Surround articulation. I. Brightness judgments

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It has been hypothesized that brightness judgments require an estimate of the illuminant. Making this estimate is difficult since luminance edges can be the result of changes in either illumination or reflectance. Articulation is the addition of equally spaced incremental and decremental patches within a surround while preserving the surround's space-average luminance. It is proposed that articulation enhances the inference that the surround's luminance edge is due to a change in illumination rather than in reflectance. Articulation results in a corresponding shift in brightness judgments for test-patch increments but not for decrements. This finding concurs with Arend and Goldstein's [J. Opt. Soc. Am. A **4**, 2281 (1987)] reported shifts in brightness as simple center-surround stimuli are transformed into more complex ecologically valid Mondrians.

OCIS codes: 330.0330, 330.1690, 330.1720.

1. INTRODUCTION

The incremental test patch on the dim surround in Fig. 1(a) appears brighter[1,2] than the incremental comparison patch of the same luminance on the bright surround. Most models of simultaneous contrast propose that this is due to discordant amounts of local contrast induction produced by surrounds that are perceived to differ in reflectance.[3] It may also be, however, that the two surrounds appear to share a common reflectance while being under different levels of illumination. In this case, the brightness difference would be the result of an inferred illumination gradient.[4] Since in either case the test would appear brighter, some means of differentiating which process is occurring is warranted.

This study will present data that support the hypothesis that adding articulation to the surrounds of simple center-surround stimuli (i.e., introducing several patches with different gray levels while preserving the surround space-average luminance) strengthens the inference that the two surrounds share a common reflectance and are under different levels of illumination. The resulting level of inferred illumination is more plausible than one estimated when a simple center-surround stimulus is used that underestimates the illumination gradient. Paradoxically, this makes brightness judgments diverge further from a veridical physical luminance match as a surround becomes more complex.

It may be, however, that local contrast between the test and the comparison patches and their respective surrounds is all that is used to make brightness judgments and that the potential illumination edge between the two surrounds (i.e., the global contrast) is neither calculated nor used. The local contrast ratio between a test patch and its surround is reduced more when the surround has articulation than when the surround is uniform. This suggests that when the surrounds include a gray scale, induction is enhanced, making the test patch appear brighter or the comparison patch appear dimmer, or both.

Thus the effect of articulation is potentially twofold. It is hypothesized that it provides a nonadjacent gray scale that can serve as an anchor[5] against which brightness judgments are made. It is also hypothesized that it strengthens the inference of an illumination gradient between backgrounds that have different mean luminance levels.

The hypothesis that articulation generates an inferred illumination gradient explains the brightness differences found between center-surround stimuli and complex Mondrian patterns of the same space-average luminance obtained by Arend and Goldstein.[6] In agreement with their findings, brightness judgments of incremental test patches on a uniform-surround approach luminance matches, while judgments of the same patches on a comparable Mondrian (articulation) surround fall closer to reflectance matches. Brightness judgments of decremental test patches, however, remain close to reflectance matches whether the patches are surrounded by a uniform surround or a Mondrian. The current articulation study systematically alters center-surround stimuli to appear increasingly like Mondrians so that we can better understand whether and how inferring the illuminant produces these differential shifts in the brightness of increments and decrements.

In an effort to extend the findings of Arend and Goldstein,[6] surround articulation has been generated in a specific way. In essence, four articulation patches (each being 4% the area of each surround) are positioned within each surround. Each articulation patch is either an increment or a decrement by either 1.4% or 2.8% of the immediate surround luminance level. This makes the local space-average luminance of the four articulation patches identical to the surround luminance in which they are located [see Fig. 1(b) and Table 1]. Across conditions, the number of articulation patches is systematically increased by reiterating the initial four articulation patches to make either eight [Figs. 2(a) and 2(b)] or sixteen articulation patches per surround [Fig. 3(a)]. This process can be extended to ultimately create the appearance of two Mondrians (i.e., twenty articulation patches and five originally colored patches) each under a separate illuminant [Fig. 3(b)].

Adding articulation to a uniform surround allows for a progression from a simple center-surround stimulus, which many researchers consider flawed owing to its intrinsic ambiguity of reflectance versus illumination edges,[7,8] toward more ecologically rich stimuli, such as Mondrians. Previous studies by Arend and Spehar[7,9] centered a center surround within a larger Mondrian to alter the perception of the center surfaces' color. They demonstrated that surface color is not determined locally. However, their paradigm did not require them to set the space-average luminance of the Mondrian to match the luminance of the inner surround. Thus, while their Mondrian provided a useful gray scale, it did not maintain a constant luminance level. Work by Schirillo and Shevell[3] using checkerboard displays showed that the bright checks of such stimuli contribute more to the induction process of a center test square than do the dim checks. An inhomogeneous surround, therefore, may produce an effect that is not comparable with its space-average homogeneous surround. Generating a Mondrian by using articulation holds the local space-average luminance constant. This allows the effects of articulation to be studied

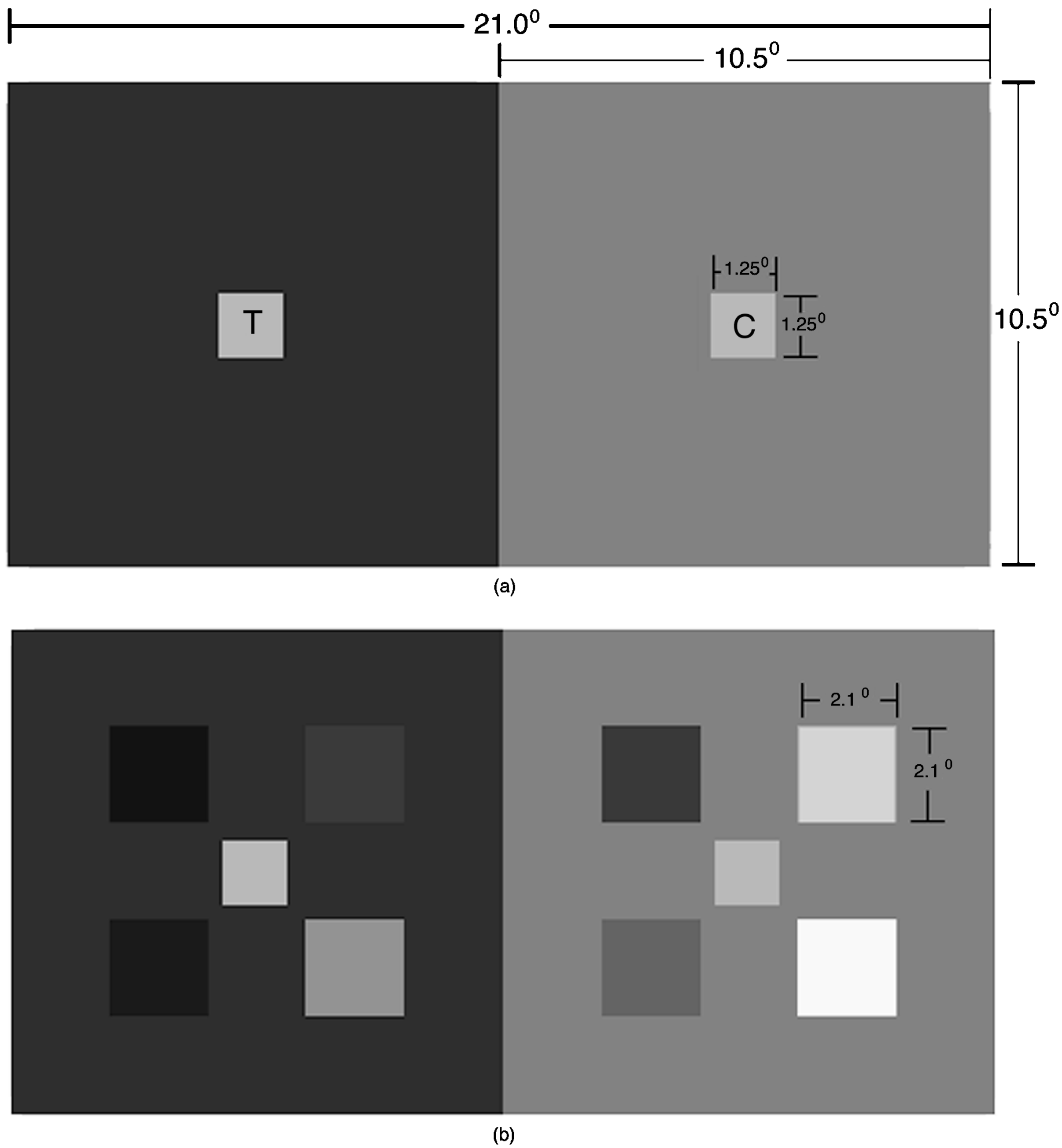


Fig. 1. (a) Test and comparison patches within two uniform surrounds; (b) four articulation patches accompany test and comparison patches within each of two surrounds. All patch intensities are listed in Table 1, where the test and comparison articulation luminance A is the 11:00 patch; articulation B is at 7:00; articulation C is at 1:00; and articulation D is at 5:00.

Table 1. Luminances (cd/m^2) for Articulation Patches on Various Surround Ratios

Surround Ratio	Test Articulate A	Test Articulate B	Test Surround	Test Articulate C	Test Articulate D	Comparison Articulate A	Comparison Articulate B	Comparison Surround	Comparison Articulate C	Comparison Articulate D
Experiments 1, 3, 4										
Uniform Surround										
6:1			3.63					21.72		
9:1			3.63					31.05		
12:1			3.63					44.40		
Articulated Surround										
6:1	1.78	2.54	3.63	5.19	7.43	10.62	15.19	21.72	31.05	44.40
9:1	1.78	2.54	3.63	5.19	7.43	15.19	21.72	31.05	44.40	63.49
12:1	1.78	2.54	3.63	5.19	7.43	21.72	31.05	44.40	63.49	90.79
Experiment 2										
9:1 10%	3.27	3.27	3.63	3.99	3.99	27.94	27.94	31.05	34.15	34.15
9:1 15%	3.09	3.09	3.63	4.17	4.17	26.39	26.39	31.05	35.71	35.71
9:1 25%	2.72	2.72	3.63	4.54	4.54	23.29	23.29	31.05	38.81	38.81
9:1 50%	1.81	1.81	3.63	5.44	5.44	15.52	15.52	31.05	46.57	46.57
9:1 75%	0.91	0.91	3.63	6.35	6.35	7.76	7.76	31.05	54.34	54.34
9:1 100%	0.00	0.00	3.63	7.26	7.26	0.00	0.00	31.05	62.10	62.10

while also providing a gray scale [compare Fig. 1(a) with Fig. 3(b)].

2. METHOD

A. Observers

Three observers were tested. All had normal or corrected acuity (20/20). Author JAS, a 41-year-old male, was knowledgeable about the experimental paradigm and had prior experience making brightness judgments using complex achromatic displays. JCS (a 21-year-old female) and TBO (a 22-year-old male) were inexperienced observers and naïve regarding the experimental design.

B. Apparatus

Stimuli were generated with a Power Macintosh 7600/132, and were presented on an accurately calibrated Radius PressView 17SR 17-in. (42.5-cm) color monitor. The 832×624 pixel screen produced achromatic stimuli at CIE chromaticity $x = 0.27$, $y = 0.28$. The scan rate was 75 Hz noninterlaced. The chromaticity of each phosphor was measured spectroradiometrically. The red, green, and blue guns were linearized by use of an 8-bit look-up table. The luminance set by the software did not vary appreciably over the effective viewing area. Luminance was approximately constant ($\pm 3\%$) within the central region of the screen that displayed the test and comparison patterns.

C. Stimuli

Observers viewed the monitor at a distance of 67 cm in a dark room. The CRT displayed the stimuli on an otherwise dark screen. Each uniform surround was 10.5° × 10.5° [Fig. 1(a)]. A 1.25° × 1.25° comparison patch (denoted C) was centered within the right surround. The computer varied the comparison-patch luminance from trial to trial over ten steps, within a range from 6.8 to 68 cd/m^2. The order of presentation was randomized. A 1.25° × 1.25° test patch (denoted T) was centered within the left surround. Observers used a joystick to vary the luminance of the test in either large (2.0 cd/m^2) or fine (0.16 cd/m^2) linear steps. This was done by either moving the stick forward and backward (large steps) or left and right (small steps). Pressing a button signaled that a satisfactory match had been achieved, at which point the test luminance was recorded and the trial ended. Between trials the test and comparison patches returned to the luminance level of their immediate surround for 3 s. Then the next trial began. Each session took approximately 1 h. To ensure that observers' measurements did not drift over sessions, the subjects repeated experiment 1 after experiment 4. There were no systematic changes in the pattern of results.

D. Procedure

Observers participated in several practice sessions before beginning the reported measurements. They maintained a stable head position with a chin rest. Observers dark adapted for 3 min and then light adapted for 3 min to a uniform field at the luminance level of the mean of the test- and comparison-surround luminances of the stimulus condition that immediately followed. Thus, for the 6:1, 9:1, and 12:1 surround ratios from experiments 1 and 3, the light-adapted screen was 12.67 cd/m^2, 17.34 cd/m^2, and 24.01 cd/m^2, respectively. In experiment 4 the light-adapted screen was 13.76 cd/m^2 in the 17:1 surround ratio condition. Then the test and comparison patches were presented as described above.

No more than six experimental conditions were embedded in a single session. Three repetitions of each comparison-patch luminance within each condition were presented in a session. The mean of these three repetitions within a session was taken as the measurement for that session. At most, two sessions were run on the same day. The means and standard errors shown in plots are based on repeated measurements from three separate sessions.

Observers used a method of adjustment to vary the luminance of the test patch (T) to match the brightness of the comparison patch (C). That is, they were told to adjust the test patch to appear identical to the comparison patch in apparent luminance.[6,10] They were also told to spend about the same amount of time looking at the right and left halves of the display by alternating their gaze between the two halves about once every 2 s. Observers were not told that the two halves of the display differed by a constant. The stimuli were large by design. The center test and comparison patches were separated by 10 deg to minimize local adaptation caused by steady fixation and to encourage eye movements across the center of the display. The data show little variability, suggesting that adaptation was stable and complete.

3. EXPERIMENTS

A. Experiment 1: Uniform versus Articulation Surrounds

Determining when the global luminance edge between the two surrounds in Fig. 1(a) will be classified as being

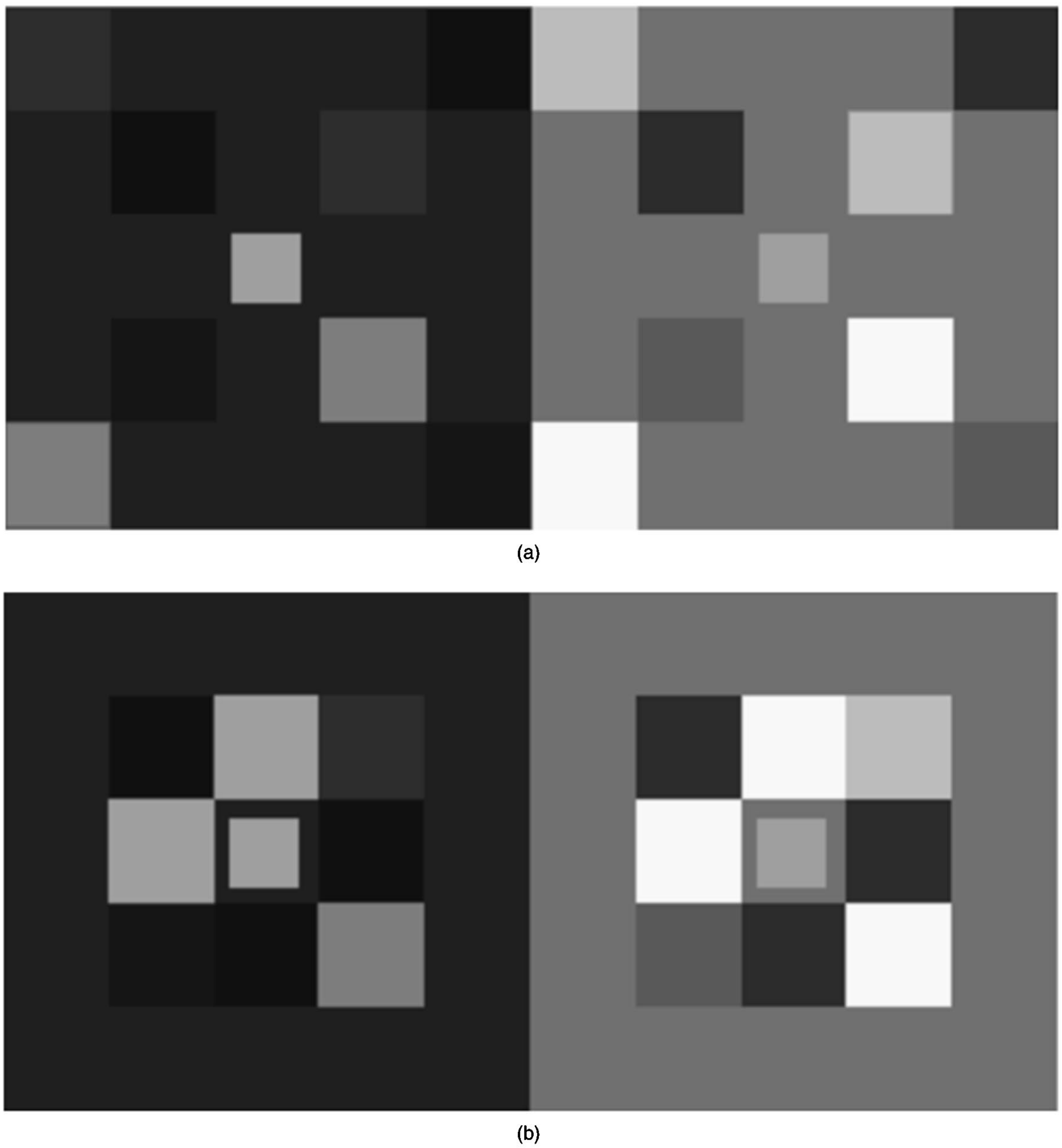
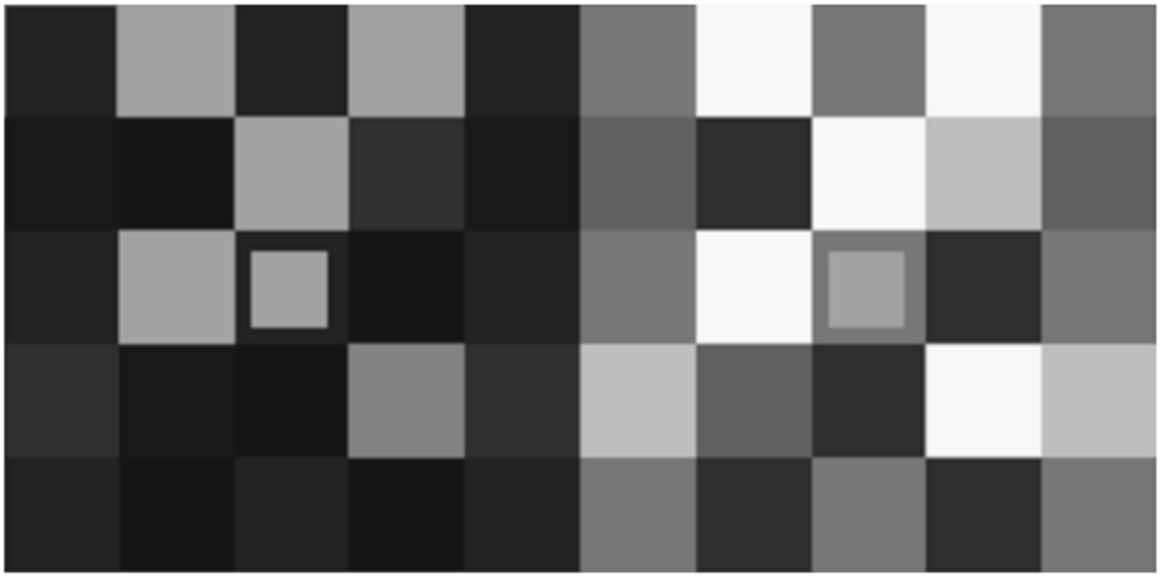
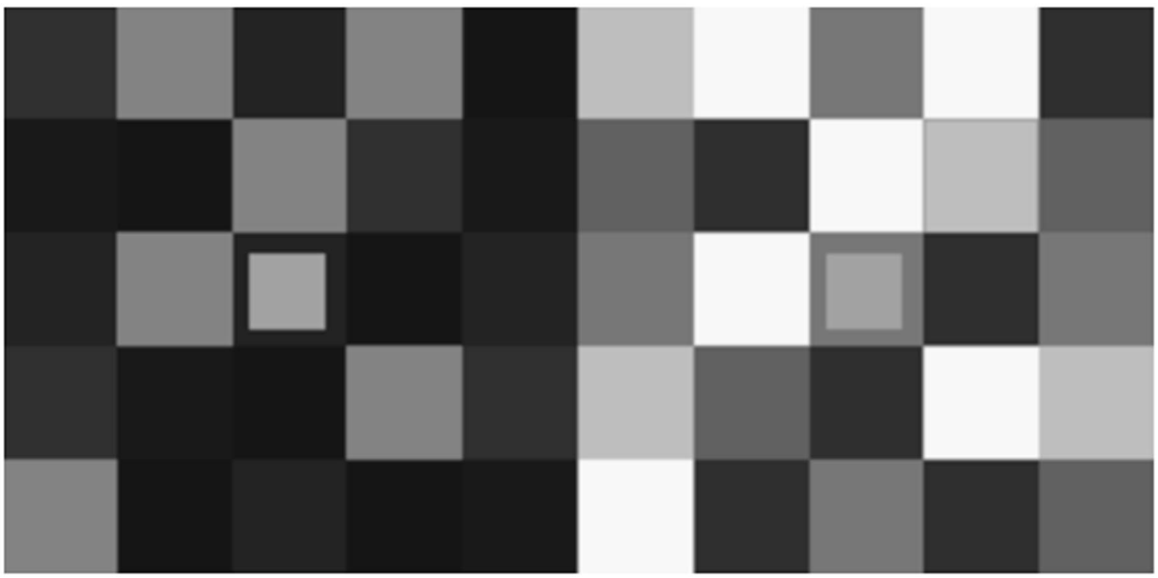


Fig. 2. (a) Eight dispersed articulation patches accompany test and comparison patches within each of two surrounds; (b) eight continuous articulation patches accompany test and comparison patches within each of two surrounds.



(a)



(b)

Fig. 3. (a) Sixteen articulation patches accompany test and comparison patches within each of two surrounds; (b) twenty articulation patches accompany test and comparison patches within each of two surrounds. This is also called a Mondrian.

due to a difference in either illumination or reflectance is necessary to understanding how brightness judgments are made.[7,9,11] In the following experiment, articulation will be used to vary brightness judgments in such a way as to suggest that observers have increased the inference that the global luminance edge is an illumination edge rather than a reflectance edge.

The luminance ratio between surrounds differed between blocks of trials and could be 6:1 (test surround = 3.63 cd/m^2, comparison surround = 21.72 cd/m^2), 9:1 (test surround = 3.63 cd/m^2, comparison surround = 31.05 cd/m^2), or 12:1 (test surround = 3.63 cd/m^2, comparison surround = 40.40 cd/m^2) (Table 1). As expected, when the luminance of the test patch was equal to the luminance of the comparison patch, the test appeared too bright. Observers therefore reduced the luminance of the test patch to achieve a brightness match (Fig. 4; 6:1 open squares, 9:1 open circles, 12:1 open diamonds). As a reference, the 45° dotted line in Fig. 4 is a theoretical equal-luminance match. As the luminance ratio increased between surrounds, observer JCS, in particular, decreased the intensity of the test patch away from a physical luminance match. That is, as the comparison surround was made brighter and approached the luminance of a given center comparison patch, she set the luminance of the test patch closer to the luminance of the test surround. Observer TBO did this also at higher comparison-patch intensities. This suggests that although naïve observers were instructed to match the absolute luminance levels of the test and comparison patches, their actual brightness matches were sensitive to local contrast ratios.

Intermixed with the three uniform-surround conditions were three conditions in which the surrounds had articulation. Each of these surrounds had four 2.1° square patches surrounding the small center test and comparison patches [Fig. 1(b)]. Two of the articulation patches on each surround were decrements. One was 1.43% (i.e., articulation patch B, lower left corner) and the other was 2.86% (i.e., articulation patch A, upper left corner) less intense than the luminance of the surround it was placed on. The other two articulation patches on each surround were increments. One was 1.43% (i.e., articulation patch C, upper right corner), and the other was 2.86% (i.e., articulation patch D, lower right corner) more intense than the luminance of the surround it was placed on. This made the local space-average luminances identical in the uniform-surround and the articulation-surround conditions (Table 1: articulation surrounds 6:1, 9:1, and 12:1).

On the articulation surrounds, observers again varied the luminance of the test to match the brightness of the comparison patch. As with the uniform-surround luminance ratios, the articulation surrounds' local space-average luminance ratios were 6:1, 9:1, or 12:1. With an articulation surround, the test patch appeared even brighter, or the comparison patch appeared even dimmer, than with a uniform surround. That is, observers reduced the intensity of the test on the articulation-surround compared with the comparable uniform-surround condition (Fig. 4, filled versus open symbols). Thus, brightness judgments more closely approximated equal local contrast ratios when articulation surrounds were used than with uniform surrounds. It is also important to notice that with uniform surrounds, brightness judgments showed an abrupt increase in test intensity when the comparison-patch luminance changed from a decrement to an increment. This abrupt luminance jump was greatly reduced when the surround had articulation.

Figure 5 replots the decrement data of Fig. 4 and includes theoretical 6:1, 9:1, and 12:1 equal-ratio matches as dashed lines. For experienced observer JAS the pattern for increments is similar to that for decrements. That is, with surround articulation, the test patch was reduced in luminance in comparison with the uniform-surround condition. However, for naïve observers JCS and TBO, both articulation- and uniform-surround conditions more closely resembled reflectance matches than luminance matches. This closely parallels the findings of Arend and Goldstein[6] for decrements.

B. Experiment 2: Articulation at Various Gray Levels

Related work by Chubb and colleagues[12] demonstrates that as the variability increases within a textured surround, the apparent contrast of a textured central disk can be reduced by almost 50%. To understand better the effects of surround articulation on a homogeneous test patch, in the following experiment we varied the level of articulation of the 9:1 surround ratio gray scale of experiment 1 from 0% to 100%. The intensities of the four articulation patches were 0% (uniform surround), ±10%, ±15%, ±25%, ±50%, ±75%, or ±100% of each surround (Table 1; Only JAS ran ±75% instead of ±15%). In making brightness matches, observers decreased the intensity of the test patch as the gray-scale range increased (Fig. 6). This suggests that as the range of articulation increases (toward 100%), observers are inferring that the illumination gradient increases, which is what makes either the test appear increasingly brighter or the comparison appear increasingly dimmer, or both.

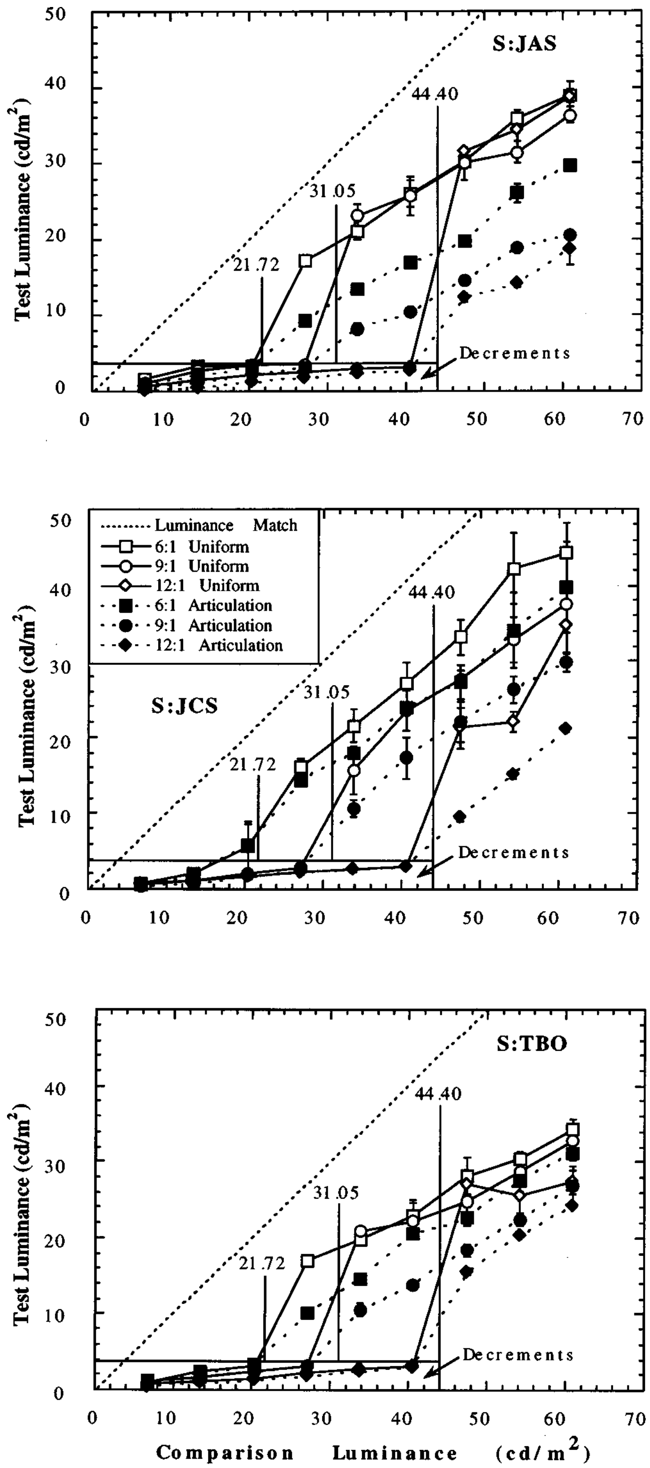


Fig. 4. Brightness matches for 6:1, 9:1, and 12:1 uniform (open squares, circles, and triangles, respectively) and articulation surrounds (filled squares, circles, and triangles, respectively) for three observers.

C. Experiment 3: Articulation and Uniform Surrounds Combined

If articulation facilitates the inferring of an illumination gradient, it is possible that articulation of only one surround while leaving the adjacent surround uniform would reduce the ability to infer the illumination gradient by half. This is because the observers could estimate the illuminant on the articulation surround but not on the adjacent uniform surround. The 6:1 and 9:1 surround ratios from experiment 1 were again used, with either only the left-hand test surround having articulation while the right-hand comparison surround remained uniform or

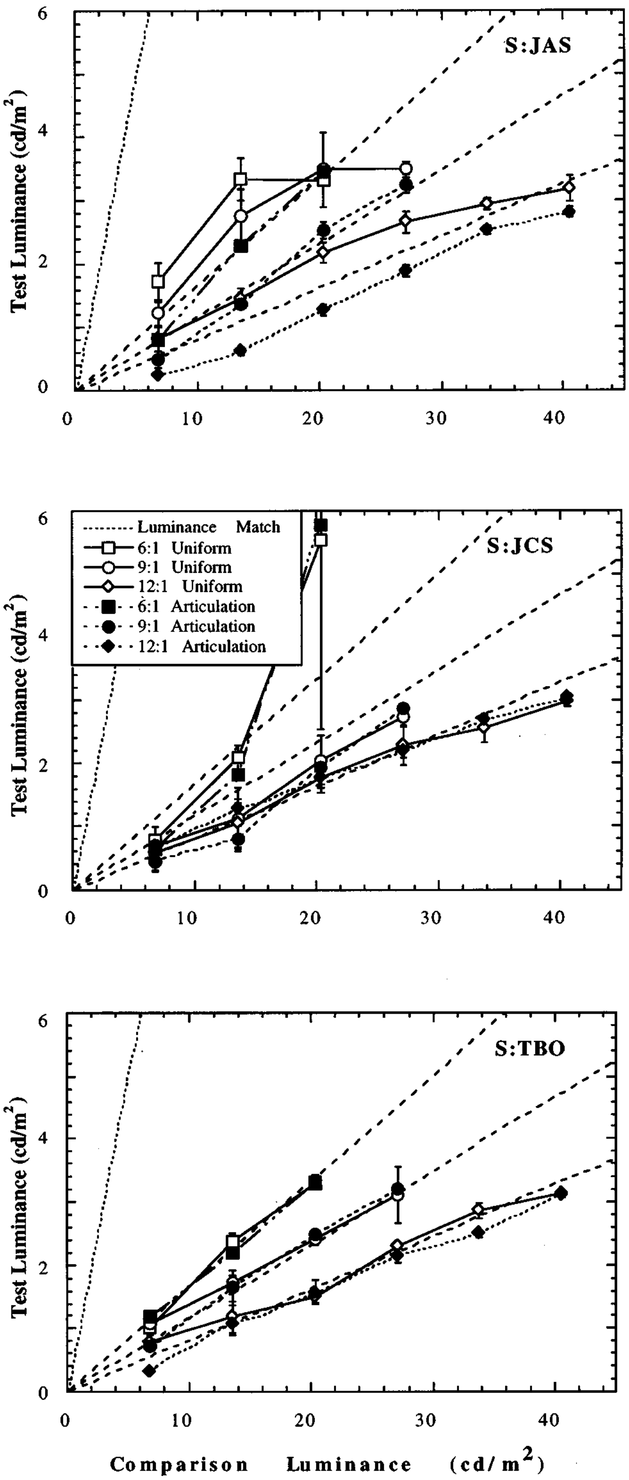


Fig. 5. Decremental brightness matches (replotted from Fig. 4) for 6:1, 9:1, and 12:1 uniform (open squares, circles and triangles, respectively) and articulation surrounds (filled squares, circles, and triangles, respectively) for three observers.

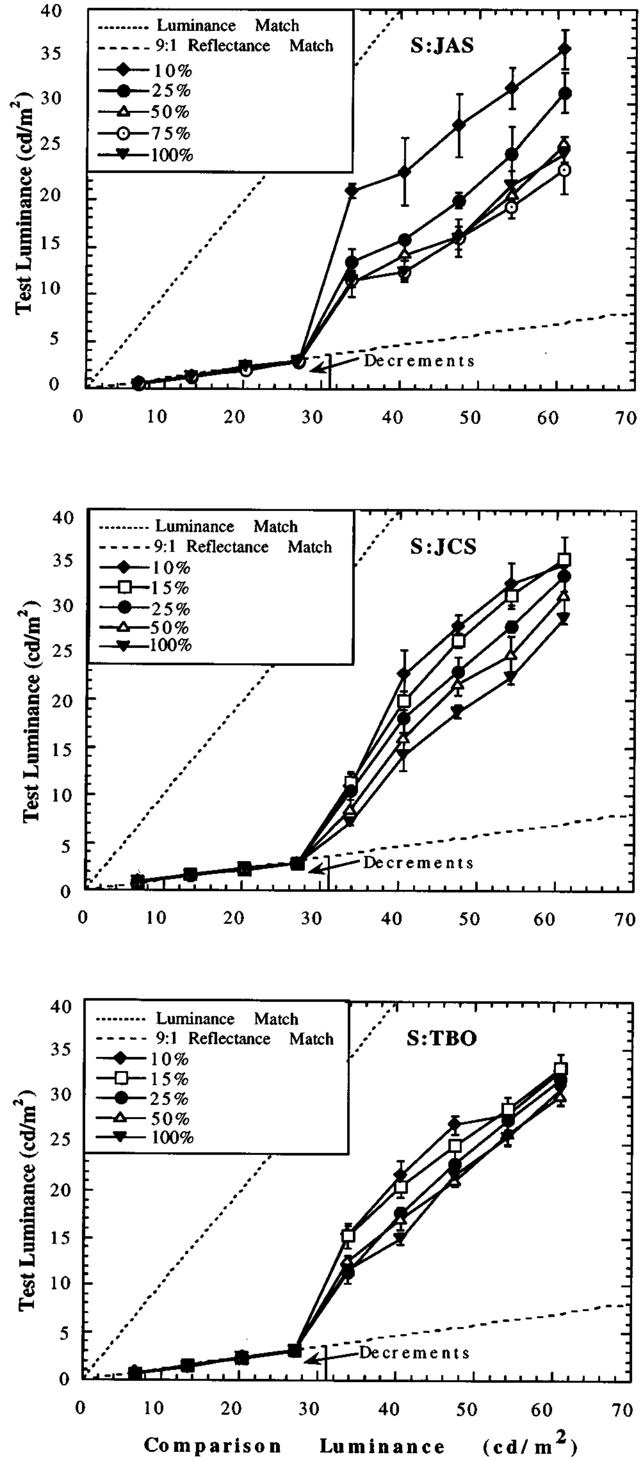


Fig. 6. Brightness matches for the 9:1 surround ratio with the articulation gray scale varying from 10% (i.e., variation from uniform surround) to 100% for three observers. 0%, filled diamonds; 15%, open squares; 25%, filled circles; 50%, open upward triangles; 75%, dot within circles; and 100%, filled downward triangles. Observer JAS did 75% in place of 15%. Observers JCS and TBO did not do 75%.

only the left-hand test surround remaining uniform while the right-hand comparison surround had articulation. When applied, the gray level of articulation was the same as in experiment 1 (Table 1).

The data of all observers were in agreement; thus, to conserve space, only data from observer JAS are shown. Overall, brightness matches made on a mixed articulation test surround and uniform comparison surround and the reverse condition were similar (Fig. 7: articulation test surround and uniform comparison surround, upright triangles; articulation comparison surround and uniform test surround, inverted triangles). More important, observers reduced the test luminance on the mixed articulation/uniform-surround conditions compared with the uniform-surround condition (replotted as open squares for 6:1 and as open circles for 9:1 from Fig. 4). The test luminance remained higher, however, than in the full articulation condition (replotted as filled squares for 6:1 and as filled circles for 9:1 from Fig. 4). Brightness matches made with mixed articulation/uniform surrounds typically straddle those made with full articulation and uniform surrounds. The fact that when only half an image is under articulation the effect of articulation also is reduced by half suggests the possibility that

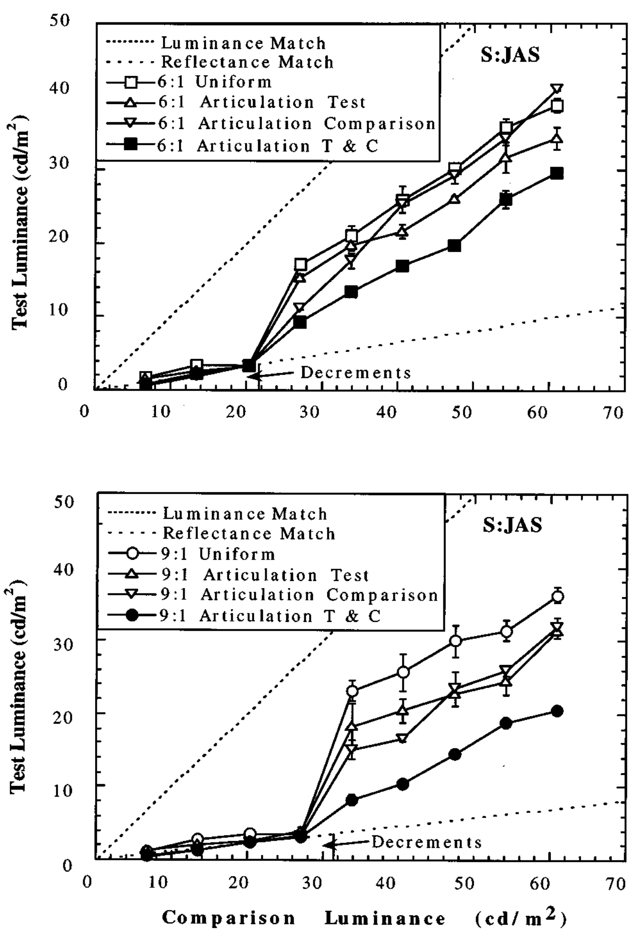


Fig. 7. Brightness matches for 6:1 and 9:1 all-uniform (open squares and open circles, respectively), all-articulation (filled squares and filled circles, respectively), test-articulation/comparison-uniform (upright triangles), and comparison-articulation/test-uniform (inverted triangles) surrounds for observer JAS.

the articulation of each surround establishes its own separate level of inferred illumination within that surround independent of the global luminance edge.

D. Experiment 4: Mondrians Derived from Articulation Surrounds

The size and placement of the four articulation patches within each surround in the previous experiments allowed for multiples of the articulation patches to be generated and used to fill in each surround to ultimately produce a Mondrian configuration. From the original four articulation patches per surround, two versions of eight articulation patches per surround were generated at two surround contrast ratios, 9:1 and 17:1. This was done by creating additional articulation patches with the luminances used in experiment 1 [Fig. 1(b)] and placing the newly created articulation patches in previously uniform-surround locations. In one stimulus [Fig. 2(a)], the four new articulation patches were reproduced and placed in the corners of each surround, with the two newly created decrements placed on the right-hand side of the surround compared with the left-hand-side position of the original decrements, and vise versa for the incremental patches. In the other stimulus [Fig. 2(b)], four new articulation patches were placed adjacent to the original four articulation patches forming a closed ring surrounding the center test and comparison patches. In this condition the darkest-decrement and the lightest-increment articulation patches were reproduced twice. The increment and decrement articulation patches closest to the surround luminance were not reproduced. This left the outer border of the surround that was removed from the center test and comparison patches as well as the border immediately adjacent to the center of the test and comparison patches, uniform. For both Figs. 2(a) and 2(b) this preserved the local test/surround and comparison/surround contrast ratios. Likewise, for both stimuli the resulting local space-average luminance remained identical to the four-articulation-patch-surround stimulus and the uniform-surround stimulus.

A 16-articulation-patch stimulus was generated by retaining the closed ring configuration from the second eight-articulation-patch stimulus [Fig. 2(b)] and adding two more patches at each of the four luminance levels in the outer region of the previous uniform surround, at two surround contrast ratios, 9:1 and 17:1 [Fig. 3(a)]. With 16 articulation patches the stimulus begins to resemble a Mondrian. To enhance the appearance of two identical Mondrians each under a different level of illumination, a final stimulus was produced that retained the sixteen articulation patches and introduced four more, at each of the four luminance levels, resulting in a stimulus with twenty articulation patches [Fig. 3(b)]. These happened to be the four articulation patches that were added to produce the first eight-articulation-patch stimulus pattern in Fig. 2(a). Each half of the resulting Mondrian display was thereby composed of 25 squares; 6 were 2.8% dimmer and 6 were 2.8% brighter than their immediate surround, 4 were 1.4% dimmer and 4 were 1.4% brighter than their immediate surround, and 5 were at the luminance of the original uniform surround. Notice that in all of the above-mentioned stimuli, the local space-average luminance is the same as in the uniform-surround condition [Fig. 1(a)]. Yet phenomenologically it appears more likely that the global luminance edge between the two surrounds is an illumination edge as articulation increases (compare Figs. 1, 2, and 3).

Brightness judgments made on 9:1 and 17:1 surrounds with various numbers of articulation patches were only moderately consistent (Fig. 8; to conserve space, data are shown only for observer JAS). One general trend that emerged is that observers set the test to a lower luminance with surrounds that had the most articulation patches (i.e., either 16 or 20 articulation patches, closed squares and cross within squares, respectively) than with surrounds with few articulation patches (i.e., 4 articulation patches, closed circles). This suggests that as articulation increases, the global edge between the surrounds increasingly appears more like an illumination edge than a reflectance edge. It is also noteworthy that observers consistently set the test to a lower luminance when the eight articulation patches formed a closed "articulation ring" [Fig. 2(b); Fig. 8, upright triangles] than when the eight articulation patches were dispersed throughout the surrounds [Fig. 2(a); Fig. 8, inverted triangles).

Increasing the number of articulation patches alters brightness judgments in a way that is similar to shifting

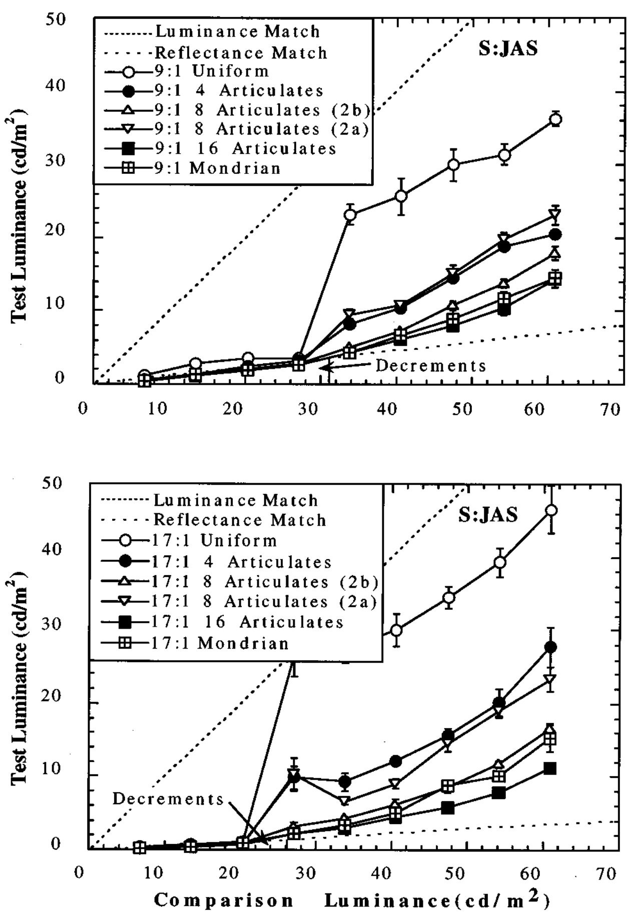


Fig. 8. Brightness matches for 9:1 and 17:1 uniform (open circles), four articulation-patch (filled circles), eight dispersed articulation-patch (upright triangles), eight closed-ring articulation-patch (inverted triangles), sixteen articulation-patch (filled squares) and twenty articulation-patch (i.e., Mondrian) (cross within squares) surrounds for observer JAS.

from a uniform surround to four-patch articulation surrounds (see experiment 1; in Fig. 4, compare open with filled symbols). This suggests that the introduction of articulation begins a process of shifting brightness judgments away from luminance matches toward local contrast-ratio matches. Increasing the number of articulation patches ultimately makes conscious the global inferred illumination edge between surrounds, which shifts brightness judgments even further toward local contrast-ratio matches.

4. DISCUSSION

Kingdom[13] has eloquently recapped the simultaneous-contrast debate initially advanced by Hering and Helmholtz. His editorial points out that whereas induction is dependent largely on local contrast, inferring an illuminant requires global contrast be unambiguously determined. Helson[14] suggests that to infer Helmholtz's illumination requires obtaining the proper weighted average of all the luminances in the visual field. The current study accepts this proposition and attempts to demonstrate that the degree that a luminance edge is classified as being due to a change in illumination is dependent on the articulation of the luminances within a complex field.

Until recently, work on complex configurations[15] has suggested that it is retinally adjacent inducers that primarily influence simultaneous contrast. Thus retinally noncontiguous articulation patches should not produce some long-distance form of induction. However, recent single-unit recording experiments in striate cortex[16] suggest that luminance changes far removed from a receptive field can influence its output. It is possible that the articulation patches in the present experiment are being grouped in striate cortex and that the range of their luminances provide a basis from which a global level of illumination can be inferred.

Adding patches of varying luminance to a uniform surround while keeping the local space-average luminance constant shifts brightness matches from approximating a physical luminance match toward approaching a local ratio match for increments. This shift resembles what would happen if global contrast were made less ambiguous by using an extended luminance border between the test and the comparison surrounds to suggest an illumination edge.[9,17]

If observers infer that the luminance edge between the two surrounds used in the current study is a reflectance edge, the brightnesses of the test and comparison patches can be computed only by using local contrast information. If, however, the edge between the surrounds appears to be an illumination edge, this inference will also effect the brightnesses of the test and comparison patches. Varying illumination changes the light falling on a surface and therefore the light that reaches the eye. This change in retinal stimulation might be thought to be the cause of changes in brightness. An important feature of the experiments here is that a change in the overall level of retinal stimulation is not necessary. Simply adding incremental and decremental patches of light arriving at the retina, which alter inferred (rather than real) illumination, also can result in changes in brightness.

These articulation experiments also support the claim that the surface with the highest luminance within a given illuminant's framework determines that level of illumination, as Cataliotti and Gilchrist[5] suggest. Figure 7 demonstrates that when only half of the display is under articulation, the test luminance is reduced by approximately 50% in comparison with the case in which the entire display (i.e., both halves) is under articulation. This means that the two incremental articulation patches on the dim (i.e., left-hand) surround are as effective in altering brightness judgments as the two incremental articulation patches on the bright (i.e., right-hand) surround. In the former case, the two incremental articulation patches are not more intense than the right-hand comparison (uniform) surround. Thus it is clear that even a highest-luminance rule must be constrained to mean the highest luminance within a given level of illumination.

A crispening effect[18] occurs when brightness changes most rapidly for test-patch luminances close to that of their immediate uniform surround. This was also found in the current study [see Fig. 4: open symbols just above and below 21.72 cd/m^2 (6:1), 31.05 cd/m^2 (9:1), and 44.40 cd/m^2 (12:1)]. Interestingly, this effect is greatly reduced when four articulation patches are introduced (see Fig. 4, filled symbols). This suggests that crispening is not governed entirely by local contrast and that providing a retinally noncontiguous gray scale (i.e., four articulation patches) increases either the number or the spacing of possible just-noticeable differences between the test and the comparison patches and their immediate surrounds.

It is also noteworthy that for two of the three observers (JAS and TBO), increasing the uniform comparison-surround luminance did not make the comparison appear brighter (see Fig. 4; i.e., the brightness of the test did not increase, as shown by the overlap in the incremental open symbols). This is reasonable, given Whittle's[19] analysis that the brightness of a surround contributes nothing to the brightness of a test and is important only for its adapting purposes. However, for all three observers, increasing the articulation comparison-surround luminance decreased the brightness of the test [see Fig. 4; filled diamonds (12:1) fall below filled circles (9:1), which fall below filled squares (6:1)].

There have been many reports in the literature[6,19–23] of incidents of increment–decrement asymmetries. Figure 5 reiterates this distinction by showing that articulation surrounds affect increments much more than decrements. It is exciting that these results mirror those of Arend and Goldstein.[6] Noguchi and Kozaki[24] note that the appearance of a white surface is affected strongly by changing illumination, whereas a black surface tends to be unchanged despite changes in illumination. The growing consensus that the brightness of decrements is impervious to illumination changes whereas that of increments covaries deserves further study.

Articulation demonstrates that as simple center-surround stimuli become increasingly complex, global luminance edges are more readily interpreted as being due to changes in illumination rather than to changes in reflectance. Thus, the current study's ecologically rich Mondrians elicit brightness judgments that begin to approximate local ratio matches, as the data from Arend and Goldstein[6] corroborate. Thus Mondrian displays begin to blur the distinction between brightness and lightness judgments in that the latter have typically been believed to involve local ratio matches more closely.[6] In a companion paper,[25] lightness judgments made on these articulation surrounds demonstrate near-perfect lightness constancy, which provides concomitant evidence that articulation produces a shift in the likelihood that a global luminance edge will be perceived as an illumination edge.

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