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Brightness with and without perceived transparency: When does it make a difference?

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Abstract. Subjects matched the brightness of test patches whose inner (adjacent) surrounds appeared either as transparent overlays on a wider background that included the test patch or as regions differing in reflectance from the test patch and the outer surround. In the above configurations the luminance and spatial extent of the inner surround was identical, thus controlling for the effects of surround luminance. Configuration condition had a significant effect on test-patch brightness. In general, test-patch brightness was significantly elevated under conditions favouring the interpretation of the stimulus as including a transparent overlay. The largest effect occurred for the configuration in which the perception of transparency was supported by stereo depth cues. The brightness effect was mediated by the virtual transmittance of the transparent overlay, increasing in magnitude with decreasing transmittance. Further, the effect of transparency on brightness was greatest for test-patch luminances near to those of their immediate surrounds.

1 Introduction

Since the time of Helmholtz the influence of coloured surrounds on the perceived colour of test patches ('induced' colour) has been rightly considered critical to our understanding of brightness (perceived luminance), lightness (perceived reflectance), and chromatic processing (James 1890/1981). Helmholtz argued that induced colour was a "deception of judgment", according to which observers judged the colour of the test region as if it were illuminated by light with the same colour composition as the surround. Thus, in the classic simultaneous-brightness-contrast display, in which a grey patch on a light surround looks darker than on a black surround, Helmholtz's view is that the visual system assumes the patch on the white surround to be the more highly illuminated. Given that the luminances of the two patches are nevertheless the same, it is inferred on the basis of this assumption that the patch on the white surround has to be of lower reflectance, and that is how it is perceived. Hering, on the other hand, advanced a different view which favoured a low-level physiological explanation for induced colour in terms of lateral interactions at the retinal level.

The Helmholtz/Hering debate predates and is in many ways cognate to recent controversy concerning the cause(s) of induced-brightness phenomena. The extent to which these phenomena reflect primarily early-stage filtering operations, as opposed to higher-level inferential mechanisms (conscious or unconscious), is still contested (eg Spehar et al 1995; Gilchrist, 1988; Kingdom et al 1997). By inferential mechanisms we refer to mechanisms which attribute categorical properties (ie object, shadow, light source) to the intensive and chromatic properties of surfaces. Such mechanisms are involved in the description of a three-dimensional world of reflecting objects and surfaces illuminated by various light sources. Inferential mechanisms are clearly essential to lightness perception, since the visual system must be able to distinguish luminance discontinuities that arise from changes in reflectance from those caused by changes in illumination. That the visual system can make this distinction under many circumstances with apparent ease is evidenced by the simple observation that one can tell the lightness of a surface to be uniform even when partially covered by shadow or by a transparent overlay, as illustrated in figure 1.

Figure 1 also demonstrates the distinction the visual system is capable of making between lightness and brightness. On the one hand the regions behind and outside of the perceived transparent overlay both appear to be made from the same piece of material, ie to possess the same *lightness*. On the other hand the same regions appear markedly different in *brightness*. The evidence that the visual system can distinguish brightness from lightness under circumstances that include an illumination component, and that inferential processes influence lightness perception under these conditions, is well documented (Gilchrist 1977, 1983; Arend and Goldstein 1990; Schirillo et al 1990; Arend and Spehar 1993a, 1993b; Schirillo and Arend 1995). The influence of inferential processes on brightness (as opposed to lightness) perception is, however, less clearly established. In principle, brightness, as perceived luminance, could be directly given. Even though the visual system appears to encode brightness via mechanisms sensitive to relative, rather than absolute, luminance (ie contrast), the visual system could nevertheless derive from those mechanisms a brightness representation for every surface in the retinal image without resort to inferential processes. There are, however, a number of studies providing evidence for just such an influence. Changes in perceived brightness attributed to inferential processes have been found for perceived stereo depth (Schirillo and Shevell 1993; Spehar et al 1995), perceived pictorial depth or shape (Knill and Kersten 1991; Adelson 1993; Buckley et al 1994; Wishart et al 1997), perceived 'belongingness' (Agostini and Proffitt 1993), and perceived transparency (Adelson 1993).

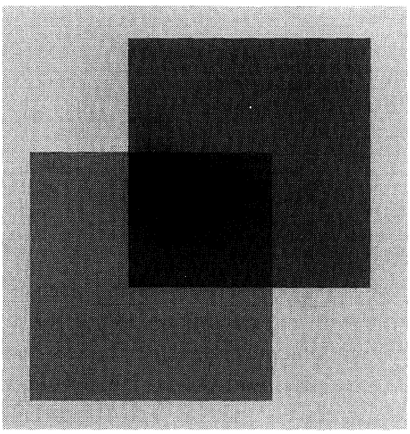


Figure 1. An example of perceptual transparency which illustrates the ability of the visual system to separate lightness from brightness. See text for details.

In this paper we examine the extent to which the brightness of a test patch is influenced by perceived transparency. Brightness was measured for test patches whose inner surrounds were made to appear either as transparent overlays on a wider background that included the test patch, or as regions differing in reflectance from the enclosed test patch and the outer surround. Example stimuli are shown in figure 3 (section 2.3). The luminance arrangement of the inner surround was identical across all conditions to control for any effects of local surround luminance. Subjects were explicitly instructed to make brightness and not lightness judgments. The results of the study show that under some conditions brightness can be significantly altered by the perceived configuration of the surround. Whereas in general the effects are quite modest, perceived transparency can under optimal conditions increase brightness matches by close to 100%.

2 Methods

2.1 *Subjects*

Five subjects participated: MM, JG, FK, BB, and BH. MM, FK, and BB were the authors and JG and BH were undergraduate student volunteers. All subjects were well-practised psychophysical observers, were stereo normal, and possessed normal or corrected-to-normal vision.

2.2 *Stimulus generation*

Stimuli were generated by means of a PC-compatible microcomputer (486/66 MHz) with a custom-modified TIGA (Texas Instruments Graphics Adapter) graphics controller (Vision Research Graphics, Inc). Images were presented on a high-resolution display monitor (21 inch IDEK Iiyama Vision Master, model MF-8221). Display format was 1024 pixels wide $\times$ 768 pixels high. Frame refresh rate was 97 Hz (noninterlaced). Viewed from a distance of 60.7 cm the entire display subtended 32 deg $\times$ 24.2 deg; individual pixels measured 0.031 deg $\times$ 0.031 deg. Mean display luminance was 50 cd m^{-2}. All images could possess 2^8 simultaneously presentable linearised intensity levels selected from a palette of approximately 2^{15}. Stereo projection was achieved by a pair of pi-cell liquid-crystal shutter glasses (Tektronix, Inc) synchronised to the monitor frame rate, so that alternate frames were presented to the two eyes. In their open state, transmittance through the shutter glasses was 35%. Thus, viewed through the shutter glasses the mean and the maximum display luminances were 17.5 and 35 cd m^{-2}, respectively.

2.3 *Stimuli*

The basic stimulus configuration is illustrated in figure 2, which indicates the arrangement of the test patch, test inner surround, test outer surround, and matching patch common to all conditions. Figures 3a and 3b present facsimiles of stimuli used in the experiments, but without the matching patch. The four configuration conditions are transparency-with-stereo-depth (figure 3a, upper panels); transparency-without-stereo-depth (figure 3a, lower panels); no-transparency-without-stereo-depth (figure 3b, upper panels);

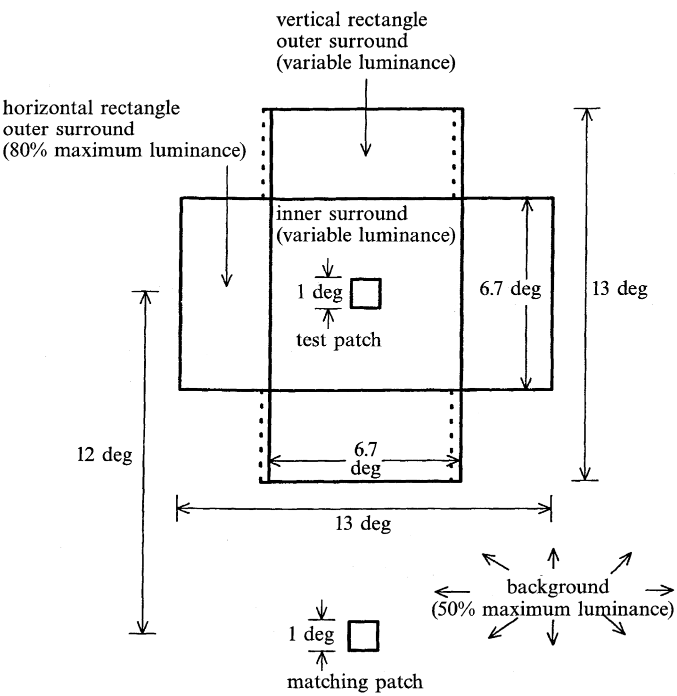


Figure 2. Diagrammatic representation of the stimulus arrangement.

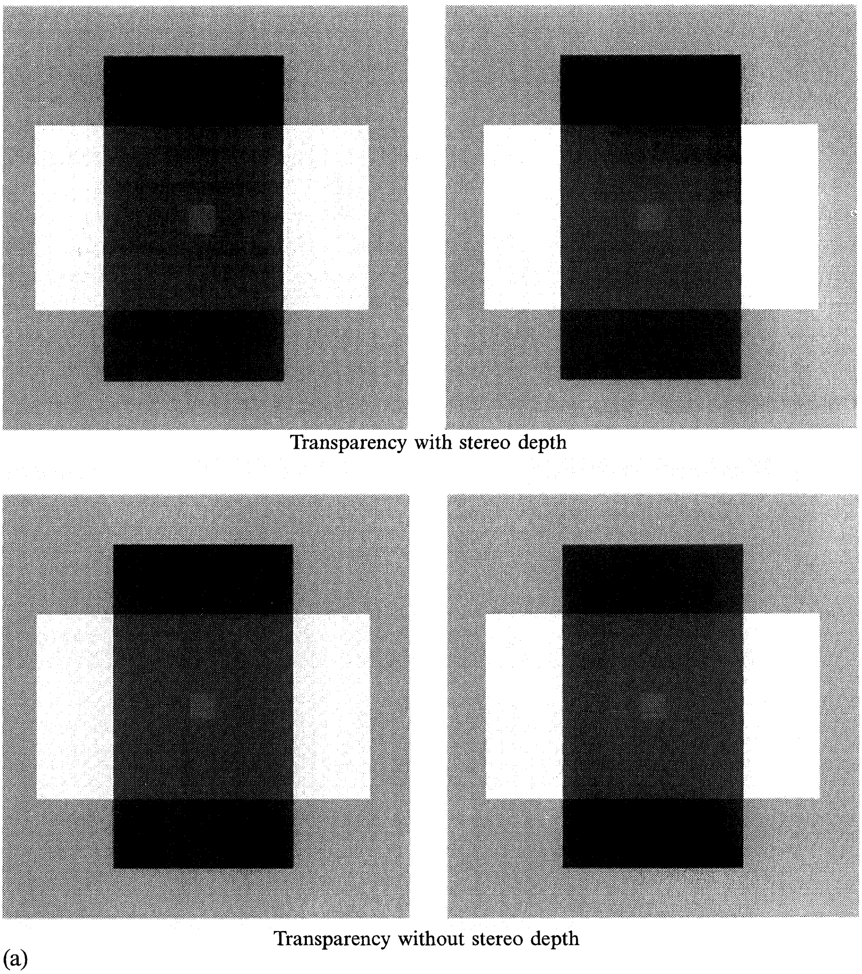
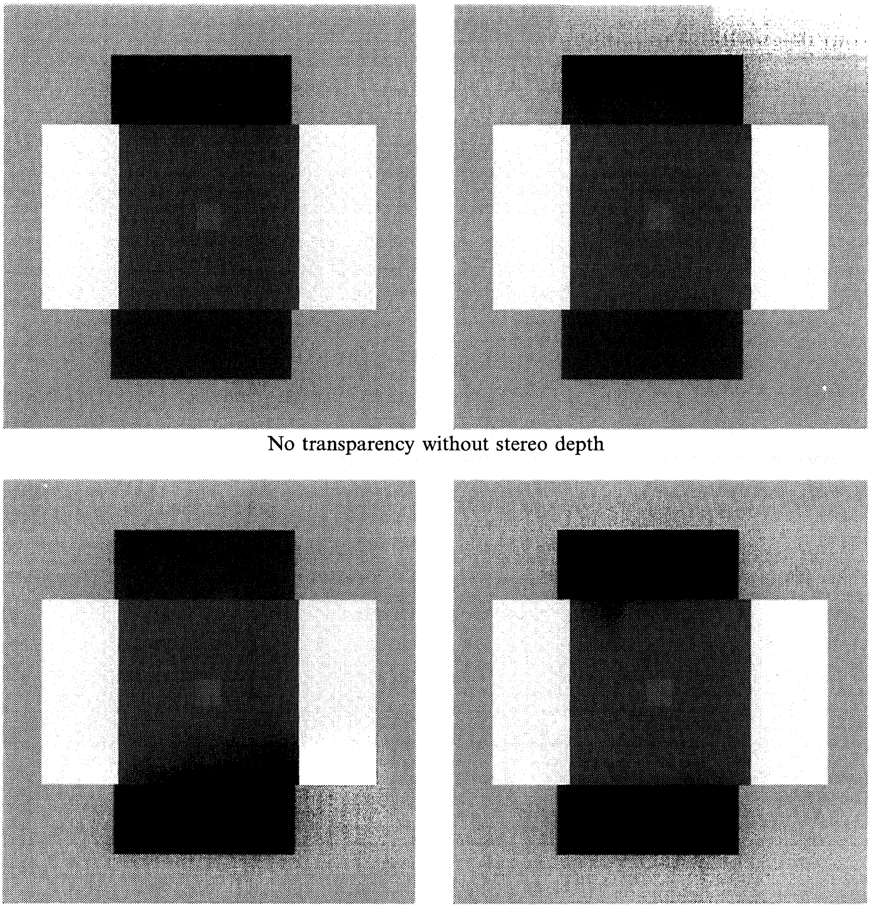


Figure 3. Facsimiles of the stimuli used in the experiments. (a) Upper panels, transparency with stereo depth cues; lower panels, transparency-without-stereo-depth; (b) (facing page) upper panels, no-transparency-without-stereo-depth; lower panels, no-transparency-with-stereo-depth. When fused by using convergence, the stimulus in the upper panels of (a) appears to consist of two surfaces, a horizontally oriented light-grey rectangle containing a coplanar test patch and a vertically oriented transparent rectangle floating in front. Pictorial depth cues in the stimulus in the lower panels of (a) also suggest the existence of a transparent overlay, but without the stereoscopic depth cues of the stimulus in the upper panels of (a). Pictorial depth cues in the stimulus in the upper panels of (b) suggest that the horizontal light-grey rectangle partially occludes the dark-grey rectangle, which thus appears to lie in a recessed depth plane. In the lower panels of (b) the addition of stereo depth enhances the impression of occlusion. Note that in all four configuration conditions, the pattern of surround luminance is identical, extending to a distance of 6.7 deg from the centre of the test patch. Transparency transmittance is 33%; test-patch luminance is 32% maximum in the stereo-depth conditions, the disparity of the transparent overlay was 0.3125 deg (10 pixels) and that of the occluded rectangle was −0.3125 deg.

and no-transparency-with-stereo-depth (figure 3b, lower panels). When fused by using convergence, the stimulus in the upper panels of figure 3a appears to consist of two surfaces, a horizontally oriented light-grey rectangle containing a coplanar test patch and a vertically oriented transparent rectangle floating in front. Pictorial depth cues in the stimulus in the lower panels of figure 3a also suggest the existence of a transparent overlay, but without the stereoscopic depth cues of the stimulus in the upper panels of figure 3a. Pictorial depth cues in the stimulus in the upper panels of figure 3b



No transparency without stereo depth

No transparency with stereo depth

(b)

Figure 3 (continued)

suggest that the horizontal light-grey rectangle partially occludes the dark-grey rectangle, which thus appears to lie in a recessed depth plane. In the lower panels of figure 3b the addition of stereo depth enhances the impression of occlusion. Note that in all four configuration conditions, the pattern of surround luminance is identical extending to a distance of 6.7 deg from the centre of the test patch. In the stereo-depth conditions, the disparity of the transparent overlay was 0.3125 deg (10 pixels) and that of the occluded rectangle was −0.3125 deg.

Three stimulus-luminance parameters were varied in the experiment: test-patch luminance and the luminances composing the vertical rectangle (the inner surround and upper and lower flanks of the outer surround). All other parameters were held constant. For ease of exposition, luminances are given in terms of the percent maximum of the full display luminance. Background luminance was fixed at 50% maximum and the luminance of the right and left flanks of the outer surround was fixed at 80% maximum (see figure 2). Five luminances of the square inner surround were employed: 8%, 27%, 54%, 72%, and 80% maximum. These were paired with five luminances of the top and bottom outer surround flanks (5%, 17.5%, 33%, 45%, and 50%), in such a way that they were consistent with the interpretation of the stimulus as a vertical transparent rectangle overlying a horizontal rectangle which included the test patch. The transmittance values of the transparent vertical rectangle were 10%, 33%, 66%, 90%, and 100% (ie no transparent overlay). Test-patch luminances spanning most of the range from 0% to 100% maximum were examined.

2.4 *Procedure*

The method of adjustment was employed to determine the luminance at which the brightness of the matching patch was the same as that of the test patch. On each stimulus presentation the subject adjusted, by button press, the luminance of the matching patch (which was situated on the 50%-maximum background) until it appeared equal in brightness to that of the test patch. Brightness was defined as the perceived intensity (amount) of light coming from the test patch. Subjects were specifically instructed *not* to match the lightness of the test patch, defined as the perceived reflectance (ie shades of grey). When subjects were satisfied with their matches another button press registered the response, and the next stimulus was presented. In each experimental session all test-patch luminances and surround luminances were presented for each configuration condition. These were presented in random order. Each subject completed between three and six sessions, from which the means and standard errors of the matches were computed.

3 Results

Figures 4a–4e illustrate the pattern of match values, with each figure giving the complete data set for one subject. In each graph mean matching luminance is plotted as a function of test-patch luminance for each of the four configuration conditions: transparency-with-stereo-depth, no-transparency-with-stereo-depth, transparency-without-stereo depth, and no-transparency-without-stereo-depth. The vertical dotted line on each panel indicates the luminance of the test patch surround, and thus also represents the

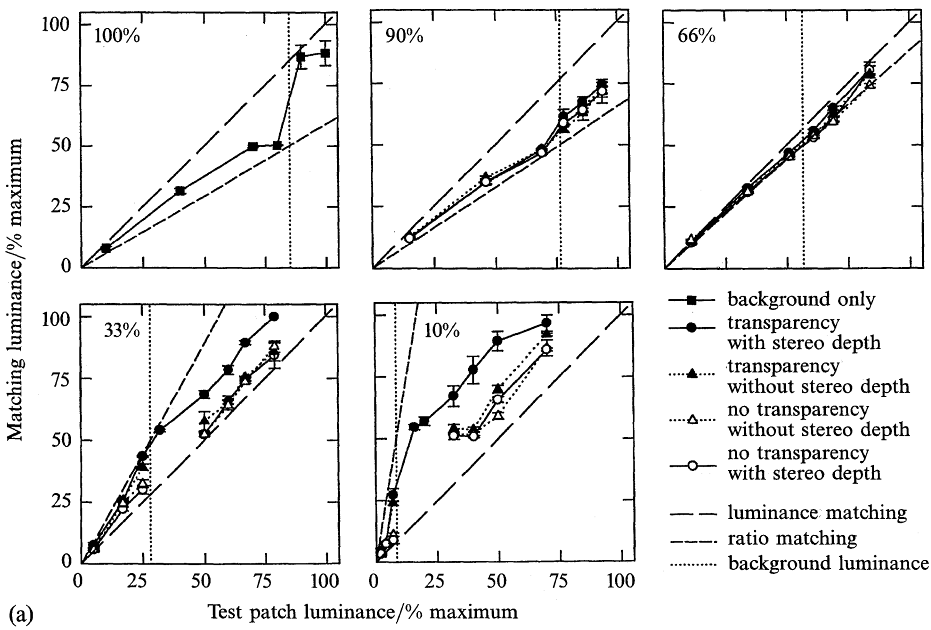


Figure 4. Mean matching luminance for each subject is plotted as a function of test-patch luminance for each of the four configuration conditions. Transparency transmittance is shown as a parameter. The squares in the condition labelled 100% are test-field-brightness matches for a control condition in which only the horizontal rectangular surround was present. The vertical dotted line is test-patch surround luminance. The diagonal (long-dash) lines show luminance matching, short-dash lines are predictions for ratio matching. (a) Subject FK, (b) subject BB, (c) subject MM, (d) subject BH, and (e) subject JG.

line dividing decrements (to the left) from increments (to the right). The number in each panel gives the virtual transmittance of the two simulated transparency conditions. Thus, the further leftward the vertical dotted lines (and the lower the associated transmittance values) the darker the inner surround of the test patches. The fixed diagonal dashed lines (long dashes) represent the prediction for perfect luminance matching, while the variable-slope dashed lines (short dashes) illustrate the predictions for perfect ratio matching. In other words, the short-dashed lines index the match luminance necessary to make the ratio of matching luminance to its immediate surround (50% maximum) equal to the ratio of test-patch luminance to its immediate surround.

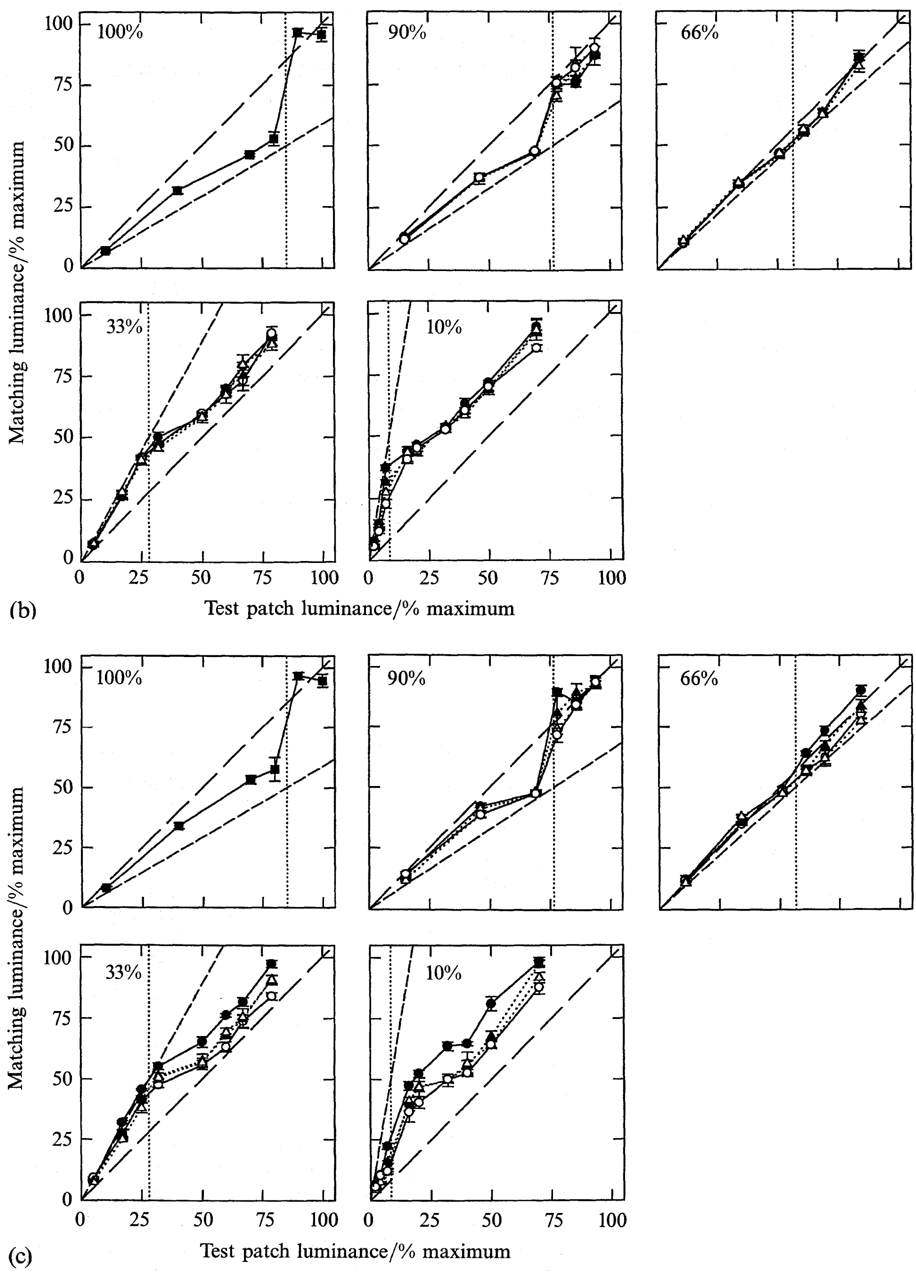
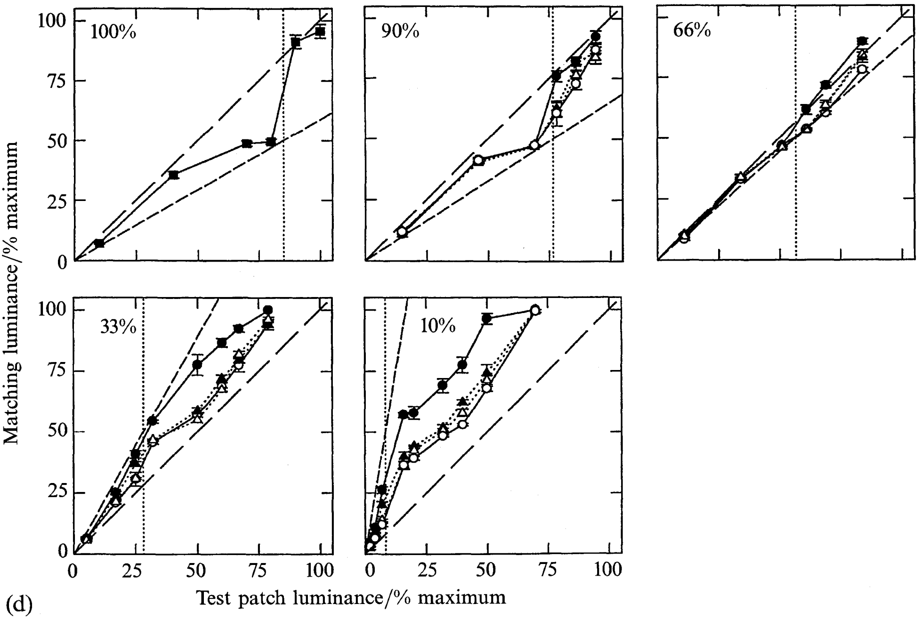
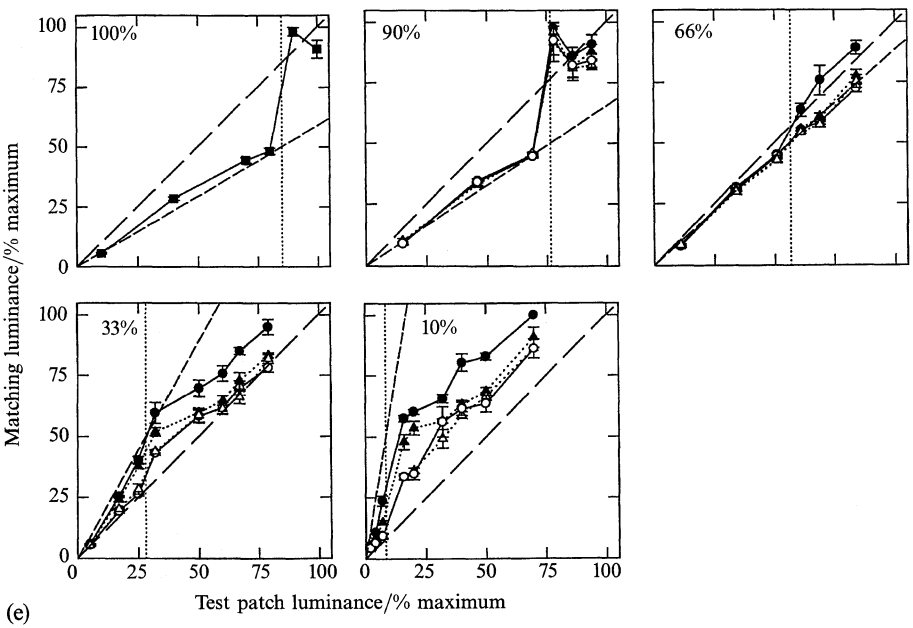


Figure 4 (continued)



(d)



(e)

Figure 4 (continued)

Consider first the condition in each figure labelled 100%. This is the condition in which only the horizontal rectangular surround was present (80% maximum), ie without the added transparent overlay or its no-transparency comparisons. Subject matches lay somewhere between luminance matching (long-dashed line) and ratio matching (short-dashed line). This is typical behaviour for brightness matching in side-by-side displays (Whittle 1994). Subjects also show the 'crispening effect' recently investigated by Whittle (1992), in which brightness changes most rapidly for test patch luminances close to that of the immediate surround.

Inspection of the results in the figures labelled 90%–10% reveals that matching luminance increases as the luminance of the inner surround decreases. This is indicated by the increase in slope of the matching functions as the dotted vertical line (inner-surround luminance) moves leftwards, or the transmittance value decreases. It is clear, in addition, that while brightness matches in all cases still fall somewhere between luminance matching and ratio matching, decrement matches are in general much closer to the ratio-matching prediction than are increment matches. Increment matches lie closer to the luminance-matching prediction (Arend and Spehar 1993a).

Most germane to this study, however, are the relative changes in test-patch brightness which occur as a function of the four configuration conditions within each local-background-luminance condition. Table 1 shows the results of an independent-groups analysis of variance conducted on the matching data of each observer at each transmittance level. At all transmittance levels there is an obvious and highly significant main effect of test-patch luminance. In the 10%-transmittance condition all subjects showed a significant ($p < 0.05$) main effect of configuration condition and a significant configuration condition by test-patch luminance interaction.

The source of the interaction, as revealed by an analysis of simple main effects, is the absence of a significant effect of configuration condition at one or more of the lowest test-patch luminances, whereas configuration condition is highly significant at higher test-patch-luminance values. The effect of configuration condition and the interaction of test-patch luminance and configuration condition were also significant at the 33% and 66% transmittance levels for all but subject BB, but remained significant for only two subjects (MM and BH) at the 90% transmittance level. A posteriori comparisons for each observer indicated that mean brightness matches in the transparency-with-stereo-depth configuration were significantly greater than in any of the other configurations for the 10%-transmittance condition (5/5 subjects) and for the 33%-transmittance and 66%-transmittance conditions (4/5 subjects). In addition, mean brightness matches in the

Table 1. Significance levels (p-values) and η^2 values (in parentheses) for two-way independent-groups ANOVAs conducted on the luminance-match distributions from the five observers in each experimental condition (CC, configuration condition; TPL, test-patch luminance).

Transmittance condition	Observer	CC	TPL	CC × TPL interaction
10%	FK	<0.0001 (0.032)	<0.0001 (0.941)	<0.0001 (0.020)
	BB	<0.0001 (0.004)	<0.0001 (0.985)	0.004 (0.005)
	MM	<0.0001 (0.017)	<0.0001 (0.965)	0.0065 (0.007)
	BH	<0.0001 (0.034)	<0.0001 (0.941)	<0.0001 (0.016)
	JG	<0.0001 (0.042)	<0.0001 (0.921)	<0.0001 (0.016)
33%	FK	<0.0001 (0.024)	<0.0001 (0.959)	0.0002 (0.009)
	BB	0.4480 (0.000)	<0.0001 (0.987)	0.6825 (0.003)
	MM	<0.0001 (0.012)	<0.0001 (0.974)	0.0392 (0.005)
	BH	<0.0001 (0.019)	<0.0001 (0.961)	<0.0001 (0.011)
	JG	<0.0001 (0.032)	<0.0001 (0.934)	0.0011 (0.010)
66%	FK	<0.0001 (0.002)	<0.0001 (0.992)	0.0092 (0.003)
	BB	0.9898 (0.000)	<0.0001 (0.993)	0.9048 (0.001)
	MM	<0.0001 (0.009)	<0.0001 (0.973)	0.0051 (0.008)
	BH	<0.0001 (0.007)	<0.0001 (0.978)	<0.0001 (0.007)
	JG	<0.0001 (0.017)	<0.0001 (0.942)	<0.0001 (0.016)
90%	FK	0.2914 (0.001)	<0.0001 (0.982)	0.9138 (0.002)
	BB	0.6203 (0.000)	<0.0001 (0.982)	0.5162 (0.004)
	MM	0.0208 (0.002)	<0.0001 (0.978)	0.0060 (0.009)
	BH	<0.0001 (0.006)	<0.0001 (0.961)	0.0005 (0.011)
	JG	0.3305 (0.001)	<0.0001 (0.963)	0.9615 (0.002)

transparency-without-stereo-depth configuration were significantly greater than in the no-transparency-with-stereo-depth configuration for the 10%-transmittance condition (5/5 subjects) and for the 33%-transmittance condition (4/5 subjects). Last, mean brightness matches in the transparency-without-stereo-depth configuration were significantly greater than in the no-transparency-without-stereo-depth configuration for the 10%-transmittance and 33%-transmittance conditions (3/5 subjects). No other pairwise comparisons were significant for more than two of the five subjects.

The effect on brightness of transparency was compared with that of simple brightness induction by calculating, across all five subjects, the percentage change (usually an increase) in brightness matches between each of the two transparency configurations and the average of the two no-transparency configurations. Percentage brightness change is plotted as a function of the ratio of test-patch luminance to inner-surround luminance in figure 5. Two features of these data are notable. First, at all transmittance levels the largest brightness enhancements occur for test patches whose luminances are very near to that of the inner-background luminance (that is, for ratios of test-patch to inner-background luminance near 1.0). Second, brightness enhancement increases with decreasing transmittance where, at maximum in the 10%-transmittance condition, test-patch brightness is enhanced by slightly less than 100% for the transparency-with-stereo-depth condition and by slightly more than 50% in the transparency-without-stereo-depth condition.

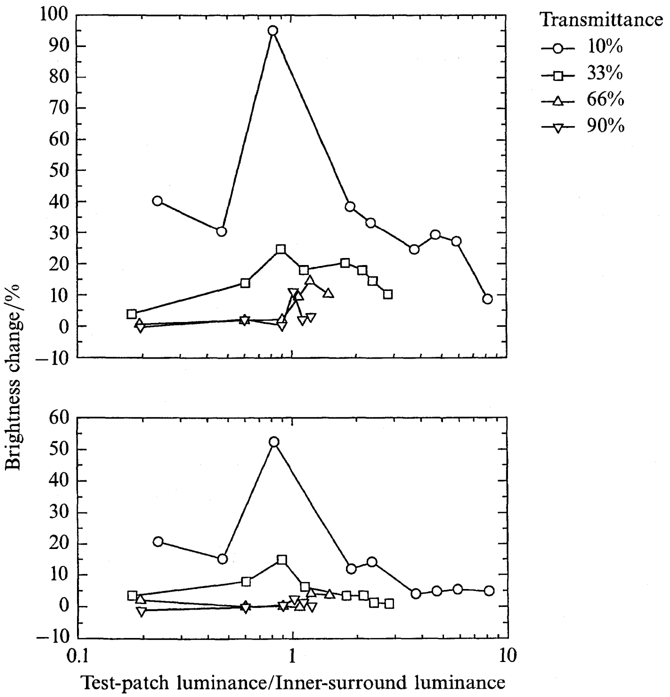


Figure 5. Mean matching luminance (percentage brightness change collapsed across observers) is plotted as a function of the ratio of test-patch luminance to inner-surround luminance. Across all levels of transmittance (shown as a parameter), the largest brightness enhancements occur for test patches whose luminances are very near to that of the inner-background luminance. Brightness enhancement increases with decreasing transmittance where, at maximum in the 10%-transmittance condition, test-patch brightness is enhanced by approximately 50% for transparency-without-stereo-depth (lower panel) and 100% for transparency-with-stereo-depth (upper panel).

4 Discussion

The purpose of this study was to determine whether, and to what degree, perceived transparency can affect the judgment of brightness. We measured the brightness of a test patch as a function of test-patch luminance, inner-surround luminance, and configuration condition. The stimulus was designed so that it could be interpreted as (i) a transparent overlay of a given transmittance in front of a horizontal rectangular surround which included the test patch or as (ii) a square surface of a given reflectance surrounding the test patch, with outer surround flanks of differing reflectance. Mean matching luminance in the transparency-with-stereo-depth condition was significantly higher than in all other configurations for the 10%-transmittance (5/5 subjects), 33%-transmittance (4/5 subjects), and 66%-transmittance (4/5 subjects) conditions. In addition, for the 10%-transmittance condition (5/5 subjects) and the 33%-transmittance condition (4/5 subjects), mean luminance matches in the transparency-without-stereo-depth condition were significantly greater than in the no-transparency-with-stereo-depth condition. Last, brightness matches were significantly greater in the transparency-without-stereo-depth configuration than in the no-transparency-without-stereo-depth configuration for the 10%-transmittance and 33%-transmittance conditions (3/5 subjects). The largest brightness increases occurred in the 10%-transmittance condition, at a ratio of test-patch to background luminance of approximately 1.0. Here brightness judgments, when compared with the average of the two no-transparency configurations, were on average 100% greater for the transparency-with-stereo-depth configuration and 50% greater for the transparency-without-stereo-depth configuration.

Our results show that the effect of transparency is small, but significant, and we must consider how it might have arisen. Transparency affected brightness in such a way that subjects perceived the test patch to be brighter than in other configuration conditions. This could occur if subjects discounted, in part, the transparency when computing brightness. A possible explanation as to why this effect manifested itself more strongly when the interpretation of transparency was supported by stereo depth is that under these circumstances there is an unambiguous and compelling impression of transparency of the vertical rectangle. According to this view one might predict a larger brightness effect, even in the absence of stereo depth cues, if the stimulus possessed a more complex background. The additional information provided by a complex background, such as more-numerous x-junctions and luminance ratios consistent with physical transparency, might render transparency a more parsimonious (and hence more compelling) interpretation, thus leading to a greater brightness effect. This is consistent with Gestalt theories where percepts are posited to be organised according to various principles such as 'goodness' or 'simplicity' (Knill et al 1996). It is important to note, as suggested by a reviewer, that the transparency-without-stereo-depth condition has an additional confounding interpretation which may have reduced its effectiveness. It is possible to perceive this stimulus as a gauzy horizontal rectangular transparency possessing an additive component, overlying a test patch embedded within a darker vertical surround rectangle. Under this interpretation a partial discounting of the transparency, as discussed earlier, would predict that the test field should appear *darker* than in the no-transparency conditions. While the authors never entertained this interpretation of the stimulus it is possible that the two naive observers did. There are two reasons, however, to suspect they did not. First, this condition was randomly interleaved with the three other conditions for which this interpretation is not applicable. Second, it does not appear from the data themselves that this interpretation of the stimulus was commonly made, since mean brightness matches are not absolutely lower than in the other conditions. We cannot, however, rule out the possibility that the brightness matches in the transparency-without-stereo-depth condition may have been reduced to some extent by this competing interpretation. Experiments employing a more complex (and unambiguous) background which eliminates this confounding interpretation, and which make the original intended simulation of transparency more perceptually compelling, are under way to resolve this issue.

Two additional noteworthy results are that the effect of transparency on brightness decreased with increasing transmittance, and that it is maximal for ratios of test field to background luminance near unity (ie when the test and background are close in luminance). This ratio corresponds to the region where brightness changes most rapidly with changes in test-field luminance, resulting in the 'crispening effect' (Whittle 1992). This is also the region where luminance-discrimination thresholds are smallest (Whittle 1986). Thus, if the effect of transparency on brightness were small, its expression might be expected to be maximal where the sensitivity of the brightness system is highest.

4.1 *Comparison with previous findings*

How do our results compare with other studies in which brightness has been measured under different configurations? Arguably the closest study to our own is that of Adelson (1993). He created a stimulus, the Argyle illusion, in which a transparent overlay consisting of a series of stripes of high and low transmittance appeared superimposed on columns of light-grey diamond-shaped patches. Despite all the diamonds being equal in luminance, subject matches indicated that the brightness of the columns of diamonds seen beneath the higher-transmittance (light) bar of the transparency appeared 59% darker than those beneath the lower-transmittance bar. In the no-transparency control condition this difference was reduced to 15%; the effect of transparency was thus 44%. It is of interest that in the Argyle stimulus the luminance ratio of the diamonds to the mean background luminance is 107%. This is very near the optimal ratio (100%) under which in the present study we find perceived transparency to most strongly influence brightness. In addition, the size of the transparency effect in the Argyle stimulus (44%) is very close to the size of the brightness effect (50%) in the transparency-without-stereo-depth configuration of the present study.

A number of prior studies have been explicitly concerned with the effects of depth on brightness. Schirillo et al (1990), in a replication of an earlier experiment by Gilchrist (1977, 1980), reported that brightness (but not lightness) was unaffected by perceived depth. Dalby et al (1995) measured the effect of stereoscopic depth on the perceived brightness[1] of a test field, where test-field depth was varied relative to a single inducing field or in relation to two inducing fields separated in depth. In neither condition was test-field brightness affected by stereoscopic depth. These studies support our conclusion that the effect of depth in the present experiment was to make the interpretation of transparency more compelling rather than to influence perceived brightness directly.

4.2 *Perceptual inferences and brightness mechanisms*

The various surround configurations in the present study were designed to bias the global interpretation of the stimulus, on the one hand, toward consisting entirely of surfaces of varying reflectance under uniform illumination and, on the other hand, toward including a transparent surface (an illumination component), while at the same time holding local luminance relationships constant. Although we intentionally measured brightness (not lightness), the data of Arend and Spehar (1993a, 1993b) lead us to expect that in the configuration conditions which bias the interpretation of the stimulus in the direction of consisting entirely of surfaces of varying reflectance under uniform illumination, lightness and brightness judgments would be identical. In the configuration conditions that bias the interpretation of the stimulus toward including a transparent surface (an illumination component) we would expect lightness judgments to be quite

[1] Although Dalby et al (1995) discuss their measurements in terms of lightness, according to the operational definitions of the present study their measurements are more consistent with our use of the term brightness.

different from brightness judgments (see figure 3). Our results show that inferential mechanisms, which are involved in segmenting scenes into different surface representations and illuminations, influence brightness perception when the interpretation of the scene includes an illumination component (the only condition under which the percepts of lightness and brightness are separable). This brightness effect, like those described by Adelson (1993), is in the direction of a lightness judgment, ie in the direction expected if the transparency (illuminant) is discounted (ie Helmholtz's hypothesis). While our results do not speak to the issue of the mechanisms underlying the brightness-matching functions themselves, the influence of inference on brightness could be mediated by setting the balance of competing edge-integration processes (as suggested by Gilchrist 1988) and/or by modifying low-level brightness percepts (such as those proposed by Hering), which have been attributed to early visual filtering operations (McCourt 1982; Foley and McCourt 1985; Kingdom and Moulden 1988, 1992; Fiorentini et al 1990; Moulden and Kingdom 1991; McCourt and Blakeslee 1993; Blakeslee and McCourt 1996).

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