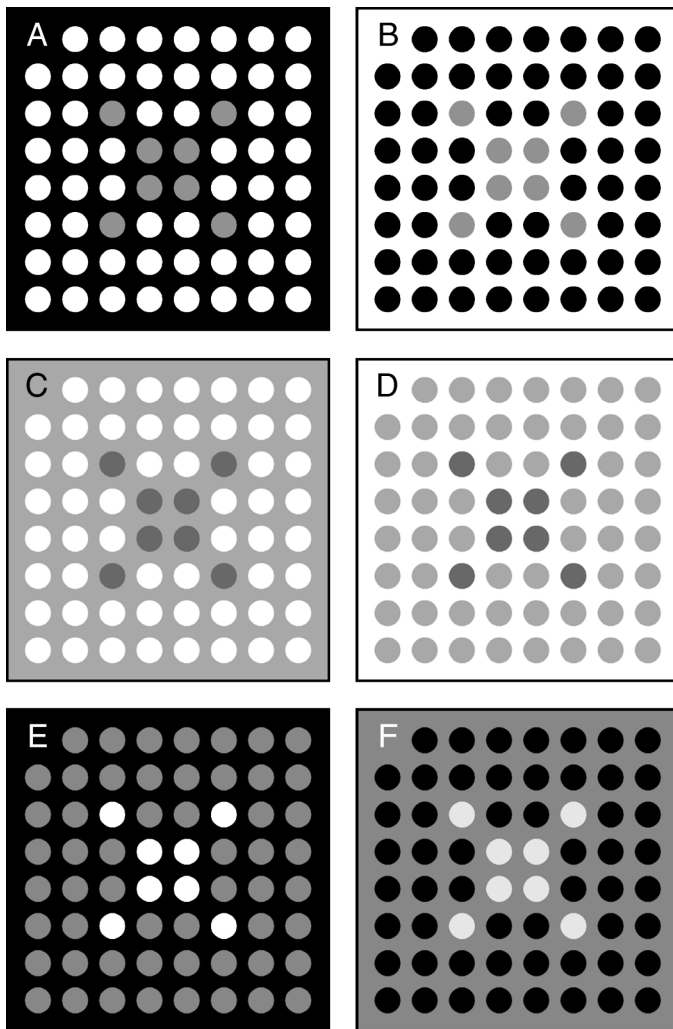


Figure 2. (A–B) Dungeon illusion (the name refers to a similarity between its original version, not shown here, and a drawing of a medieval prison gate; Bressan, 2001): the gray targets in A and B have the same luminance but are perceived as darker in A than in B. (C–D) Double-decrement inverted-dungeon illusion: the dark-gray targets in C and D have the same luminance but are perceived as lighter in C than in D. (E–F) Double-increment inverted-dungeon illusion: the light-gray targets in E and F have the same luminance but are perceived as lighter in E than in F.

contextual disks are expected to have opposite effects on target lightness, in Figure 2D they are expected to have similar effects. That is, double-anchoring theory predicts that Figure 2D, unlike Figure 2B, will lead to a simple simultaneous contrast effect.

From the comparisons of Figures 2A and 2C and of Figures 2B and 2D, it follows that whereas Figure 2A–B leads to a reverse-contrast effect, Figure 2C–D should lead to a weaker one, or to a regular simultaneous contrast effect. For analogous reasons, Figure 2E–F should also lead

to a weaker reverse-contrast effect than Figure 2A–B, or to a regular simultaneous contrast effect.

Remote luminance predictions

By definition, the sum of the relative weights that are assigned to grouping cues remains constant. This definition implies that whenever one cue gains weight, another must lose some. That is, whenever grouping between some regions is weakened, the grouping between other regions must strengthen.

As discussed in the previous section, grouping is relatively weak if targets and contextual disks have opposite luminance polarities (e.g., Figures 2C and 2F) and is relatively strong if they have the same luminance polarities (e.g., Figures 2D and 2E). When grouping between the targets and the contextual disks is weak, grouping between the targets and the local and remote backgrounds will be relatively strong. If Figures 2C–2F are each presented separately and their luminances are held constant, then a manipulation of the luminance of the remote surround (the computer screen on which they are presented) should have a larger effect on target lightness in Figures 2C and 2F than in Figures 2D and 2E. More precisely, we predict that when the remote surround has a lower luminance than the targets, it should lighten the targets more in Figure 2C than in 2D, and more in Figure 2F than in 2E. Conversely, when the remote surround has a higher luminance than the targets, it should darken the targets more in Figure 2C than in 2D, and more in Figure 2F than in 2E.

In the previous section, we predicted that the two inverted-dungeon displays (Figures 2C–D and 2E–F) should either yield weaker reverse-contrast effects than the dungeon display (Figure 2A–B), or a regular simultaneous contrast effect. In Figure 2C–D, a regular simultaneous contrast effect would consist in lighter targets in Figure 2C than in Figure 2D. We predicted that a remote surround with a lower luminance than that of the targets should lighten these targets more in Figure 2C than in Figure 2D. Hence, we also predict that if Figure 2C–D produces a simultaneous contrast effect, this should be larger when the remote luminance is low than when it is high.

Similarly, in Figure 2E–F, a regular simultaneous contrast effect should consist in darker targets in Figure 2F than in Figure 2E. We predicted that a remote surround with a higher luminance than that of the targets should darken these targets more in Figure 2F than in Figure 2E. Hence, we also predict that if Figure 2E–F produces a simultaneous contrast effect, this should be larger when the remote luminance is high than when it is low. That is, we predict that *the double-decrement inverted-dungeon illusion (Figure 2C–D) and the double-increment inverted-dungeon illusion (Figure 2E–F) will be affected in opposite ways by remote luminance.*

In two experiments, we formally establish the existence of the dungeon and inverted-dungeon illusions and test our predictions.

Methods

Subjects

Twenty-six naive observers participated in Experiment 1, and 33 different ones in Experiment 2.

Apparatus and stimuli

Stimuli similar to those shown in Figures 2A–2F were presented separately in the center of a calibrated BARCO monitor (1280 × 960 pixels), using a Prolog program on a Macintosh G4 computer. The experimental room was dark. The viewing distance was 60 cm. The stimuli consisted of matrices of 8 × 8 disks, 1 cm in diameter, on a 11 × 11-cm square (the *local background*). Eight of the central disks (gray) served as *targets*; the remaining ones were *contextual disks* (e.g., the white ones in Figure 2A).

The targets had a luminance of either 14.50 cd/m² (Figures 2A and 2B), 1.45 cd/m² (Figures 2B and 2C), or 39.96 cd/m² (Figures 2E and 2F). The luminance of the local background, the luminance of the contextual disks, and the luminance of the targets were different from each other and either 0.07 cd/m² (black), 5.70 cd/m² (dark gray), 14.50 cd/m² (light gray), or 82.88 cd/m² (white). An adjustable disk, 1 cm in diameter, was displayed at the bottom of the screen, in the center of a horizontal strip that was 2 cm high and 45 cm wide (as wide as the screen). The adjustable disk had an initial luminance that varied randomly between 3.54 and 6.55 cd/m², and the background strip had a luminance of either 0.07 cd/m² or 82.88 cd/m² in regular dungeon displays (Figures 2A–B), 82.88 cd/m² in double-decrement dungeon displays (Figures 2C and 2D), and 0.07 cd/m² in double-increment dungeon displays (Figures 2E and 2F).

Luminance matches between two regions are more difficult to make when their luminance polarities are different rather than the same (that is, matching two increments or two decrements is much easier than matching an increment and a decrement; Whittle, 1994). On trials with a double-decrement display (either Figure 2C or 2D), the adjustable disk was therefore also a decrement. For the same reason, on trials with a double-increment display (either Figure 2E or 2F), the adjustable disk was also an increment. On trials in which neither double decrements nor double increments were presented (either Figure 2A or 2B), the adjustable disk was a decrement on half of the trials and an increment on the other half.

Apart from the strip at the bottom, the rest of the monitor (the *remote background*) was always 0.07 cd/m² (perceived as black) in Experiment 1 and always 82.88 cd/m² (perceived as white) in Experiment 2. In both experiments, the plastic frame of the monitor was hidden by black cardboard.

Experiments 1 and 2 each contained 8 trials, presented in random order. The dungeon displays (Figures 2A and 2B) were shown once with the adjustable disk on black, and once with the adjustable disk on white; the double-decrement inverted-dungeon displays (Figures 2C and 2D) were shown once with the adjustable disk on white, and the double-increment inverted-dungeon displays (Figures 2E and 2F) were shown once with the adjustable disk on black.

Procedure

Observers adjusted the luminance of the adjustable disk, until its lightness matched that of the targets. For this purpose, two buttons could be pressed in the lower-right corner of the screen, one to increase the luminance of the adjustable disk and one to decrease it. The observers advanced to the next trial by pressing a third button, also in the lower-right corner of the screen.

Results

Consider first the results of Experiment 1 (Figure 3, top panel), in which the remote background was black. The data points labeled *incdec* (*D*) and *decinc* (*D*) show that the targets were seen as darker in Figure 2A (10.6 cd/m²) than in Figure 2B (18.5 cd/m²) when the adjustable patch was a luminance decrement relative to its background (paired-samples $t(25) = 8.42$, $p < .001$; all t -tests are two tailed). This means that Figure 2A–B gave rise to the dungeon illusion (in fact, not a single one of the 26 subjects saw a regular simultaneous contrast effect in this case, and only one of them failed to see the illusion).

The data points labeled *incdec* (*I*) and *decinc* (*I*) show a replication of this result with the adjustable patch being a luminance increment (4.5 cd/m² vs. 8.0 cd/m²; paired-samples $t(25) = 4.10$, $p < .001$). The data points labeled *decdec* (*D*) show that the targets were seen as lighter in Figure 2C (3.1 cd/m²) than in Figure 2D (1.5 cd/m²). Figure 2C–D did not give rise to the dungeon illusion but instead to a simultaneous contrast effect (paired-samples $t(24) = -6.78$, $p < .001$). Thus, the double-decrement dungeon display gives rise to an inverted-dungeon illusion, just like the double-decrement White display gives rise to an inverted-White illusion.

The data points labeled *incinc* (*I*), finally, show that the targets were perceived about equally light in Figure 2E (30.3 cd/m²) as in Figure 2F (32.9 cd/m²). Thus, the

stimulus of Figure 2E–F gave rise neither to the dungeon illusion nor to the inverted-dungeon illusion (paired-samples $t(25) = 0.95$, $p = .35$). In this case, therefore, double increments did not appear to have a similar effect on the dungeon illusion as on White’s illusion (which reverses when its targets are double increments). However, we have not considered remote effects yet, and these are important for the proper interpretation of these results.

Consider the results of Experiment 2 (Figure 3, bottom panel), in which the remote background was white. The data points labeled *incdec* (D) and *decinc* (D) show that in Experiment 2, just like in Experiment 1, the targets were seen as darker in Figure 2A (12.2 cd/m^2) than in Figure 2B (17.5 cd/m^2) when the adjustable patch had a white background (paired-samples $t(32) = 5.61$, $p < .001$). The data points labeled *incdec* (I) and *decinc* (I) show a replication of this result with the adjustable patch on a black background (6.8 cd/m^2 vs. 10.2 cd/m^2 ; paired-samples $t(32) = 5.66$, $p < .001$).

The data points labeled *decdec* (D) show that the targets were seen as lighter in Figure 2C than in Figure 2D (2.1 cd/m^2 vs. 1.3 cd/m^2 ; paired-samples $t(32) = -3.65$, $p = .001$), just as in Experiment 1. However, the data points labeled *incinc* (I) show that, unlike in Experiment 1, the targets in Figure 2E (32.3 cd/m^2) were now perceived as lighter than in Figure 2F (27.7 cd/m^2). Thus, the display of Figure 2E–F now did give rise to a simultaneous contrast effect and thereby to an inverted-dungeon illusion (paired-samples $t(32) = -2.96$, $p = .006$).

The only difference between Experiments 1 and 2 was the luminance of the remote background, which was black in Experiment 1 and white in Experiment 2. The question now is whether this difference affected the inverted-dungeon illusion in the particular ways that we had predicted based on the double-anchoring theory.

We predicted that the double-decrement inverted-dungeon illusion (Figure 2C–D) should be bigger when the remote luminance is low (Experiment 1) than when it is high (Experiment 2). Figure 3 shows that the difference between the two data points labeled *decdec* (D) was indeed larger in Experiment 1 than in Experiment 2 (respectively, 1.6 cd/m^2 and 0.9 cd/m^2 ; independent-samples $t(56) = 2.10$, $p = .040$). We also predicted that the double-increment inverted-dungeon illusion (Figure 2E–F) should be bigger when the remote luminance is high (Experiment 2) than when it is low (Experiment 1). Figure 3 shows that the difference between the two data points labeled *incinc* (I) was indeed larger in Experiment 2 than in Experiment 1 (respectively, 4.9 cd/m^2 and -2.6 cd/m^2 , where the negative value indicates that the effect went in the opposite direction; independent-samples $t(57) = 2.10$, $p = .019$). It is thus clear that the fact that the double-increment inverted-dungeon illusion only appeared in Experiment 2 and not in Experiment 1 was due to remote luminance effects, and that these effects followed the predictions based on Bressan’s (2006a) double-anchoring theory.

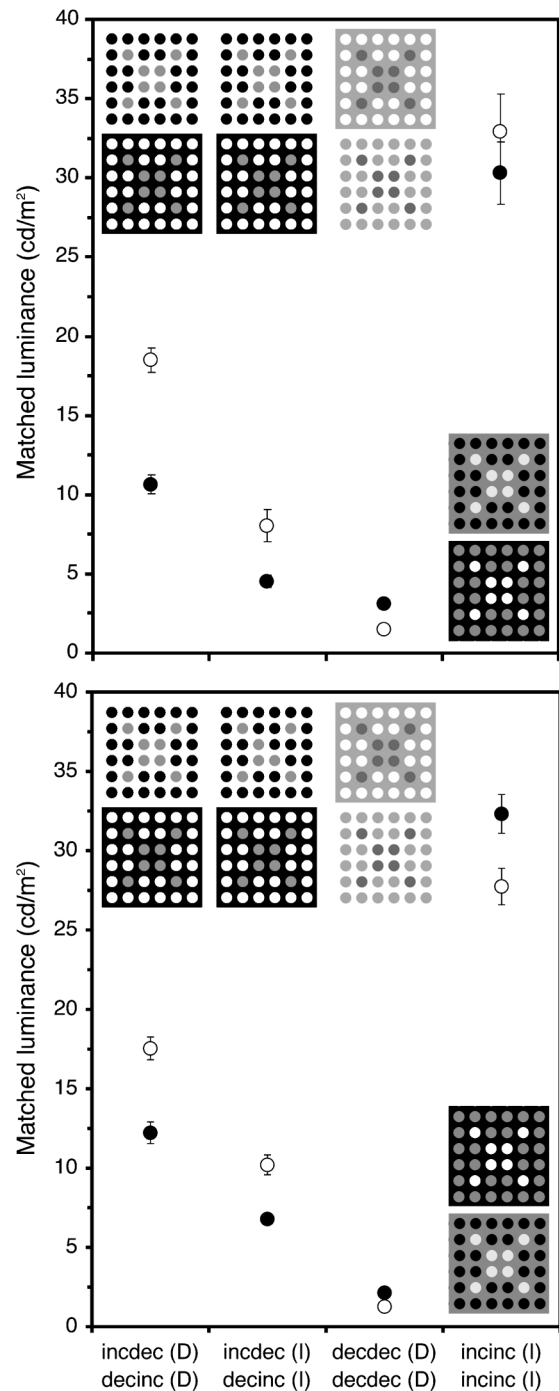


Figure 3. Ordinate: mean adjusted luminances ($\pm 1\text{SEM}$) in Experiments 1 and 2 (top and bottom panels). In each panel, the upper (lower) insets correspond to the upper (lower) data points. Open and filled symbols stand for bright and dim local backgrounds. Open symbols above filled ones represent dungeon illusions; filled symbols above open ones represent simultaneous contrast effects. Abscissa: target luminances could be increments (inc) or decrements (dec) relative to the contextual disks and the background, respectively (top labels refer to top insets and bottom labels refer to bottom insets), and the initial adjustable-disk luminance could be either a decrement (D) or an increment (I) relative to its background.

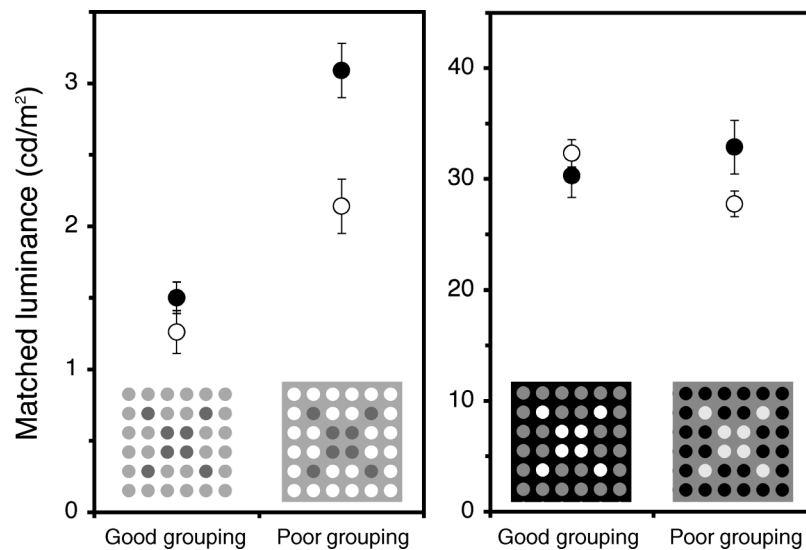


Figure 4. Mean adjusted luminances (± 1 SEM) in Experiments 1 and 2, for the double-decrement (left panel) and double-increment (right panel) inverted-dungeon displays. In Experiment 1 (filled symbols), the remote background was black; in Experiment 2 (open symbols), it was white. “Good grouping” and “poor grouping” refer to the grouping between the targets and the contextual disks.

Figure 4 reveals the effects of remote luminance in more detail by contrasting the results of Experiment 1 (black remote background, filled symbols) with those of Experiment 2 (white remote background, open symbols).

The left panel shows the results for the two double-decrement displays (Figure 2C–D), and the right panel for the two double-increment displays (Figure 2E–F). As predicted, in both panels, the left two data points show that when the targets grouped well with the contextual disks, by luminance polarity and similarity (Figures 2D and 2E), their lightness was not significantly affected by the remote background luminance (independent-samples $t(56) = 1.21$, $p = .23$ and $t(57) = -.91$, $p = .37$, respectively). As also predicted, in both panels, the right two data points show that when luminance polarity and similarity discouraged the grouping between targets and contextual disks (Figures 2C and 2F), the target lightness was significantly affected by the remote background luminance (independent-samples $t(57) = 3.57$, $p = .001$ and $t(57) = 2.05$, $p = .045$, respectively).

Remote luminance was lower in Experiment 1 than in Experiment 2. In both panels of Figure 4, the right two data points show that, as a consequence, the targets were seen as lighter in Experiment 1 than in Experiment 2.

Discussion

We have formally demonstrated the existence of the dungeon and inverted-dungeon illusions (Bressan, 2001, 2006a). Importantly, no spatial-frequency-filtered version of Figures 2C–2F can produce luminance profiles

suggestive of the lightness perceived by our subjects. We cannot exclude that multiscale banks of filters might be able to produce the proper output. However, Economou, Zdravkovic, and Gilchrist (2007) have shown that an influential multiscale filtering model (Blakeslee & McCourt, 1999, 2004) does not even provide a good fit for the simultaneous contrast effect (whereas the double-anchoring model does: see Bressan, 2006a).

Unlike White’s, the dungeon display does not contain junctions. Importantly again, no spatial-frequency-filtered version of any of our figures can produce the junctions that would be necessary to support a junction theory of our results. The dungeon and White’s illusions both consist in effects opposite to simultaneous contrast and, as we have shown here, both are inverted under the same circumstances (i.e., when the targets are either double decrements or double increments relative to their surrounding regions). We therefore conclude that the dungeon and White illusions are most likely due to one common underlying mechanism. Any theory of White’s illusion must also be able to explain the dungeon illusion if it is to be convincing.

Incidentally, it is interesting that the dungeon illusion, just like White’s illusion (Gindy, 1963; Wright, 1969), appears to have its equivalent in the color domain too (Bressan, da Pos, & Kramer, 2007). For example, the targets in the top two panels of Figure 5 are all the same shade of gray, but look bluish on the left, and greenish on the right. If the contextual disks are removed, as in the bottom two panels, the reverse is seen (i.e., the targets on the left look greenish and those on the right bluish). Thus, the contextual disks in the colored dungeon display produce a color effect that is opposite to local color contrast, just like the contextual disks in an achromatic

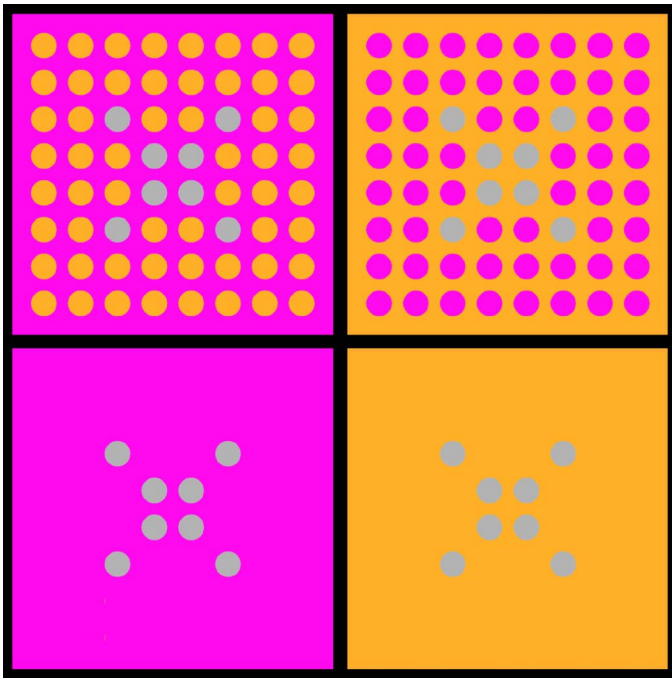


Figure 5. In each panel, the central eight disks are gray, but they look bluish in the top left panel and greenish in the top right panel (color version of the dungeon illusion), whereas they look greenish in the bottom left panel and bluish in the bottom right panel (simultaneous color contrast).

dungeon display produce a lightness effect that is opposite to local lightness contrast.

Our main goal in this article was to investigate the effects of remote luminance on lightness. We found that the double-decrement dungeon display gave rise to an inverted-dungeon illusion, and that, as predicted, this illusion was larger when the remote luminance was low than when it was high. The double-increment dungeon display also gave rise to an inverted-dungeon illusion. However, this illusion only emerged when the remote luminance was high, for which we predicted it to be larger, and not when the remote luminance was low, for which we predicted it to be smaller. In general, we found that targets are more affected by remote luminance if they group poorly, than if they group well, with contextual elements.

On the basis of the double-anchoring theory, it is straightforward to derive similar predictions for White's illusion as for the dungeon illusion. In the double-decrement White illusion (Figure 1B), the target on the left is a luminance decrement, whereas the stripe on which it is located is a luminance increment, relative to their common surround (the dim flanking bars). In this case, the target and the stripe have opposite luminance polarities and hence do not group well. In contrast, the target on the right and the stripe on which it is located are both luminance decrements relative to their common surround (the bright flanking bars). In this case, the target and stripe

have the same luminance polarity and group much better. Consequently, we predict that the lightness of the target on the left should be more affected by remote luminance than the lightness of the target on the right.

These predictions have two corollaries. The first corollary is that the target on the left in Figure 1B should lighten more than the one on the right when a white remote surround is replaced by a black one. That is, the double-decrement inverted-White illusion (Figure 1B) should be larger when printed on a black than on a white page (indeed, on the white journal page, the direction of the illusion is not clear). The second corollary is that the target on the right in Figure 1D should darken more than the one on the left when a black remote surround is replaced by a white one. That is, the double-increment inverted-White illusion (Figure 1D) should be larger when printed on a white than on a black page (indeed, on the white journal page, the illusion in Figure 1D is much clearer than the one in Figure 1B). Future research will have to test our predictions for the inverted-White illusion experimentally.

In the meanwhile, our present results with the dungeon and inverted-dungeon illusions stress the importance of grouping cues other than T-junctions (such as luminance polarity and similarity), support Bressan's (2006a) double-anchoring theory, and challenge other accounts by showing that remote luminances can produce significant and entirely unexpected lightness effects under some specific conditions while producing no effects under others.

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References

- Adelson, E. H. (2000). Lightness perception and lightness illusions. In M. Gazzaniga (Ed.), *The new cognitive neurosciences* (2nd ed., pp. 339–351). Cambridge MA: MIT Press.
- Anderson, B. L. (1997). A theory of illusory lightness and transparency in monocular and binocular images: The role of contour junctions. *Perception*, *26*, 419–453. [[PubMed](#)]

- Blakeslee, B., & McCourt, M. E. (1999). A multiscale spatial filtering account of the White effect, simultaneous brightness contrast and grating induction. *Vision Research*, *39*, 4361–4377. [PubMed]
- Blakeslee, B., & McCourt, M. E. (2004). A unified theory of brightness contrast and assimilation incorporating oriented multiscale spatial filtering and contrast normalization. *Vision Research*, *44*, 2483–2503. [PubMed]
- Bressan, P. (2001). Explaining lightness illusions. *Perception*, *30*, 1031–1046. [PubMed]
- Bressan, P. (2006a). The place of white in a world of grays: A double-anchoring theory of lightness perception. *Psychological Review*, *113*, 526–553. [PubMed]
- Bressan, P. (2006b). Inhomogeneous surrounds, conflicting frameworks, and the double-anchoring theory of lightness. *Psychonomic Bulletin & Review*, *13*, 22–32. [PubMed]
- Bressan, P. (2007). Dungeons, gratings, and black rooms: A defense of double-anchoring theory and a reply to Howe et al. (2007). *Psychological Review*, *114*, 1111–1114. [PubMed]
- Bressan, P., da Pos, O., & Kramer, P. (2007). *Reversals of color contrast*. Manuscript in preparation.
- Dakin, S. C., & Bex, P. J. (2003). Natural image statistics mediate brightness ‘filling in.’ *Proceedings of the Royal Society B: Biological Sciences*, *270*, 2341–2348. [PubMed] [Article]
- Economou, E., Zdravkovic, S., & Gilchrist, A. (2007). Anchoring versus spatial filtering accounts of simultaneous lightness contrast. *Journal of Vision*, *7*(12):2, 1–15, <http://journalofvision.org/7/12/2/>, doi:10.1167/7.12.2. [PubMed] [Article]
- Gilchrist, A., Kossyfidis, C., Bonato, F., Agostini, T., Cataliotti, J., Li, X., et al. (1999). An anchoring theory of lightness perception. *Psychological Review*, *106*, 795–834. [PubMed]
- Gindy, S. S. (1963). *Techniques for subjective colour measurement and their application to colour contrast phenomena*. Unpublished doctoral dissertation, University of London, London, UK.
- Masin, S. C. (2003). Effects of algebraic and absolute luminance differences on achromatic surface grouping. *Perception*, *32*, 615–620. [PubMed]
- Ripamonti, C., & Gerbino, W. (2001). Classical and inverted White’s effects. *Perception*, *30*, 467–488. [PubMed]
- Ross, W. D., & Pessoa, L. (2000). Lightness from contrast: A selective integration model. *Perception & Psychophysics*, *62*, 1160–1181. [PubMed]
- Spehar, B., Gilchrist, A., & Arend, L. (1997). Qualitative boundaries critical in White’s effect and square wave brightness induction: A reply to Kingdom et al. (1997). *Vision Research*, *37*, 1044–1047.
- Wertheimer, M. (1923). Untersuchungen zur Lehre von der Gestalt. *Psychologische Forschung*, *4*, 301–350.
- White, M. (1979). A new effect of pattern on perceived lightness. *Perception*, *8*, 413–416. [PubMed]
- Whittle, P. (1994). Contrast brightness and ordinary seeing. In A. Gilchrist (Ed.), *Lightness, brightness, and transparency* (pp. 111–158). Hillsdale, NJ: Erlbaum.
- Wright, W. D. (1969). *The measurement of colour*. London: Hilger.
- Yang, Z., & Purves, D. (2004). The statistical structure of natural light patterns determines perceived light intensity. *Proceedings of the National Academy of Sciences of the United States of America*, *101*, 8745–8750. [PubMed] [Article]