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THE PERCEPTION OF TRANSPARENCY WITH ACHROMATIC COLORS

Jacob Beck
University of Oregon
and
Kvetoslav Prazdny
Fairchild Instrument and Camera Corporation

ABSTRACT

Metelli has proposed a model of the intensity relationships in perceptual transparency based on Talbot's law of color fusion. Four constraints follow from the application of Talbot's law. Violations of two constraints (Constraints i and ii) adversely affect the perception of transparency, while violations of two other constraints (Constraints iii and iv) do not. Many common occurrences of transparency are in terms of subtractive rather than additive color mixture. The constraints derived from the Metelli model have been found to also hold for subtractive color mixture. A difficulty of the Metelli model is that the degree of perceived transparency varies linearly not with reflectance but with lightness, a nonlinear function of reflectance. The hypothesis is proposed that the perception of transparency results from a higher-order encoding of the pattern of lightnesses in a stimulus. An alternative derivation of Constraints i and ii, not based on Talbot's law, is presented in terms of lightness values. Constraints iii and iv are not interpretable in terms of lightness, and are not implemented by the visual system. Their violation, therefore, does not adversely affect the perception of transparency.

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The Perception of Transparency with Achromatic Colors

Jacob Beck
University of Oregon
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Kvetoslav Prazdny
Fairchild Instrument and Camera Corporation

Metelli (1974a,b) has proposed a model for the intensity relationships in perceptual transparency. The central assumption of Metelli's model is that transparency occurs in accordance with Talbot's law of color fusion. The proximal stimulus resulting when an episcotister rotates in front of the surfaces A and B is depicted in Figure 1. Rotating the episcotister rapidly produces the perception of a transparent color (regions d and c) lying in front of surfaces A and B. According to Talbot's law, the apparent reflectances of regions d and c are equal to

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Insert Fig. 1 about here

$$(1)\ d = \alpha a+(1-\alpha)e$$

$$(2)\ c = \alpha b+(1-\alpha)e$$

$d = p$
$c = q$ $e = t$
(e = episcotister color)

where α is the areal fraction occupied by the open sectors of the episcotister, $1-\alpha$ is the areal fraction occupied by the blades of the episcotister, a is the reflectance of surface A, Non ci sono vincoli nella situazione dell'episcotista perché α essendo l'angolo vuoto non può essere maggiore di 1 $\left(\frac{360}{360}\right)$ né minore di zero e altrettanto vale per la riflettanza dell'episcotista t (~~e~~ secondo B.). I vincoli ci sono quando si considerano le altre situazioni (mosaici di grigi), dove però le (3) e (4) si possono dedurre soltanto se $\alpha = \alpha'$ e $t = t'$. Naturalmente ci può essere trasparenza anche se $\alpha \neq \alpha'$ e $t \neq t'$, ma si tratta di trasparenza non equilibrata, per la quale il modello non vale. È chiaro che in quest'ultimo caso non si può esigere che valgano i vincoli (3) e (4), perché non è lecito dedurre la formula (4). Interessante il fatto che il vincolo (1) sembra valere anche per la trasparenza non equilibrata, benché non sia deducibile la formula (3).

b the reflectance of surface B, and e the reflectance of the episcotister blades. Solving Equations (1) and (2) for α and e yields

$$(3)\ \alpha = (d-c)/(a-b)$$

$$(4)\ e = (ac-bd)/(a+c)-(b+d)$$

Alpha is the proportion of the apparent reflectances of d and c determined by the reflectances a and b and is an index of the transparency of the apparent disk. Since α is restricted to values between 0 and 1, Equation 3 implies (i) if $a>b$, then $d>c$ and vice versa if $a<b$, and (ii) the absolute difference $|a-b|$ must be greater than the absolute difference $|d-c|$. Constraint i is a restriction on the order of the intensities and insures that α is positive. Constraint ii is a restriction on the magnitudes of the intensities and insures that α is less than 1. Since e is also restricted to values greater than or equal to 0 and less than 1, order and magnitude constraints can also be derived from Equation 4.[1] Equation 4 implies (iii) if $(a+c)>(b+d)$ then $ac>bd$ and vice versa if $(a+c)<(b+d)$, and (iv) the absolute difference $|(a+c)-(b+d)|$ must be greater than the absolute difference $|ac-bd|$. Constraint iii insures that e is non-negative, and Constraint iv insures that e is less than 1. The four constraints are independent. Numerical values can be assigned to the reflectances a, b, c, and d in Equations 3 and 4 that satisfy three of the constraints but not the fourth.

Già detto! ital. p. 125

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Vedere sag. di [illegible]

Metelli (1974b) has demonstrated that the perception of transparency occurs when Constraints i and ii derived from

Equation 3 are met and fails to occur when either of these constraints are violated. He has, however, not investigated the consequences of violating Constraints iii and iv derived from Equation 4. This may be because it does not seem that they would affect the perception of transparency since it appears doubtful that people are able to make the judgments required by Constraints iii and iv. To anticipate, we will present evidence that violations of Constraints iii and iv do not adversely affect the perception of transparency. We argue that the computations carried out by the visual system in perceiving transparency are in terms of lightness values rather than in terms of reflectances or luminances. The order relationships in Constraint i and the difference relationships in Constraint ii are interpretable in terms of lightness values. (A theoretical justification of Constraints i and ii not based on Talbot's law and using lightness values rather than reflectances is presented later.) Central visual processes are able to determine whether a pattern of lightness values satisfy certain order relationships, and whether the difference between two lightness values is greater or less than that between two other lightness values. Constraints iii and iv which involve the operations of addition and multiplication are not readily interpretable in terms of lightness values. It is not clear what it means to add or multiply two lightness values, and central visual processes appear not to be able to manipulate lightness values in the ways necessary to determine whether Constraints iii and iv are satisfied.

No! I never considered judgments

No: perchè non possono essere interpretati parallelamente

e il modello dell' episcotister?

dove?

?!

?!

Perchè i processi cerebrali dovrebbero seguire le vie indicate dalle formule?!

In contraddizione con quanto dice dopo

The present study seeks to clarify both the factual background and the theoretical issues in the perception of transparency. Experiments are reported that test and extend the ? Metelli model. An alternative model of the intensity relationships in transparency is presented in terms of the transmission of light by a filter. The filter model is compared with the episcotister model proposed by Metelli. The experimental results and the theoretical analyses support the hypothesis that the perception of transparency results from the encoding of the structural information in a stimulus pattern by higher-order perceptual processes.

Atti di fede nella teoria dell'informazione

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Experiment 1

Experiment 1 was designed to investigate how the pattern of image intensities and the figural configuration affects the perception of transparency. Two supplementary experiments that answer questions raised by Experiment 1 are also reported.

Method

Qui si deve vedere se α=α' e t=t'

Stimuli.- The stimuli were computer generated Polaroid pictures.[2] Two sets of stimuli were prepared. Set 1 consisted of 4 regions of differing intensity depicting two overlapping squares on a larger square as illustrated in Figure 2a. The regions of differing intensity are identified by lower case letters and the squares by capital letters. The smaller squares were approximately 2.7 cm on a side and the larger square 6.6 cm on a side. The area of overlap was a square 1.3 cm on a side.

rectangles?

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NB quando la trasparenza non è equilibrata non si possono dedurre i vincoli

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Insert Fig. 2 about here

Un happy selection of the figure: invertibility, partial tr. and complete tr. can alternate and give rise to different results

The intensities of the 4 regions were 100, 150, 200, and 250 abdc ? on a linear gray scale ranging from 0 to 255. Twenty-four stimuli were generated corresponding to the 24 possible permutations of the four intensity values. A stimulus is identified by a sequence of the four letters a, b, c, and d, e.g., dcba. The letter order indicates increasing gray levels of the regions from lowest to highest. Table 1 lists the 24 stimuli. Stimuli 1 through 10 satisfy or effectively satisfy Constraints i and ii. (Stimuli 1, 2, 4, 5, and 7 through 10 technically violate constraint ii since the absolute difference |d-c| is equal to the absolute difference |a-b|. An α equal to 1 is the limiting value for the occurrence of transparency. Observations, however, indicated that the perception of transparency is affected only if Constraints i and ii are clearly violated. Stimuli which violate the constraints at limiting values will be considered to effectively satisfy the constraints.) Stimuli 11 through 16 violate Constraint i in a strong sense. If the gray levels in the 4 quadrants at the x-junction in the upper left of Figure 2a are traced out in increasing magnitude, the gray levels criss-cross (see Figure 2b). Stimuli 17 and 18 violate Constraint ii in the strong sense that the intensity interval ab is contained within the intensity interval cd. Stimuli 19 and 20 violate both Constraints i and ii strongly.

?

Why not give the reflectances?

X

?

~~come fa a rilevare non ha le misure delle riflettanze~~ ?

perfect transparency

??

? È chiaro che la formula di α dà un risultato differente se a, p, q, b differiscono per una costante additiva. Ma la formula di t dà un risultato diverso anche se la c. è moltiplicata

Stimuli 21 through 24 violate Constraint i, but the brightness values do not criss-cross. They effectively satisfy Constraint ii. All 24 stimuli satisfy Constraint iii. The gray scale values may be normalized to take on values between 0 and 1 if they are divided by 255, the maximum value. Constraint iv is satisfied if the ratio of the normalized gray scale values |ac-bd| divided by |(a+c)-(b+d)| (e in Equation 4) is less than 1, and is violated if the ratio is equal or greater than 1. Since (a+c)-(b+d) is equal to 0 for stimuli 1, 2, 4, 5, 7, 8, 9, and 10, Constraint iv is violated with these stimuli. The violation, however, is weak. A change of the lowest gray level from 100 to 110 would lead to satisfying Constraint iv. A change of 10 on the gray scale is a 4 percent change. The remaining stimuli in Set 1 satisfy Constraint iv.

Vedere

Set 2 consisted of 40 stimuli and investigated the effect of figural configuration on the perception of transparency. The two configurations illustrated in Figure 3 were compared. Configuration I was similar to that in Set 1. The differences were that the lower square was changed to a rectangle and located to the right, rather than to the left, of the upper square. The sizes of the squares were the same as in Set 1. The rectangle was 4 cm x 2 cm. The area of intersection was a rectangle 1.7 cm x 1.0 cm. Configuration II consisted of 4 differing intensity regions depicting an inner square overlying a bipartite background composed of two adjacent rectangles. The inner square

Perchè
non
essere
la stessa
figura?

was 3.4 cm on a side, and the background rectangles 3.4 cm x 6.7 cm. The intensities of the four regions in Set 2 were not,

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Insert Fig. 3 about here

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as in Set 1, permutations of the same four intensities but varied. Pairs of stimuli were generated in which the corresponding regions in Configurations I and II were the same intensities. Eight stimuli each with Configurations I and II satisfy Constraints i and ii. The stimulus orders and their numbers were $\overset{\text{ba 1.}}{\text{abdc}}$ (1), $\overset{\text{ab 5.}}{\text{bcda}}$ (2), $\overset{\text{ab 8.}}{\text{cdba}}$ (3), and $\overset{\text{ba (3,4}}{\text{dcba}}$ (2). Four stimuli each with Configurations I and II were generated with the order $\overset{\text{ab (23.)}}{\text{cdab}}$. Two stimuli satisfy Constraint ii but not Constraint i and two stimuli fail both constraints. The interval cd exceeds the interval ab by 25 (a 10 percent gray scale difference) and 10 (a 4 percent gray scale difference) respectively. Four stimuli each with Configurations I and II were generated with the order $\overset{\text{8.}}{\text{cdba}}$. The stimuli satisfy Constraint i but not Constraint ii. The intensity difference between regions d and c exceeds the intensity difference between regions a and b by 17 (a 7 percent gray scale difference) on 2 stimuli, and by 40 (a 16 percent gray scale difference) on 2 stimuli. Eight stimuli violate Constraint I storngly and involve a criss-crossing of brightness values. The stimulus orders were $\overset{\text{12}}{\text{acdb}}$(2), $\overset{\text{13}}{\text{bdac}}$(1), $\overset{\text{14}}{\text{bdca}}$(3), and $\overset{\text{15}}{\text{cadb}}$(2). The eight stimuli satisfy Constraint ii and occur only with Configuration I. ?

8

All stimuli in Set 2 satisfy Constraint iii. Two of the eight stimuli satisfying Constraints i and ii in Set 2 violate Constraint iv. The ratio of the normalized gray scale values of stimulus abdc substituted in Equation 4 is 2.2. The lowest gray level must be increased by 25 (10 percent) to satisfy Constraint iv. The value of $|(a+c)-(b+d)|$ is 0 for one of the cdba stimuli. The violation, however, is weak, and an increase of the lowest gray level by 4 percent leads to satisfying Constraint iv. The remaining stimuli in Set 2 all satisfy Constraint iv. Sample stimulus displays are shown in Figure 4.

Insert Fig. 4 about here

Procedure.- Sets 1 and 2 were alternated. Before presenting either set of stimuli, subjects were shown examples of overlap with and without transparency. Before Set 1, transparency was illustrated by showing subjects a Polaroid filter overlying gray papers. They were arranged as in Figure 2. ?? Overlapping without transparency was illustrated by showing subjects four gray papers corresponding to regions a,b,c, and d in Figure 2 superimposed on one another. The four gray papers were seen as opaque. The subjects were told that they would be shown photographs of surfaces arranged as in Figure 2 and asked to judge whether the bottom square (D) was transparent. They were instructed that they were to judge the

Vanno perdute le inversioni

bottom square as transparent only if <u>both</u> the background (A) and the top square (B) were seen through the bottom square. If only the background or only the top square were seen through the bottom square, but not both, the bottom square was to be judged as not transparent. Subjects were also told that we were concerned only with the perceived transparency of the bottom square. Only if the background and the top square were seen through the <u>bottom</u> square should a stimulus be judged as transparent. If the background and the bottom square were seen through the top square, the stimulus should be judged as not transparent. Similar instructions and examples were given before Set 2 was presented. Subjects were shown examples of overlapping with and without transparency using a Polaroid filter and gray papers arranged as in Configurations I and II of Figure 3. Subjects were cautioned that a stimulus was to be reported as transparent only if they could see both the top square and the background through the bottom rectangle (Configuration I), or if they could see through the inner square to both background rectangles (Configuration II). A stimulus was also to be judged as not transparent if a surface other than the indicated surface was seen as transparent. For example, the top square was seen as transparent with Configuration I or the left or right half of the inner square was seen as transparent but not the entire square with Configuration II. To report a stimulus as transparent one should see through

partial transp. perchè escluderla?

perchè? questo viene soltanto una priorità, non la nontrasparenza

si dovrebbe tener conto di tutti questi casi applicando correttamente la formula the bottom rectangle with Configuration I and through the inner square with Configuration II to both underlying surfaces.

The subjects were told that we were interested in their immediate visual perception. They were instructed to make an immediate judgment based on their visual impression, and not to try to reason things out. The two sets of stimuli were presented by means of a Gerbrands tachistoscope. The viewing distance was 59.7 cm and the exposure duration was 2 seconds. A subject initiated a stimulus presentation by pressing a switch. Before presenting each stimulus set, 5 practice stimuli were presented. The 5 practice stimuli contained 2 stimuli which are generally judged as not transparent, and one stimulus in which a surface other than the indicated surface was seen as transparent. The 5 practice stimuli presented before Set 2 consisted of 3 stimuli with Configuration I, and 2 stimuli with Configuration II. The stimuli within each set was presented in a different random order to each subject.

è una
sensazione
e non
un giudizio

!!

qual'è lo
schema adottato
di presenta-
zione?

perchè non
2 e 2?

Subjects.- Twenty-one volunteers with normal or corrected to normal vision served as subjects. They were naive concerning the purpose of the experiment.

Results

Table 1 presents the results with Set 1. The mean number transparency judgments of stimuli 1 through 10 satisfying

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Insert Table 1 about here

Constraints i and ii is 18.3 with a standard deviation of 1.7. The weak violation of Constraint iv by stimuli 1, 2, 4, 5, and 7 through 10 did not adversely affect the perception of transparency. The perception of transparency was also not affected by the pattern of lightness changes. The lightnesses of the overlapping regions (regions c and d) are increased with stimuli abdc, bacd, adbc, and bcad, decreased with stimuli cdba, dcab, cbda, and dacb, and the lightness of the darker surface is increased while the lightness of the lighter surface is decreased with stimuli adcb and bcda. Inspection of Table 1 shows that the occurrence of transparency judgments was not affected.

questo è
interessante.
Vedere
Remondino

The perception of transparency did not occur when either the order relations in Constraint i or the magnitude relations in Constraint ii were violated strongly. The mean number of transparency judgments of the six stimuli (stimuli 11 through 16) with criss-crossing brightnesses which satisfy Constraint ii but strongly violate Constraint i is .83 with a standard deviation of .98. The mean number of transparency judgments of the two stimuli (stimuli 17 and 18) which satisfy Constraint i but strongly violate Constraint ii is .50 with a standard deviation of .71. The two stimuli (stimuli 19 and 20) which fail to satisfy both Constraints i and ii were never judged to be transparent.

Stimuli 21 through 24 fail to satisfy Constraint i. Significant numbers of transparency judgments were obtained with stimuli cdab and badc. The stimulus cdab received 13 transparency judgments (over 50 percent), and the stimulus badc 6 transparency judgments (over 25 percent). Why do these two stimuli produce exceptions and not the stimuli abcd and dcba? A stimulus is ambiguous as to whether surface D is seen overlying surface B or surface B is seen overlying surface D. The theoretical derivation assumes that the overlying transparent regions are d and c and the underlying opaque regions are a and b. If surface B is seen overlying surface D, then the regions b and d are interchanged. Thus, the stimulus abcd becomes adbc and the stimulus dcba becomes bcda. Both adcb and bcda satisfy the order and magnitude restrictions respectively of Constraints i and ii. What is suggested is that subjects tended to see these surfaces as transparent with surface B over surface D (See Figure 4f). The low number of transparency judgments reflect that the instructions asked subjects to report the stimulus as transparent only if surface D is seen overlying surface B. Support for this conjecture comes from a preliminary study in which the stimuli in Set 1 were presented using slides to a group of 18 subjects. The instructions were similar to those given in Experiment 1. The main difference was that subjects were first asked to judge whether they saw a stimulus as transparent, and then asked to judge whether surface D was seen overlying surface B or whether surface B was seen overlying surface D. Two subjects judged the stimulus abcd

qpab (13) bapq (6)

abqp pqba

abqp apbq pqba bqpa

Vorrei
vederlo

Sono tutte e due
sopra di tre
parziale!

!!

?

13

transparent with surface D overlying surface B while 16 subjects judged the stimulus transparent with surface B overlying surface D (stimulus adcb). Two subjects judged the stimulus dcba transparent with surface D overlying surface B while 15 subjects judged the stimulus transparent with surface B overlying surface D (stimulus order bcda). One subject judged the stimulus as not transparent.

In contrast, stimuli cdab and badc cannot be seen as surface B overlying surface D. If surface B is seen overlying surface D, then cdab becomes cbad and badc becomes dabc. Both cbad and badc strongly violate Constraint ii. The interval cd is included in the interval ab. The occurrence of transparency judgments with stimuli cdab and badc indicates that if figural conditions strongly suggest transparency, the perception of transparency can occur even if the pattern of image intensities contradicts it. We shall return to this question in the General Discussion.

No

questo non spiega affatto perchè si vedano trasparenti cdab e badc e non abcd e dcba

Table 2 presents the results with Set 2. The mean number of transparency judgments with Configuration I was 17.8 with a

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Insert Table 2 about here
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standard deviation of 1.5. The mean number of transparency judgments with Configuration II was 14.8 with a standard deviation of 2.6. A *t* test is significant at the .01 level (*t*(7) = 3.97, *p*<.01). The number of transparency judgments of the abdc

abfg

Invece probabilmente è perchè nei 2 primi è possibile vedere la trasparenza parziale (senza inversione) e non negli altri due.

14

qpba

and cdba stimuli which violated Constraint iv were both 17 with Configuration I and 15 and 14 respectively with Configuration II. The fact that the transparency judgments with stimulus abdc was similar to the other stimuli suggests that the violation of Constraint iv does not detrimentally affect the perception of transparency.

The four stimuli with the order cdab fail to satisfy the order relation in Constraint i. The mean number of transparency judgments with Configuration I is 10.0 with a standard deviation of 2.5, and with Configuration II 1.5 with a standard deviation of 1.0. (Subjects' judgments of the two stimuli failing Constraint ii were similar to those of the two stimuli satisfying Constraint ii.) A t test of the difference is significant (t(3) = 5.47, $p<.05$). Thus, exceptions to Constraint i with stimulus cdab occurred more readily with Configuration I than with Configuration II. The local cues for transparency are similar for Configurations I and II. The x-junctions indicate the possibility of transparency on both configurations. The fact that Configuration I was more effective than Configuration II in producing the perception of transparency indicates that the global figural configuration affects the perception of transparency. The component regions in Configuration II are more regular and symmetric with a nontransparent organization than the corresponding regions in Configuration I.

Vedere probabilità tr. parziale

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?

?

perfetto

The four stimuli with the order cdba satisfy Constraint i but fail to satisfy Constraint ii. The mean number of transparency judgments with Configuration I is 13.0 with a standard deviation of 1.2 and with Configuration II 10.5 with a standard deviation of 2.7. A t test of the difference is not significant (t(3) = 1.89, p>.1).

The eight criss-cross stimuli occurred only with Configuration I. The mean number of transparency judgments is 2.1 with a standard deviation of 2.9. A relatively large number of transparency judgments (8) occurred with one of the aqpb acdb stimuli. Region c in this stimulus is less than .5 of a Munsell step lighter than region d. The closeness in lightness of the two regions appears to have facilitated the perception of transparency. If regions c and d are interchanged, the order becomes apqb adcb which satisfies both the order and magnitude constraints. The results again indicate that if figural cues strongly suggest transparency, then contradictory indications from the pattern of intensities may be overriden with some subjects.

dove?
in tab. 2
non appare

Supplementary Experiments

Supplementary Experiment 1.- The aims of the first supplementary experiment were (a) to determine whether the transparency judgments evoked by stimulus aqpb acdb described in the previous paragraph is replicatable, (b) to examine how the magnitude of the violation of Constraint i anche! with stimulus qabp cabd and of Constraint ii with stimulus qbpa cbda affects the perception of

aqpb
qabp
qbpa

transparency, (c) to examine further whether violations of Constraint iv detrimentally affect the perception of transparency. $t > 1$

The procedure was the same as in Experiment 1. Nineteen stimuli were presented. Four of the eight criss-cross stimuli in Experiment 1 were presented. The stimulus orders were $\overset{aqpb}{acdb}$, $\overset{bpaq}{bdac}$, $\overset{bpqa}{bdca}$, and $\overset{qapb}{cadb}$. (The $\overset{aqpb}{acdb}$ stimulus was the stimulus which evoked transparency judgments in Experiment 1.) 2 ! Four new $\overset{qpab}{cdab}$ stimuli were prepared. The stimuli violated only Constraint i. The gray scale difference between a and b was constant, 125; the gray scale differences between $\overset{q}{c}$ and $\overset{p}{d}$ were 10, 20, 40, and 60 respectively. (If $\overset{q}{c}$ and $\overset{p}{d}$ are permuted, the stimulus order becomes dcab which satisfies Constraint i.) Two new $\overset{qpba}{cdba}$ stimuli were prepared. The gray scale difference between a and b was constant, 25; the gray scale differences between c and d were 40 and 100 respectively. $\overline{\overset{II}{|a-b| < |p-q|}}$ |a- Three stimuli were presented which violated only Constraint iv. The $\overset{abpq}{abdc}$ stimulus of Experiment I was presented. Two new stimuli with the stimulus orders $\overset{baqp}{bacd}$ and bcad were prepared. The ratios of the normalized gray scale values substituted in Equation 4 were 2.0 for both stimuli. The minimum difference necessary to satisfy Constraint iv was a gray scale change of 23 (a 10 percent change) with both stimuli. ! Twenty-five new volunteers with normal or corrected to normal vision served as subjects. They were naive concerning the purposes of the experiment.

Stimulus $\overset{aqbp}{\text{acdb}}$ again evoked a significant number of transparency judgments. Fourteen subjects judged stimulus $\overset{aqbp}{\text{acdb}}$ as transparent. Only one other of the criss-cross stimuli evoked transparency judgments. Three subjects judged stimulus $\overset{bpqa}{\text{bdca}}$ transparent. We have suggested that it is the closeness in lightness of regions $\overset{q}{\text{c}}$ and $\overset{p}{\text{d}}$ on stimulus $\overset{qqpb}{\text{acdb}}$ that is responsible for the large number of transparency judgments. This is supported by the finding that transparency judgments vary inversely with the salience with which Constraints i and ii are violated. Transparency judgments with stimulus $\overset{qpab}{\text{cdab}}$ were 17, 10, 5, and 2 respectively when the gray value value of $\overset{p}{\text{d}}$ exceeded that of $\overset{q}{\text{c}}$ by 10, 20, 40, and 60 respectively. Transparency judgments with stimulus $\overset{qpba}{\text{cdba}}$ were 19 and 4 when the gray scale difference between c and d exceeded that between a and b by 15 and 75 respectively. The mean number of transparency judgments of the six stimuli satisfying Constraint iv was 24.6 with a standard deviation of .82. The mean number of transparency judgments of the 3 stimuli failing to satisfy Constraint iv was 23.3 with a standard deviation of 1.53. Unlike Constraints i and ii, violation of Constraint iv does not affect transparency judgments. Figures 5c and 5d show two of the stimuli (abdc and bacd) which violate Constraint iv. Figures 5a and 5b show two stimuli which satisfy Constraints i, ii, and iv, but violate Constraint iii. In 5a (a+c) exceeds (d+b) by 60, while bd exceeds ac by 1000. In 5d (d+b) exceeds (a+c) by

Severe

equivalenti

Insert Fig. 5 about here

60, while ac exceeds bd by 1000. The demonstrations indicate that violations of Constraint iii also does not detrimentally affect the perception of transparency.

<u>Supplementary Experiment 2</u>.- Constraints i and ii are not always sufficient to uniquely determine the perception of transparency. For example, Table 1 shows that stimuli abdc, adbc, cbda, and cdba all satisfy the order and magnitude constraints. If surface B is seen as overlying surface D, then stimulus abdc becomes adbc, and stimulus adbc becomes abdc. Similarly stimulus cbda becomes cdba, and stimulus cdba becomes cbda. Auxiliary principles become necessary to predict whether surface D is seen as transparent and overlying surface B or surface B is seen as transparent and overlying surface D when subjects are not instructed to see a particular arrangement as in Experiment 1. One possible principle is that region c in Figure 2 is joined to regions b or d depending on which it differs least from in lightness. An experiment was conducted to test this possibility.

abpq apbq qbpa qpba

Petter

The six stimuli abdc, adbc, cbda, cdba, cadb, and dbac from Set 1 were presented individually using 4 different random orders to 40 subjects in two classes. To familiarize subjects with the phenomenon, they were shown pictures of surfaces arranged as in Configuration II in which the perception of

-1/1-2 1-#/1

transparency occurred and in which it failed to occur. Subjects were asked to indicate on a data sheet, first, whether a stimulus was seen as transparent and, second, if a stimulus was seen as transparent, whether the top square was seen to overlie the bottom square or whether the bottom square was seen to overlie the top square. The subjects were instructed to base their judgments on their immediate visual impression. To avoid position biases, 19 subjects were presented with the stimuli upright and 21 with the stimuli inverted.

Stimuli cadb and dbac have criss-crossing brightnesses and should be judged as not transparent. Region c is closer in lightness to region d than to region to b for stimuli abdc and cdba, while for stimuli adbc and cbda region c is closer in lightness to region b than to region d. According to the hypothesis proposed, surface D should be seen to overlie surface B (D/B) with stimuli abdc and cdba, and surface B should be seen to overlie surface D (B/D) with stimuli adbc and cbda.

Table 3 presents the number of non-transparency judgments, of D/B transparency judgments, and of B/D transparency judgments. The frequencies in Table 3 combine the judgments made with both the upright and inverted presentations of the stimuli. The number of non-transparency judgments was 66 and

Insert Table 3 about here

of transparency judgments 14 with stimuli cadb and dbac. The reason for the larger number of transparency judgments than in

Experiment 1 is not clear. It may simply reflect a criterion difference. ? The instructions in Experiment 1 were given individually and emphasized that a stimulus was to be judged transparent only if one saw through the overlying surface to both underlying surfaces. The number of transparency judgments of D/B was 61 and of B/D 14 with stimuli abdc and cdba. The number of transparency judgments of B/D was 54 and of D/B 20 with stimuli adbc and cbda. The percentage difference of .54 is significant ($z = 4.50$, $p<.01$). The results clearly show that there is a presumption to join the region c with the region which is closest in lightness. The results also indicate a position bias. Twenty-two of the 34 judgments counter to the hypothesis were judgments that the top square was transparent and overlay the bottom square. The percentage of judgments differ significantly from the 50 percent chance level at the .05 significance level ($z = 1.88$). The fact that in Experiment 1 stimuli adbc and cdba gave as many transparency judgments with surface D overlying surface B as stimuli abdc and cbda indicates that the predisposition to unite regions which are closer in lightness can easily be overcome by an instructional set.

Filter Model

? The question may be raised: Since Constraints i and ii are not wholly ecologically representative, why do they predict the occurrence of transparency as well as they do? ? The luminances of the areas d and c in Figure 1 are the result of stimulating the retina by the light reflected from the episcotister and from the surfaces A and B behind the episcotister. The resulting addition of luminances is known as additive color mixture and is given quantitatively by Talbot's law. Additive color mixture occurs in some natural scenes as, for example, with clouds of dust. Many common occurrences of transparency, however, are in terms of subtractive rather than additive color mixture. When an object is viewed through a liquid, mist, or glass, subtractive color mixture occurs. The luminance of the overlapping area in subtractive color mixture is the result of the light intensity reflected by the background surface and transmitted by the transparent medium plus the light intensity reflected by the transparent medium.

What are the relations among image intensities when transparency occurs in terms of subtractive color mixture? The physical situation is depicted in Figure 6a. We will assume an achromatic surface viewed in neutral illumination through a transparent medium that is nonselective for wavelength. In

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Insert Fig. 6 about here

Figure 6a, a is the reflectance of surface A, b the reflectance of surface B, f the reflectance of filter F, and t the transmittance of the filter. Figure 6b illustrates the pattern of reflectance and transmittance assumed to occur. The apparent reflectances of regions d and c are equal to

$$(5)\quad d = f+(t^2a)/(1-fa)$$

$$(6)\quad c = f+(t^2b)/(1-fb)$$

anche perciò [illegible] per
l'esposizione [illegible] e [illegible]

Solving equations 5 and 6 for t and f yields

$$(7)\quad t = \sqrt{(c-bcd+bd^2-d)(b-a-abc+a^2c)/(b-a+abd-abc)^2}$$

$$(8)\quad f = (bd-ac)/b(1+ad)-a(1+bc)$$

Order and magnitude constraints for the perception of transparency with subtractive color mixture can be derived from Equations 7 and 8. Since the perception of transparency occurs when t is restricted to values between 0 and 1, Equation 7 implies that (v) $(c-bcd+bd^2-d)(b-a-abc+a^2c)>0$ and that (vi) $(b-a+abd-abc)^2$ is greater than $(c-bcd+bd^2-d)(b-a-abc+a^2c)$. Since the reflectance of the filter, f, is also restricted to values greater than or equal to 0 and less than 1, Equation 8 implies (vii) if $bd>ac$ then $b(1+ad)>a(1+bc)$ and vice versa if $bd<ac$ and (viii) the absolute difference $b(1+ad)-a(1+bc)$ must be greater than the absolute difference $bd-ac$. Constraints v and vii insure that t and f are positive and non-negative respectively while constraints vi and viii insure that t and f are less than 1.

What is the relationship between the equations derived from the episcotister and the filter models? Equations 1 and 2 are clearly not equal to Equations 5 and 6. For example, if $a=.5$, $b=.3$, and $t=.7$, and e and $f = .2$, d and c are equal to .41 and .27 from Equations 1 and 2, while d and c are equal to .47 and .36 from Equations 5 and 6. The order and magnitude constraints, however, defining the boundary conditions for solutions of the two sets of equations, appear to be closely related. Equations

5 and 6 of the filter model imply Constraints i and ii derived from Equation 3 of the episcotister model, and Equations 1 and 2 of the episcotister model imply Constraints v and vi derived from Equation 7 of the filter model.[3] Although we have not been able to demonstrate it mathematically, a computer search of the solutions of Equations 5 and 6 of the filter model has failed to find any solutions which violate Constraints iii and iv derived from Equation 4. Similarly, a computer search of the solutions of Equations 1 and 2 of the episcotister model has failed to find any solutions which violate Constraints vii and viii derived from Equation 8 of the filter model. What is suggested is that the solution sets of Equations 1 and 2 and Equation 5 and 6 are the same or very nearly the same.

The physical occurrences of transparency involve both color addition and color subtraction and set the normative conditions for the perception of transparency. If perception is to be adaptive, it must satisfy these conditions except in unimportant ways. This does not mean, however, that the visual system solves Equations 1 and 2, and 5 and 6. The visual system may utilize heuristics to judge transparency which in the main agree with physical reality. Constraints i and ii derived from Metelli reflect order and difference relations that occur both with additive and subtractive color mixture. The two constraints are, therefore, ecologically valid indicators of physical transparency and can serve as a basis for adaptive behavior. The constraints with additive

Is the episcotister not a physical occurrence?

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and subtractive color mixture are, of course, not always the same. In the case of hue, for example, yellow plus blue yields white with additive color mixture while yellow plus blue yields green with subtractive color mixture. Beck (1972, 1975) presented demonstrations showing that hue transparency occurs with subtractive color mixture. An experiment investigating the perception of transparency with hue has found that it occurs as readily with subtractive color mixture as with additive color mixture. The results of this experiment will be reported in a separate paper.

grey

Experiment 2

We have indicated that the equations describing transparency with additive and subtractive color mixture are not quantitatively equal. Transparency judgments based on Equation 3, for example, will not be quantitatively correct with subtractive color mixture. This is, however, not very important because in general one is not able to make quantitatively accurate judgments of transparency. We will show that transparency estimates are based not on physical luminance or reflectance values but on sense distances. Metelli's Equations 1 and 2 describing transparency assume that transparency is determined by the physical luminance or reflectance values. Equal increments of reflectance, however, do not represent equal increments in lightness. For example, the lightness difference between two papers that have reflectances of 80 percent and 90 percent is very small while the difference between papers having reflectances of 5 percent and 15 percent

Eq. 3 e 7 danno risultati diversi ma questo non dipende dal fatto che una ~~[illegible]~~ misura la miscela addit. e l'altra quella sottrattiva is very large. Since the visual system does not have direct information about reflectances, it is likely that transparency judgments will vary linearly not with reflectance difference but with lightness difference. Thus, to predict quantitative judgments of transparency, one must introduce a psychophysical function, such as the Munsell value scale, which describes how lightness varies as a function of reflectance. The aim of Experiment 2 was to determine whether transparency judgments vary linearly with reflectance difference or with lightness difference.

Method

The stimulus consisted of three intensity regions arranged to depict two overlapping rectangles as shown in Figure 7.

Insert Figure 7 about here

The stimulus color of region a was a Munsell value of 1 (1.2 percent reflectance) and of region b a Munsell value of 8 (59.1 percent) and of region c a Munsell value of 4 (12 percent). The stimulus is ambiguous and can be seen as the upright rectangle overlying the diagonal rectangle or of the diagonal rectangle overlying the upright rectangle.

The Munsell papers were pasted on a matte black background. The background was cut away so that only the stimulus figure was visible. The stimuli were supported by a stalk fitted into a wooden base located at eye level 5 feet from a subject. The illumination came from a projector using a bulb having a color temperature of 2900K. The light passed through a 1-62 Corning filter which converts the illuminant to C.I.E. illuminant C (6500K). Subjects viewed the stimuli monocularly through a viewing tube that limited visibility to the immediated stimulus surround. An electrically controlled shutter limited viewing time to a 2 second period. Subjects were allowed to view a stimulus for as many two-second periods as they wished, but were urged to make their judgments upon their immediate visual impression.

Subjects were first acquainted with the phenomenon of transparency through examples. The test stimulus was presented together with 10 other stimuli made up of colored Munsell papers.[4] Subjects judged the chromatic stimuli only with respect to whether they were seen as transparent or not. Following the presentation of the chromatic stimuli, subjects were instructed that the next stimulus would be achromatic, and that they would judge the stimulus not only with respect to whether it appears transparent but also with respect to how transparent it appears. They were told that a surface can vary in transparency. Different degrees of transparency were described by asking subjects to think about mixing ink with water or milk with water. Adding milk or ink to the water decreases the transparency of the mixture. Subjects were asked to judge whether they saw transparency or not. If a subject reported seeing transparency, the subject was then asked whether the upright rectangle or the diagonal rectangle was seen as the overlying surface. Subjects were asked to estimate the transparency of the overlying surface from near zero percent (nearly completely opaque) to near 100 percent (nearly completely transparent). Following the transparency judgment, subjects were asked to try to see the three regions as coplanar and to match the lightnesses of the regions to grays on a Munsell chart. The Munsell chart was placed on a shelf to the left of a subject and illuminated by an Easel lamp which simulated C.I.E. illuminant C. Subjects were allowed to view the stimulus without time limit while matching the stimulus to the Munsell grays.

(cir contrasto)

Subjects.- Eleven subjects served in the experiment. They all had normal or corrected to normal vision, and were naive about the purpose of the experiment.

Results and Discussion

In Figure 7a, a represents the reflectance of the top surface T, and b the reflectance of the bottom surface B. The transparency of the top surface in the area of overlap is represented by α. According to Talbot's law, the apparent reflectance of region c is equal to

$$(9) \quad c = \alpha b+(1-\alpha)\cancel{a}\,t$$

where α and $(1-\alpha)$ represent respectively the proportions of which the apparent reflectance c is made up of the reflectances of surfaces B and T. Solving Equation 9 for α, yields

$$(10) \quad \alpha = (c-a)/(b-a)$$

If the diagonal black surface is seen as transparent, the perceived transparency calculated in terms of reflectance is

Beck substitutes Munsell values (or lightness judgements) to reflectances and obtains a good match of the judged degree of transparency. This is a happy intuition. Then he tries to justify this result. This is not the correct way - justifying the good result obtained by using in an arbitrary way a formula, by constructing a theory. He should have reduced the formula from his theory.

.19 and in terms of Munsell value .43. The mean of subjects' lightness matches of regions a, c, and b were Munsell values of 3.1, 5.5 and 9.2. The transparency estimate when these values are substituted in Equation 10 is .39. The mean of subjects' transparency estimates is 41.4 with a standard deviation of 5.1. Thus, one must introduce into Equation 10 lightness values rather than reflectances to accurately predict quantitative transparency judgments.

The finding that the perception of transparency is determined not by the physical reflectances, but by lightness values, argues that the phenomenon of transparency is not ? based on Talbot's law. In fact, if one sets up an episcotister, judgments of transparency would be inaccurate. Rather, the perception of transparency appears to be based on the lightness values which are a nonlinear function of reflectance. What is the theoretical justification for using the Munsell values of regions a, b, and c in Equation 10? A justification may be given based on the hypothesis that the perceived transparency is a function of the relative similarity of the lightness of region c to the lightness of the underlying region b and to the lightness of the overlying region a. The perception of transparency is the result of encoding the lightness of region c as the lightness of the underlying region b modified by the lightness of the overlying region a. The more similar the lightness of c is to the lightness of a, the less the perceived transparency, and the more similar the lightness of c is to the

This is a descrip-tion, not an expla-nation lightness of b, the greater the perceived transparency. The Munsell value scale is based on direct estimates of lightness differences and reflects lightness similarities. If M(a), M(b), and M(c) are the Munsell values of the regions a, b, c, the relative similarity of lightness c to lightness a is given by the difference, d1, (M(c)-M(a)) divided by the difference, d2, (M(b)-M(a)) (see Figure 7b). The equation for perceived transparency has the same form as Equation 10, but with Munsell values substituted for reflectances:

$$(11)\quad \alpha = M(c)-M(a)/M(b)-M(a)$$

Partial Transparency.- The perception of transparency with a three-part stimulus is anomalous. One does not perceive a transparent surface through which other objects and surfaces are seen. ? Rather, one perceives a surface which is in part transparent and in part opaque. Metelli (1974) has called this special kind of transparency "partial transparency." As pointed out above, a model based on Talbot's law and color addition requires the reflectance of the overlapping region c to lie between the reflectance of the a region and the reflectance of the b region. The similarity algorithm we have proposed for judging the degree of transparency also requires that the lightness of the overlapping region c lie between the lightness of the a region and the lightness of the b region. In contrast, a model based on a filter and subtractive color mixture allows the reflectance of the overlying region c to be greater than the ?

reflectances of the a and b regions. Inspection of Equation 6 shows that this will occur, for example, if f, the reflectance of the top surface, is greater than b, the reflectance of the bottom surface. Informal observations indicate that the occurrence of partial transparency is much more difficult, if not impossible, without the assumption of a special attitude, when the reflectance of the overlying region c is greater than the reflectances of regions a and b. Partial transparency, as pointed out, is not ecologically representative and appears to occur because of a preference by the visual system for minimizing the complexity of the perceptual interpretation. The perception of transparency in Figure 7 both simplifies the shapes and minimizes the lightness changes. Encoding the lightness of an overlying region in terms of the lightnesses of the base and top surfaces may simply require that the encoded lightness lie between the two reference lightnesses. This may simply reflect our greater experience with the mixing of paints and the overlapping of filters to that of the adding of lights. If T and B in Figure 7 are two projected rectangles of light, the intensity in the overlying area is greater than the intensities of the non-overlying areas of the rectangles. If is also of interest to note that if partial transparency occurs in nature, it occurs in terms of additive color mixture. For example, the threads in the corner of an opaque fabric may be pulled apart. When viewed from a distance in which the individual threads cannot be resolved,

eq. 6 is for complete transp. if k (or q) > b, there is no transparency

~~falso~~

ovvero la trasparenza a cui la tr. parziale è innaturale

è quanto è stato dedotto

e i bambini?

e allora?

part of the surface is seen as opaque and part of the surface is seen as transparent.

Complete Transparency.- Equation 3 gives the degree of transparency according to Talbot's law for two surfaces of differing reflectance seen through a transparent medium as in the case of an episcotister. Metelli (1974a) describes this kind of transparency as "complete transparency." Though we have not conducted any experiments, we believe that with complete transparency, as with partial transparency, the degree of perceived transparency will not be correctly predicted when physical reflectance or luminance values are substituted in Equation 3. We conjecture that substituting lightness values for reflectances in Equation 3 will correctly predict the perceived degree of transparency. Our hypothesis is that the estimate of transparency is based on the amount of apparent contrast reduction. ? The perception of the degree of transparency is assumed to be a function of the similarity of the lightnesses d and c relative to the similarity of the lightnesses a and b (see Figure 2). If the contrast between the lightness of regions d and c is very similar to the contrast between the lightnesses of the regions a and b, then the perceived transparency is very high. why? If the lightnesses of the regions d and c are equal, i.e., their contrast is zero, then the degree of perceived transparency is zero. As the lightness difference between the regions d and c approaches the lightness difference between the regions a and b, the perceived degree of transparency goes to 100 percent. The similarities between the lightnesses d and c, and a and b are given by their differences on the Munsell value scale which describes how subjective lightness differences vary as a function of reflectance differences, i.e., M(d)-M(c) and M(a)-M(b). The degree of transparency is a function of the relative similarity of the lightnesses d and c to that of a and b and is given by the equation

$$(11)\quad \alpha = M(d)-M(c)/M(a)-M(b)$$

Equation 11 has the same form as Equation 3 but with Munsell values substituted for reflectance values.

General Discussion

Perceptual transparency is a function of the stimulus information indicating that the overlying surface is not opaque and transmits as well as reflects light. Transparency is indicated by the alteration in image intensities produced by the overlying surface, the image distortions occurring because of light refraction, and the cues provided by figural configuration, depth, and motion.

che cosa fornirebbe questa informazione?

questo presuppone un'esperienza specifica

condizioni non necessarie

The finding that the perception of transparency is a function of lightness indicates that transparency is not, as suggested by Metelli (1974b), the result of splitting a stimulus luminance into the luminance of the background surface and the luminance of the transparent surface, i.e., the reverse of color fusion. In fact, constraints based on reflectance or luminance which involve a nonlinear

?
1 experiment

not a result but a splitting

The contrary of fusion in terms of lightness

Transparency = splitting

33

transformation of lightness information cannot be implemented by the visual system. Since lightness is a nonlinear function of reflectance, the magnitude relations embodied in Constraint ii can be satisfied in terms of either lightness or reflectance and not the other. The stimuli in Experiment 1 and in the supplementary experiments reported were chosen so that the perceived lightness and the physical gray scale values were consistent. If a stimulus satisfied Constraint i in terms of gray scale values, the stimulus effectively satisfied the constraint in terms of lightness values.[5] The visual system also appears to be able to make only order and relative difference judgments of lightnesses. Constraints iii through vii which involve the addition and multiplication of physical intensities are not reinterpreted in terms of lightness relations.

invece sì

?

?

da che cosa appare?

but can be

How do the cues deriving from the pattern of intensities relate to other stimulus information affecting the perception of transparency? The other variable that has been systematically studied is figural configuration. Metelli (1974b) has identified three main figural conditions for perceiving transparency: figural unity of the transparent layer, continuity of the boundaries in the transparent region with the boundaries of the nontransparent regions, and stratification of the transparent region into two overlaying layers. Our observations suggest that figural cues are primary and that if the figural configuration indicates the possibility of transparency then the pattern of lightness relationships are checked to see if they are consistent with transparency. Transparency will be seen if the pattern of lightnesses satisf~~y~~ies Constraints i and ii. If more than one stratification of the surfaces satisf~~y~~ies the constraints, then instructional sets or subsidiary principles determine what is seen. One such principle is that the overlapping region tends to the region from which it deviates least in lightness.

If the figural cues for transparency are strong enough, then transparency may be seen even when the pattern of lightness relationships are incorrect. A striking example of this is described by Metzger (1955). Metzger showed that if a disk is made to rotate slowly about a point, two intersecting circles on the disk will become separated in depth. There is a splitting of the intersecting region into two planes based on two kinds of contour movements. One plane is defined by contours which move into each other, and the other plane by contours which are displaced over the retina. An observer sees a moving circle rotating around a stationary circle. What is of interest is that the cues for seeing overlapping circles are so strong that the perception of transparency occurs for color combinations that strikingly violate both additive and subtractive color mixture. Transparency can also occur with stationary stimulus patterns when the pattern of hues or lightnesses are incorrect. The stimulus order qbab cdab with Configuration I evoked judgments of transparency despite the

Musatti

qui non
può vedere
che non
c'è

?

quali

violation of the order constraint by the pattern of lightnesses. When transparency occurs in such cases, the hues and lightnesses of the overlapping region may not appear correct. One needs to distingush between the perception of transparency and <u>color scissioning</u>. We use "color scissioning" to refer to perceiving the color in the intersecting area as being composed of the base color and the overlying transparent color. Transparency can occur with and without color scissioning.

When does color scissioning occur? Metelli (1974a) explains color scissioning as a splitting of the stimulus luminance into the luminances of the background surface and of the overlying transparent surface. We have argued that color scissioning is not the reverse of Talbot's law of color fusion. Rather, it is a higher-order more cognitive encoding of the structural information in a stimulus. We hypothesize that color scissioning is the result of an encoding of a stimulus in terms of the color of an opaque surface and the color of a transparent surface overlying the opaque surface. Encoding in terms of a perceptual schema such as overlying planes of colors appears to require sensory support. Sensory support can occur in various ways. Phenomenological observation suggests that all colors can be described using the color names "red," "yellow," "green," "blue," "black" and "white." For example, orange can be described be seen as a combination of a red color and a yellow color. Color scissioning can therefore occur in which an orange stimulus color is seen as a red through a yellow or vice versa. Another way of

No, perceptual splitting measured in terms of reflectance

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?

so called luminous a [illegible] [illegible]

Perception is not a judgement but a phenomenal presence providing sensory support may be in terms of contrast colors at the boundaries of the transparent and the nontransparent regions, or flecks of the nontransparent color may leak through the transparent medium. Transparency with color scissioning occurs when sensory support leads to the visual system encoding the overlapping color as the opaque underlying color modified by the color of the transparent surface. When such an encoding is not induced in the visual system, the perception of transparency occurs without color scissioning, i.e., one has impression of transparency but the colors in the overlapping region are all wrong. ?

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Footnotes

It is a fact
not a possibility
$\alpha=0 \rightarrow$ c black

1. Metelli (1975) suggests the possibility of seeing a surface through a black transparent color when e=0. The density of the transparent color varies inversely with α.
2. The stimuli were prepared at the Computer Vision Laboratory at the University of Maryland.
3. We are indebted to Dr. Seymour Haber of the National Bureau of Standards for these proofs.
4. The results with the chromatic stimuli will be reported in a separate paper dealing with color transparency.
5. When making the stimuli, the authors judged adjacent gray level differences in Set 1 to give equal lightness differences. Subsequent matches of the gray levels to Munsell Grays by other observers showed that some judged the lightness difference between gray levels of 100 and 150 to be greater than the lightness difference between the gray levels of 150 and 200, and 200 and 250. The increased difference was never judged to be more than .5 of a Munsell value step. A comparison of transparency judgments of the stimuli in Set 1 shows that the possible greater difference in lightness between the two lowest gray levels did not affect the results. For example, the number of transparency judgments with stimulus cdba (in which the lightness difference between

regions c and d would be slightly greater than that of ab) was the same as with stimulus bacd (in which the lightness difference between regions a and b would be slightly greater than that of cd.

Table 1

Frequency of Transparency Judgments in Set 1

Satisfy Constraints i and ii

	Stimuli		f	
1.	abdc	#a>b>p>q	15	n=22
2.	adbc	a>p>b>q	18	
3.	adcb		18	
4.	bacd		18	
5.	bcad		20	
6.	bcda		21	
7.	cbda		20	
8.	cdba		18	
9.	dacb		18	
10.	dcab		17	
	$\overline{X}$=18.3		SD=1.7	

Fail Constraint ii Strongly (The interval ab is included within the interval cd.)

	Stimuli	f
17.	cbad	0
18.	dabc	1
	$\overline{X}$=.50	SD=.71

Fail Constraints i and ii Strongly

	Stimuli	f
19.	cabd	0
20.	dbac	0

Fail Constraint i Strongly
(Criss-cross Stimuli)

	Stimuli	f
11.	acbd	1
12.	acdb	2
13.	bdac	0
14.	bdca	0
15.	cadb	0
16.	dbca	2
	$\overline{X}$=.83	SD=.98

Fail Constraint i
not criss cross

	Stimuli	f	
21.	abcd	3	
22.	badc	6	Vasarely } Fig. 2
23.	cdab	13	Vasarely } Fig. 2
24.	dcba	0	
	$\overline{X}$=5.5	SD=5.6	

Note.- All stimuli in Set 1 satisfy Constraint iii. Stimuli 1, 2, and 4 through 10 violate Constraint iv (see text). Stimuli satisfy constraints unless otherwise noted.

Table 2

Mean Frequency Transparency Judgments in Set 2

Stimuli	Configuration I		Configuration II	
	Mean	SD	Mean	SD
Satisfy Constraints i and ii (Eight stimuli: abdc[1],bcda[2],cdba[3], dcba[2]) no	17.8	1.5	14.8	2.6
qpab Fail Constraint i (Four stimuli with order cdab. Two stimuli satisfied Constraint ii and two stimuli did not.) tr. parziale	10.0	2.5	1.5	1.0
Fail Constraint ii (Four stimuli with order cdba in which cd>ab) — 4	13.0	1.2	10.5	2.7
Fail Constraint i Strongly (Eight criss-cross stimuli: acdb[2],bdac[1],bdca[3], cadb[2])	2.1	2.9	--	

la 21 rapporti

Note.- All stimuli in Set 2 satisfy Constraint iii. Stimulus abdc and one of the cdba stimuli fail to satisfy Constraint iv (see text). Stimuli satisfy constraints unless otherwise noted.

Table 3

Distribution of Judgments in Supplementary Equipment 1

Stimuli	Not transparent	D/B	B/D
abdc	4	32	4
adbc	6	8	26
cadb	32	3	5
cdba	1	29	10
cbda	0	12	28
dbac	34	1	5

Note.- D/B: square D is seen as transparent and is seen to overlie square B. B/D: square B is seen as transparent and is seen to overlie square D (see Figure 2).

Figure Captions

Figure 1. The proximal stimulus that results when an episcotister rotates in front of two surfaces differing in reflectance. Capital letters A and B indicate the background surfaces. Lower case letters indicate regions of differing intensity.

Figure 2. a. Stimulus configuration in Set 1. Lower case letters indicate regions of differing intensity. Capital letters indicate the surfaces depicted. b. Diagram illustrating the criss-crossing of gray levels with stimulus acdb (see text).

Figure 3. Stimulus configurations I and II in Set 2. Lower case letters indicate regions of differing intensity. Capital letters indicate the surfaces depicted.

Figure 4. Sample stimuli: a. Stimulus cdba satisfying Constraints i through iv (Configuration I); b. Stimulus cdba satisfying Constraints i through iv (Configuration II); c. Criss-cross stimulus acdb violating only Constraint i; d. Stimulus cdba violating only Constraint ii; e. Stimulus cdab violating only Constraint i; f. Stimulus dcba violating only Constraint i: f is seen with the top square overlying the bottom square, i.e., stimulus order bcda which satisfies Constraint i. g; Stimulus cdba in which c is closer in lightness to b than to d. There is a tendency to see the top square over the bottom square, i.e., adcb.

h. Stimulus cdba in which c is closer in lightness to d than to b. There is a tendency to see the bottom square over the top square.

Figure 5. Displays a and b violate only Constraint iii; Displays c and d violate only Constraint iv.

Figure 6. a. Illustration of subtractive color mixture occurring with a filter. b. Illustration of the pattern of reflectance and transmittance (see text).

Figure 7. a. Stimulus figure in Experiment 2. b. Relative similarity of region c to that of regions a and b (see text).

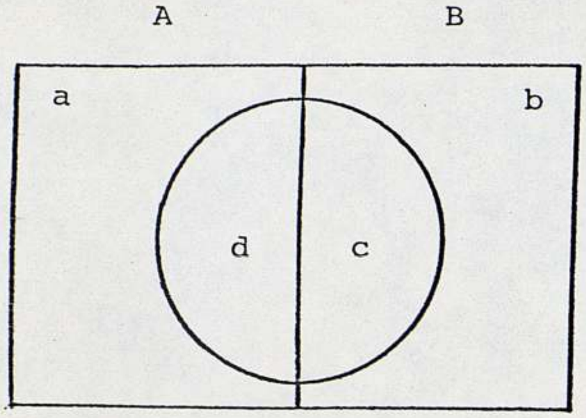
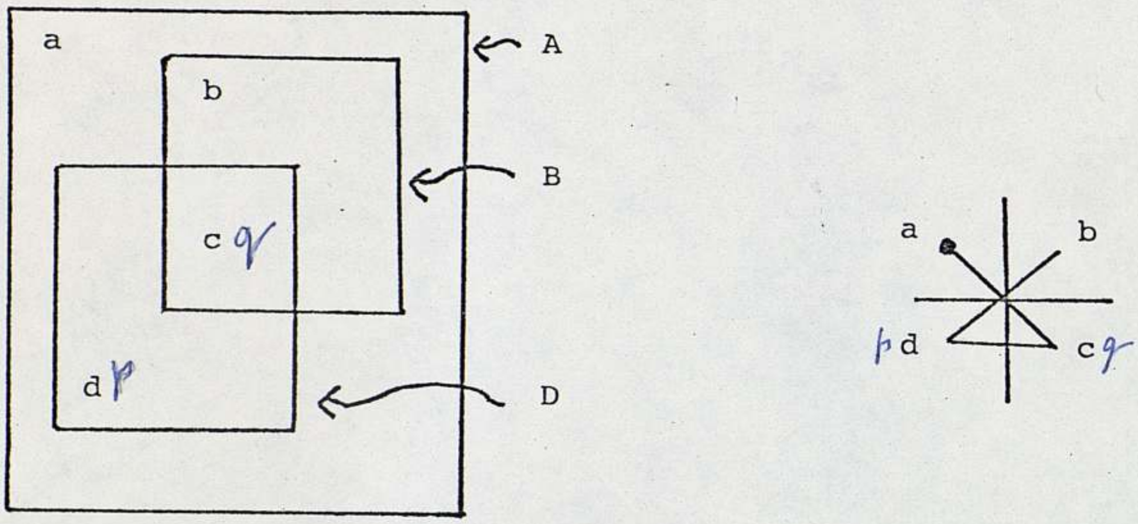


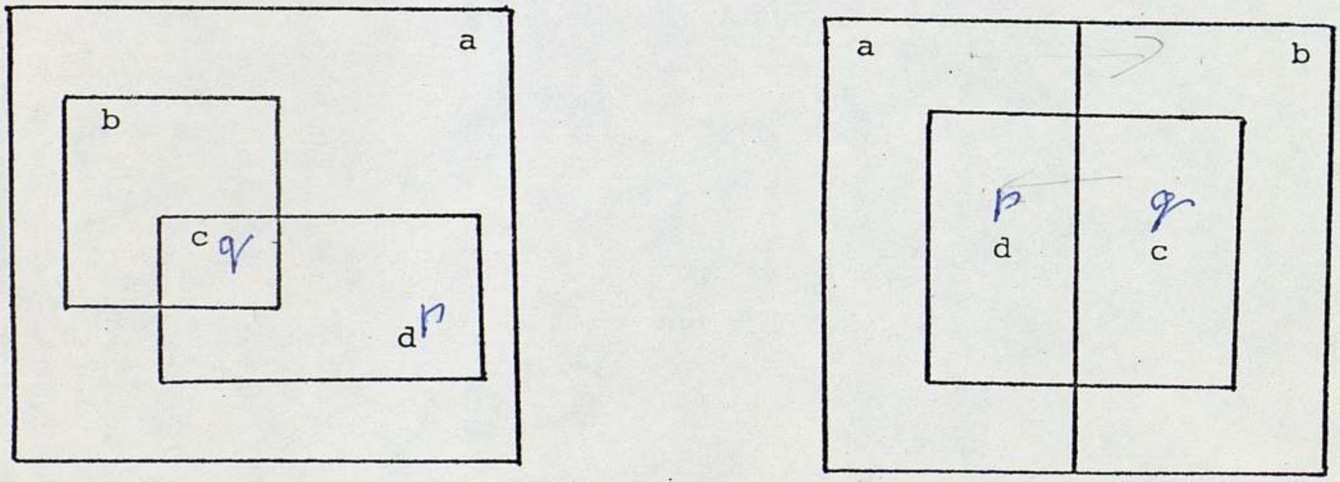
Figure 1



a

b

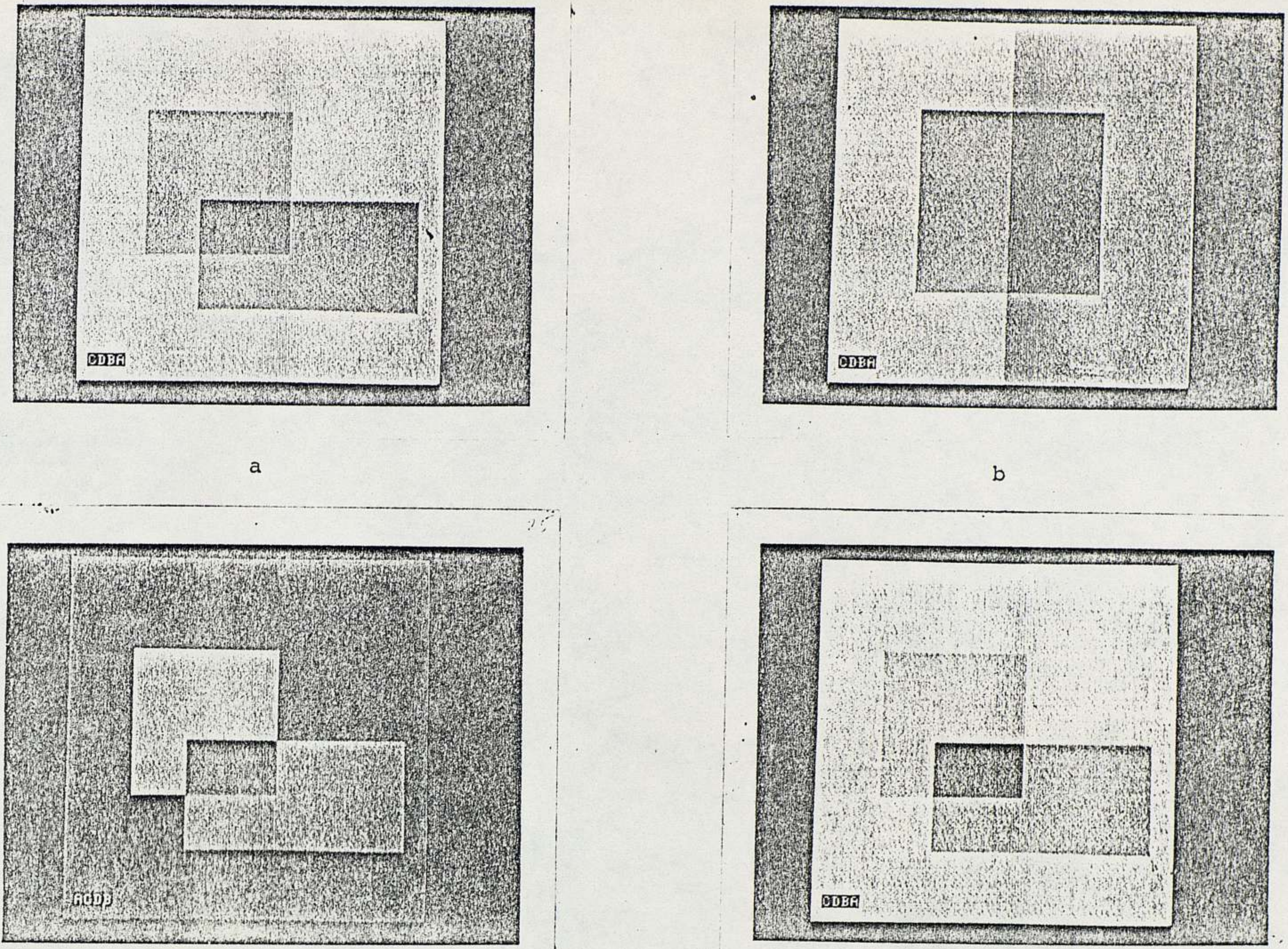
Figure 2



I

II

Figure 3



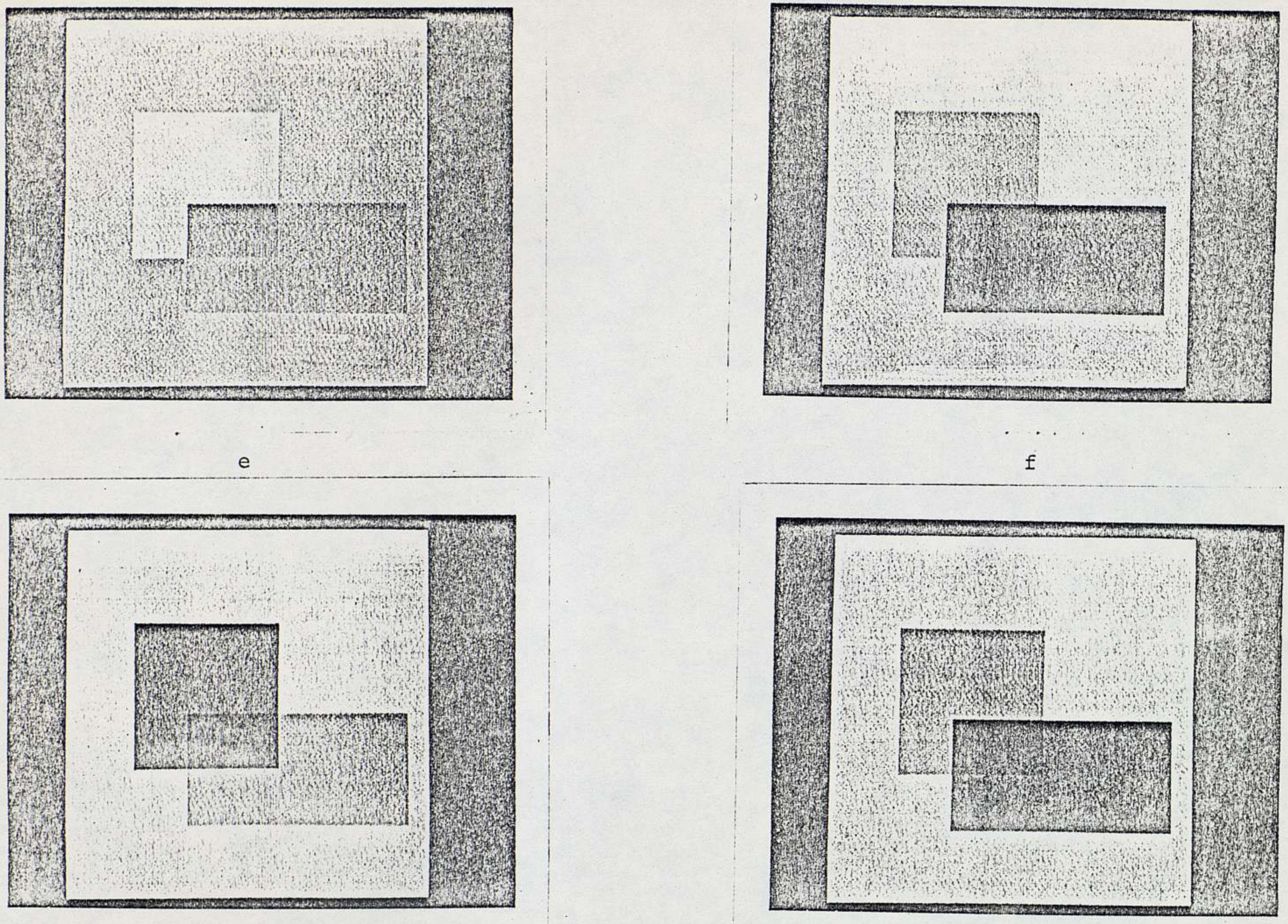
a

b

c

d

Figure 4



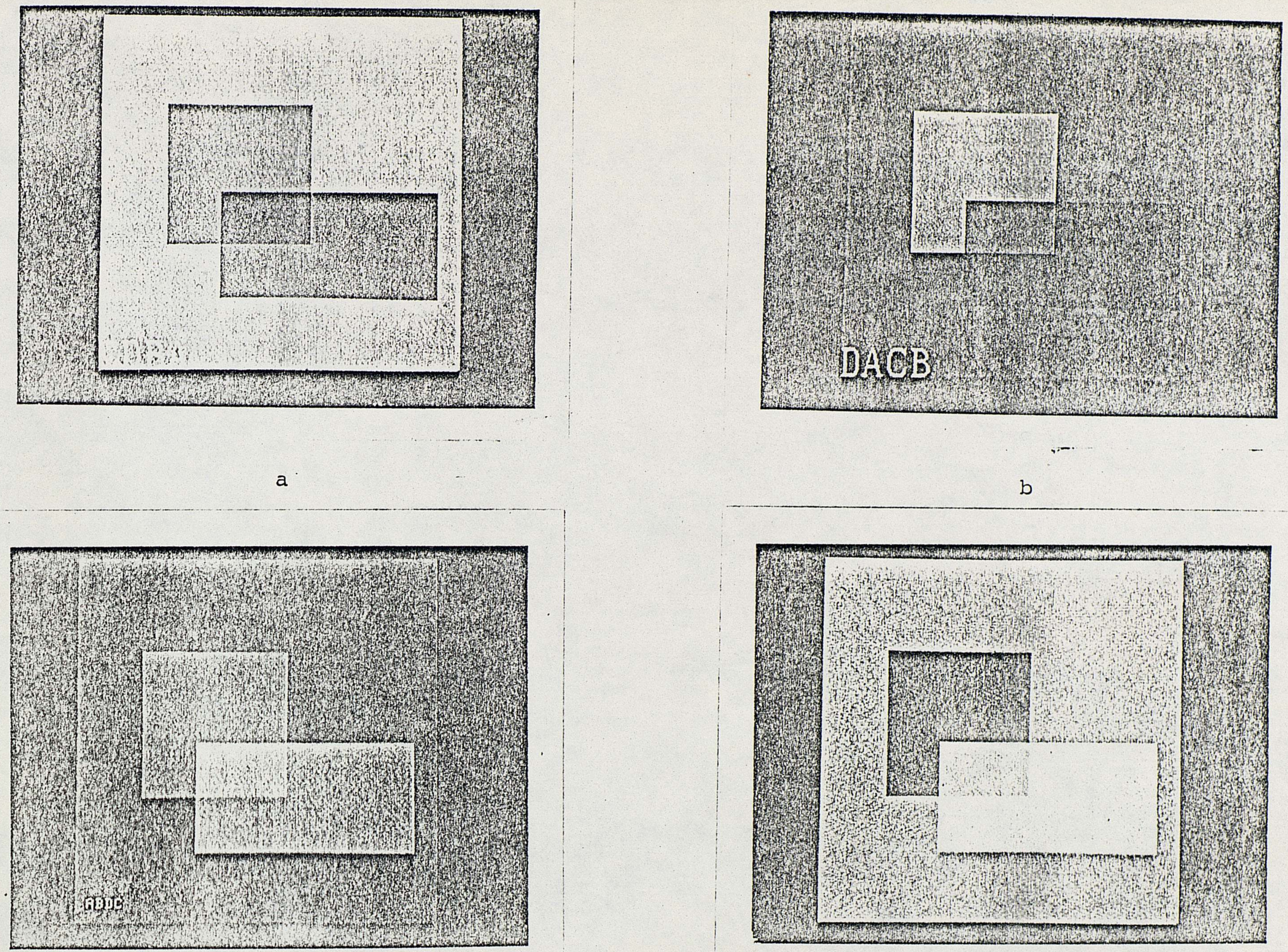
e

f

g

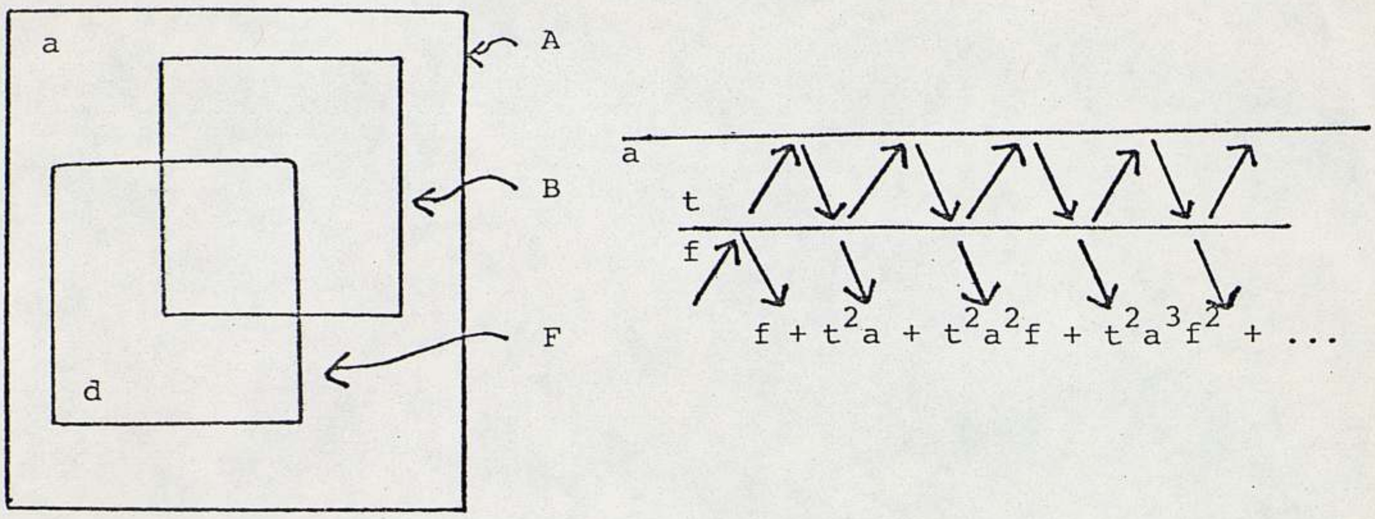
h

Figure 4, cont'd.



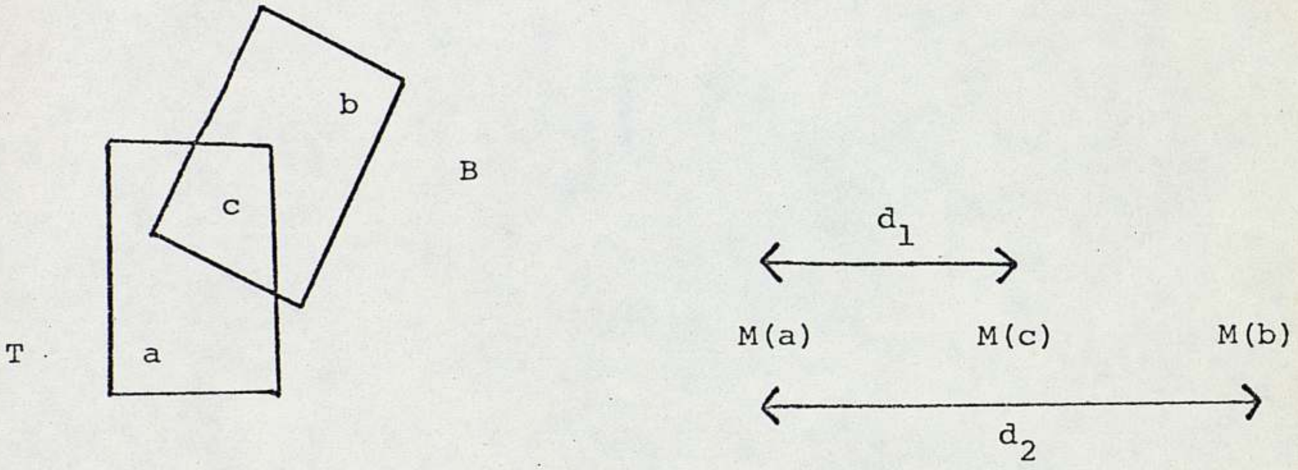
a b c d

Figure 5



a b

Figure 6



a b

Figure 7

Ultima edizione

The Perception of Transparency with Achromatic Colors

Jacob Beck
University of Oregon, Eugene, Oregon
K. Prazdny
Fairchild Camera and Equipment Corporation, Palo Alto, California
Richard Ivry
University of Oregon, Eugene, Oregon

Abstract

Metelli has proposed a model of the intensity relationships in perceptual transparency based on Talbot's law of color fusion. Four constraints follow from the application of Talbot's law. The experiments indicate that violations of constraints i and ii adversely affect the perception of transparency, while violations of constraints iii and iv do not. Many common occurrences of transparency are in terms of subtractive rather than additive color mixture. The constraints derived from the Metelli model appear also to hold for subtractive color mixture. An assumption of the Metelli model is that the degree perceived transparency varies linearly with reflectance. An experiment indicates that the degree of perceived transparency varies linearly not with reflectance but with lightness, a nonlinear function of reflectance. The results are discussed in terms of how the pattern of intensities relate to other stimulus information such as figural configuration in producing the perception of transparency.

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Metelli (1974 a, b) has proposed a model for the intensity relationships in perceptual transparency. The central assumption of Metelli's model is that transparency occurs in accordance with Talbot's law of color fusion. The proximal stimulus resulting when an episcotister rotates in front of the surfaces A and B is depicted in Fig. 1. Rotating the episcotister rapidly produces the perception of a transparent color (regions d and c) lying in front of surfaces A and B.

Insert Fig. 1 about here

According to Talbot's law, the apparent reflectances of regions $\overset{p}{d}$ and $\overset{q}{c}$ are equal to

$$(1) \quad \overset{p}{d}=\alpha a+(1-\alpha)\overset{t}{e}$$

$$(2) \quad \overset{q}{c}=\alpha b+(1-\alpha)\overset{t}{e}$$

where α is the areal fraction occupied by the open sectors of the episcotister, $1-\alpha$ is the areal fraction occupied by the blades of the episcotister, a is the reflectance of surface A, b the reflectance of surface B, and $\overset{t}{e}$ the reflectance of the episcotister blades. Solving equations (1) and (2) for α and e yields

$$(3) \quad \alpha=\overset{p-q}{(d-c)}/(a-b)$$

$$(4) \quad e=(a\overset{p}{c}-b\overset{q}{d})/(a+\overset{p}{c})-(b+\overset{q}{d})$$

Alpha is the proportion of the apparent reflectances of d and c determined by the reflectances a and b and is an index of the transparency of the apparent disk. Since α is restricted to values between 0 and 1, equation 3 implies (1) if $a>b$, then $\overset{p}{d}>\overset{q}{c}$ and vice versa if $a<b$, and (ii) the absolute difference $|a-b|$ must be greater than the absolute difference $|\overset{p}{d}-\overset{q}{c}|$. Constraint i is a restriction on the order of the intensities and insures that α is positive. Constraint ii is a restriction on the magnitudes of the intensities and insures that α is less than 1. Since $\overset{t}{e}$ is also restricted to values greater than or equal to 0 and less than ?

or equal to 1, order and magnitude constraints can also be derived from equation 4.[1] Equation 4 implies (iii) if $(a+c)>(b+d)$ then $ac>bd$ and vice versa if $(a+c)<(b+d)$, and (iv) the absolute difference $|(a+c)-(b+d)|$ must be equal to or greater than the absolute difference $|ac-bd|$. Constraint iii insures that e is non-negative, and constraint iv insures that e is less than or equal to 1. The four constraints are independent. Numerical values can be assigned to the reflectances a, b, c, and d in equations 3 and 4 that satisfy three of the constraints but not the fourth.

Metelli (1974 b) has demonstrated that the perception of transparency occurs when constraints i and ii derived from equation 3 are met and fails to occur when either of these constraints are violated. He has, however, not investigated the consequences of violating constraints iii and iv derived from equation 4. This may be because it does not seem that they would affect the perception of transparency since it appears doubtful that people are able to make the judgments required by constraints iii and iv. To anticipate, we will present evidence that violations of constraints iii and iv do not adversely affect the perception of transparency. We argue that the computations carried out by the visual system in perceiving transparency are in terms of lightness values rather than in terms of reflectances or luminances. Processing of the intensity information involves checking whether the lightnesses in a pattern satisfy the order restrictions of constraint i and the magnitude restrictions of constraint ii. Constraints iii and iv involve operations of addition and multiplication that are not readily interpretable in terms of lightness values.

The present study seeks to clarify both the factual background and the theoretical issues in the perception of transparency. Six experiments test and extend the Metelli model. A model of the intensity relationships when transparency occurs in terms of a filter that transmits light is also presented. The relations between the intensity values when transparency occurs with a filter and with an episcotister are compared.

EXPERIMENT 1

Experiment 1 was designed to investigate how the pattern of image intensities and the figural configuration affect the perception of transparency. Two supplementary experiments answering questions raised by Experiment 1 are also reported.

Method

Stimuli. A PDP-11 computer was used to generate two sets of Polaroid pictures at the Computer Vision Laboratory, University of Maryland. A computer controlled a flying spot in focus on a CRT, and an oscilloscope camera imaged the CRT face plate onto the film. The stimuli in Set 1 consisted of 4 regions differing in reflectance and depicted two overlapping surfaces, B and D, on a larger background surface, A (Fig. 2a). Capital letters in the figures identify depicted surfaces and lower case letters regions of differing reflectance. The figures B and D were 2.7 x 2.4 cm with the area of overlap 1.3 x 1.2 cm. The background figure A was 6.6 x 6.0 cm. The four reflectances were programmed to differ by equal increments. The reflectances of 10 stimuli were measured with a Spectra-Pritchard photometer. The mean reflectances of the 4 regions were .22 (SD=.02), .34 (SD=.02), .47 (SD=.02), and .59 (SD=.03).

23 35 46 59

5500 4000 3600 2000

Insert Fig. 2 about here

Set 1 contained 24 stimuli corresponding to the 24 possible permutations of the 4 different reflectances. A stimulus is identified by a sequence of the four letters, a, b, c, and d, e.g., dcba. The letter order indicates increasing gray levels from lowest to highest. Table 1 lists the 24 stimuli. Stimuli 1 through 10 satisfied or effectively satisfied constraints i and ii. (Stimuli 1, 2, 4, 5, and 7 through 10 technically violated constraint ii since the absolute difference $|c-d|$ was equal to the absolute difference $|a-b|$. An α equal to 1 is the limiting value for the occurrence of transparency. Observations, however, indicated that the perception of transparency is affected only if constraints i and ii are clearly violated. Stimuli which violated constraints at limiting values will be considered effectively to satisfy the constraints.) Stimuli 11 through 16 violated constraint i in a strong sense. If the gray levels in the 4 quadrants at the x-junction in the upper left of Fig. 2a are traced out in increasing magnitude, the gray levels crisscross (Fig. 2b). Stimuli 17 and 18 violated constraint ii in the strong sense that the gray level interval ab is contained within the gray level interval cd. Stimuli 19 and 20 violated both constraints i and ii strongly. Stimuli 21 through 24 violated constraint i, but the gray levels do not crisscross. They effectively satisfied constraint ii.

Since $(a+c)-(b+d)$ is equal to 0 for stimuli 1, 2, 4, 5, and 7 through 10, e is undefined and constraints iii and iv are not satisfied. On each of the stimuli decreasing the highest reflectance by 4 percent satisfied constraints iii and iv. Stimuli 1, 2, 4, 5, and 7 through 10 may be considered to weakly violate constraints iii and iv. The remaining stimuli in Set 1 satisfied both constraints iii and iv.

Set 2 investigated the effect of figural configuration on the perception of transparency. Configuration I was similar to that in Set 1 and is illustrated in Fig. 3a. The overlapping figures B and D were a square 2.6 cm on a side and a rectangle 4 x 2 cm. The area of overlap was a rectangle 1.7 x 1 cm. The background figure A was a square 6.7 cm on a side. Configuration II is illustrated in Fig. 3b. The 4 regions of differing reflectance were arranged to depict an

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Insert Fig. 3 about here

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inner square, D, overlying a bipartite background consisting of two adjacent rectangles, A and B. The inner square was 3.4 cm on a side, and the background rectangles 3.4 x 6.7 cm. The gray levels of the 4 regions in Set 2 were not, as in Set 1, permutations of the same 4 reflectances but varied. Table 2 lists the stimulus reflectances. Negative values for α and for e indicate that a stimulus violated constraints i and iii respectively; absolute values greater than 1 and α for e indicate that a stimulus violated constraints ii and iv.

sono 24! Set 2 contained 40 stimuli. Sixteen pairs of stimuli were generated in which corresponding regions in configurations I and II were the same reflectances. Seven stimuli each with configurations I and II satisfied constraints i and ii (stimuli 1 through 7 in Table 2). Four stimuli each with configurations I and II were generated with the order cdab (stimuli 8 through 11). (The order cdab violated constraint i. Three stimulus pairs also violated constraint ii.) Five stimuli each with configurations I and II were generated with the order cdba (stimuli 12 through 16). These pairs of stimuli violated constraint ii but not constraint i. Eight stimuli were generated only with configuration I. They violated constraint i strongly and involved a crisscrossing of gray levels (stimuli 17 through 24). These eight stimuli satisfied constraint ii. 24!

Stimuli 4, 5, and 6 in Table 2 violated constraint iii. These violations, however, are small. Increasing the reflectance of c in stimulus 4 by 2 percent, in stimulus 5 by 1 percent, and in stimulus 6 by 2 percent satisfies constraint iii. The remaining stimuli in Set 2 satisfied both constraints iii and iv. Sample stimulus displays are shown in Fig. 4. It should be noted that the halftone process fails to accurately reproduce the gray values of the stimuli in Figs. 4 and 7.

Insert Fig. 4 about here

Procedure. Sets 1 and 2 were alternated. Before presenting each set of stimuli, subjects were shown examples of overlap with and without transparency. Before Set 1, transparency was illustrated by showing a Polaroid filter overlying gray papers arranged as in Fig. 2a. Overlapping without transparency was illustrated by superimposing four gray papers corresponding to regions a, b, c, and d in Fig. 2a. They appeared opaque. The subjects were told that they would be shown photographs of surfaces arranged as in Fig. 2a and asked to judge whether the bottom square-like figure (D) was transparent. They were instructed that they were to report D transparent only if both the background (A) and the top square (B) were seen through D. If only A or only B were seen through D, but not both, the stimulus was to be judged as not transparent. Similar instructions and examples were given before Set 2 was presented. Subjects were again cautioned that a stimulus was to be reported as transparent only if they could see both the top square and the background through the bottom rectangle (Fig. 3a), or if they could see through the inner square to both background rectangles (Fig. 3b). The instructions with both sets also stressed that a stimulus was to be judged as not transparent if a surface other than the indicated surface was seen as transparent. For example, a stimulus was to be judged as not transparent if the top square was seen as transparent with configuration I, or the left or right half of the inner square was seen as transparent but not the entire square with configuration II. Finora ha parlato di 24 stimoli. E gli altri 16?

The subjects were instructed to make an immediate judgment based on their visual impression. The individual stimuli were mounted on pieces of white cardboard and presented by means of a Gerbrands tachistoscope. The viewing distance was 59.7 cm and the exposure duration was 2 seconds. A subject initiated a stimulus presentation by pressing a switch. Before presenting each stimulus

allora
erano
carte!

set, 5 practice stimuli were presented. The 5 practice stimuli contained 2 stimuli which in pre-tests were judged as transparent, 2 stimuli which were judged as not transparent and 1 stimulus in which a surface other than the indicated surface was seen as transparent. The 5 practice stimuli presented before Set 2 consisted of 3 stimuli with configuration I, and 2 stimuli with configuration II. The stimuli within each set were presented in a different random order to each subject.

Subjects. Twenty-one volunteers with normal or corrected to normal vision served as subjects. They were naive concerning the purpose of the experiment.

Results

Table 1 presents the results with Set 1. The mean number of transparency judgments of stimuli 1 through 10 satisfying constraints i and ii is 18.5

Insert Table 1 about here

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with a SD of 2.0. The (weak) violation of constraint iv by stimuli 1, 2, 4, 5, 6 and 7 through 10 did not adversely affect the perception of transparency. The perception of transparency was also not affected by the pattern of lightness changes. The lightnesses of the overlapping regions (region c and d) are increased with stimuli abdc, bacd, adbc, and bcad, decreased with stimuli cdba, dcab, cdba, and dacb, and the lightness of the darker surface is increased while the lightness of the lighter surface is decreased with stimuli adcb and bcda. Inspection of Table 1 shows that the occurrence of transparency judgments was not affected.

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The perception of transparency did not occur when either the order relations in constraint i or the magnitude relations in constraint ii were violated strongly. The mean number of transparency judgments of the 6 stimuli (stimuli 11 through 16) with crisscrossing gray levels which satisfied constraint ii but strongly violated constraint i is .67 with a SD of .82. The mean number of transparency judgments of the two stimuli (stimuli 17 and 18) which satisfied constraint i but strongly violated constraint ii is .50 with a SD of .71. The two stimuli (stimuli 19 and 20) which failed to satisfy both constraints i and ii were never judged to be transparent.

Stimuli 21 through 24 fail to satisfy constraint i. Significant numbers of transparency judgments were obtained with stimuli cdab and badc. The stimulus cdab (Fig. 4e) was judged transparent 13 times (over 50 percent), and the stimulus badc 6 times (over 25 percent). Why do these two stimuli produce exceptions and not the stimuli abcd and dcba? A stimulus is ambiguous as to whether surface D is seen overlying surface B or surface B is seen overlying surface D. The ? theoretical derivation assumes that the overlying transparent regions are d and c and the underlying opaque regions are a and b. If surface B is seen overlying surface D, then the regions b and d are interchanged. Thus, the stimulus abcd becomes adbc and the stimulus dcba (Fig. 4f) becomes bcda. Both adcb and bcda satisfied constraints i and ii. What is suggested is that subjects tended to see these surfaces as transparent with surface B overlying surface D. The low number of transparency judgments reflect that the instructions asked subjects to report the stimulus as transparent only if surface D is seen overlying surface B. Support for this conjecture comes from a preliminary study in which the stimuli in Set 1 were presented using slides to a group of 18 subjects. The instructions were similar to those given in Experiment 1. The main difference was that subjects were first asked to judge whether they saw a stimulus as transparent, and then asked to judge whether surface D was seen overlying surface B or whether surface B was seen overlying surface D. Two subjects judged the stimulus abcd transparent with manca la tabella

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surface D overlying surface B while 16 subjects judged the stimulus transparent with surface B overlying surface D (stimulus adcb). Two subjects judged the stimulus dcba transparent with surface D overlying surface B while 15 subjects judged the stimulus transparent with surface B overlying surface D (stimulus bcda). One subject judged the stimulus as not transparent.

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In contrast, stimuli cdab and badc cannot be seen as surface B overlying surface D. If surface B is seen overlying surface D, then cdab becomes cbad and badc becomes dabc. Both cbad and badc strongly violate constraint ii. The interval cd is included in the interval ab. The occurrence of transparency judgments with stimuli cdab and badc indicates that if figural conditions strongly suggest transparency, the perception of transparency occurs even when the pattern of image intensities contradicts it.

Table 2 presents the results of Set 2. The mean number of transparency judgments for the 7 stimuli satisfying constraints i and ii with configuration I is 17.9 with a SD of 1.6. The mean number of transparency judgments for the corresponding stimuli with configuration II is 14.9 with a SD of 2.8. A t-test of the difference between means is significant t(6)=3.44, p<.05 . Combining the number of transparency judgments with configurations I and II, the mean number of transparency judgments of the 8? stimuli satisfying constraint iii? was 17.5 with a SD of 2.2. The mean number of transparency judgments of the 6 stimuli violating constraint iii was 14.8 with a SD of 2.6. A t-test of the difference is not significant [t(12)=2.06, p>.05]. ?

Insert Table 2 about here

The four stimuli with the order cdab violated the order relation in constraint i. The mean number of transparency judgments with configuration I is 10.0 with a

La ragione è che in cfg. II non ci sono tante possibilità di inversioni
e trasparenze parziali

SD of 2.5, and with configuration II 1.5 with a SD of 1.0. A t-test of the difference is significant [t(3)=5.47, p<.05]. Thus, exceptions to constraint i with stimulus cdab occurred more readily with configuration I than with configuration II. The local cues for transparency are similar for configurations I and II. The x-junctions indicate the possibility of transparency on both configurations. The fact that configuration I was more effective than configuration II in producing the perception of transparency indicates that the global figural configuration affects the perception of transparency. The component regions in configuration II are more regular and symmetric with a nontransparent organization than the corresponding regions in configuration I.

The five stimuli with the order cdba satisfied constraint i but failed to satisfy constraint ii. The mean number of transparency judgments with configuration I is 13.2 with a SD of 3.0 and with configuration II 11.8 with a SD of 2.5. A t-test of the difference is not significant [t(4)=.93, p>.4].

The eight crisscross stimuli occurred only with configuration I. The mean number of transparency judgments is 2.1 with a SD of 2.9. A relatively large number of transparency judgments (8) occurred with one of the acdb stimuli (stimulus 17 in Table 2). Region c in this stimulus differs by 1 percent from region d.[2] The closeness in lightness of the two regions is likely to have facilitated the perception of transparency. If regions c and d are interchanged, the order becomes adcb which satisfies both the order and magnitude constraints. The results again indicate that if figural cues strongly suggest transparency, then contradictory indications from the pattern of intensities may be overridden.

3a

Supplementary Experiments

Supplementary Experiment 1. The aims of the experiment were (a) to examine how the magnitude of the violation of constraint i and of constraint ii affects the perception of transparency, and (b) to determine whether the judgments of supplementary

transparency evoked by stimulus 17 in Experiment 1 replicates.

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The procedure was the same as in Experiment 1. Nineteen stimuli were presented. The stimulus arrangement was that of configuration I. Table 3 lists the stimulus reflectances. Nine stimuli satisfied constraints i through iv

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Insert Table 3 about here

(stimuli 1 through 9 in Table 3). Four stimuli were generated which violated constraint i (stimuli 10 through 13). The stimulus order was cdab. The reflectance of region d exceeded that of region c by 1, 2, 4 and 8 percent. If c and d are permuted, the stimulus order becomes cdab which satisfies constraint i. Two stimuli violated constraint ii (stimuli 14 and 15). The difference in reflectance between regions d and c exceeded that between regions a and b by 4 percent for stimulus 14 and by 27 percent for stimulus 15. Four crisscross stimuli were presented (stimuli 16 through 19). Twenty-five new volunteers with normal or corrected to normal vision served as subjects. They were naive concerning the purposes of the experiment.

gpab

The mean number of transparency judgments of the 9 stimuli satisfying constraints i through iv is 23.9 with a SD of 2.0. Stimulus acdb (stimulus 16) again evoked a significant number of transparency judgments. Fourteen subjects judged stimulus acdb as transparent. Only one other of the crisscross stimuli was seen as transparent. Three subjects judged stimulus bdca (stimulus 18) as transparent. We have suggested that it is the closeness in reflectance of regions c and d on stimulus acdb that is responsible for the relatively large number of transparency judgments. This is supported by the finding that transparency judgments varied inversely with the salience with which constraints i and ii are violated. The number of transparency judgments with the stimulus order cdab were 17, 10, 5 and 2 when the reflectance of d exceeded that of c by 1, 2, 4, and

4

8 percent respectively. The number of transparency judgments with the stimulus order cdba were 19 and 4 when the reflectance difference between c and d exceeded that between a and b by 4 and 27 percent respectively.

Chi l'ha mai detto?

Supplementary Experiment 2. Constraints i and ii are not sufficient to uniquely determine the perception of transparency. For example, Table 1 shows that stimuli abdc, adbc, cbda, and cdba all satisfy the order and magnitude constraints. If surface B is seen as overlying surface D, then stimulus abdc becomes adbc, and stimulus adbc becomes abdc. Similarly stimulus cbda becomes cdba, and stimulus cdba becomes cbda. Auxiliary principles become necessary to predict whether surface D is seen as transparent and overlying surface B or surface B is seen as transparent and overlying surface D when subjects are not instructed to see a particular arrangement as in Experiment 1. One possible
5 principle is that region c in Fig. 2 is joined to regions b or d depending on which it differes least from in lightness. (Figs. 4g and 4h) An experiment was conducted to test this possibility.

già visto da Petter

The 6 stimuli abdc, cdba, adbc, cbda, cadb, and dbac from Set 1 were presented individually using 4 different random orders to 40 subjects in two classes. To familiarize subjects with the phenomenon, they were shown pictures of surfaces arranged as in configuration II in which the perception of transparency occurred and in which it failed to occur. Subjects were asked to indicate on a data sheet, first, whether a stimulus was seen as transparent, and second, if a stimulus was seen as transparent, whether the top square was seen to overlie the bottom square or whether the bottom square was seen to overlie the top square. The subjects were instructed to base their judgments on their immediate visual impression. To avoid position biases, 19 subjects were presented with the stimuli upright and 21 with the stimuli inverted.

Stimuli cadb and dbac have crisscrossing gray levels and should be seen as not transparent. Region c is closer in lightness to region d than to region b for stimuli abdc and cdba, while for stimuli adbc and cbda region c is closer in lightness to region b than to region d. According to the hypothesis proposed, surface D should be seen to overlie surface B (D/B) with stimuli abdc and cdba, and surface B should be seen to overlie surface D (B/D) with stimuli adbc and cbda.

Table 4 presents the number of nontransparent judgments, of D/B transparent judgments, and of B/D transparent judgments. The frequencies in Table 4 combine the judgments made with both the upright and inverted presentations of the stimuli. The number of nontransparency judgments was 66 and of transparency judgments

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Insert Table 4 about here

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14 with stimuli cadb and dbac. The reason for the larger number of transparency judgments than in Experiment 1 is not clear. It may reflect a criterion difference. The instructions in Experiment 1 were given individually and emphasized that a stimulus was to be judged transparent only if one saw through the overlying surface to both underlying surfaces. The total number of transparency judgments of D/B was 61 and of B/D 14 for stimuli abdc and cdba. The total number of transparency judgments of B/D was 54 and of D/B 20 for stimuli adbc and cbda. A t-test tested the hypothesis that there is a presumption to unite regions having more similar lightnesses. The number of B/D judgments were subtracted from the

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numbers of D/B judgments. The mean of the difference scores for stimuli abdc and cdba was 23.5, and for cbda and adbc -17.0. A t-test of the difference between the two means is significant [$t(2)=8.79$, $p < .05$]. The results also suggest a position bias. Twenty-two of the 34 judgments counter to the hypothesis were judgments that the top square was transparent and overlay the bottom square. The percentage of judgments differ significantly from the 50 percent change level at the .05 significance level ($z=1.88$). The fact that in Experiment 1 stimuli adbc and cbda gave as many transparency judgments of D/B as stimuli abdc and cdba indicates that the predisposition to unite regions which are closer in lightness can easily be overcome by an instructional set.

EXPERIMENT 2

Experiment 2 investigated how violations of constraints iii and iv affect the perception of transparency.

Method

Stimuli. Ten stimuli arranged as in configuration II were constructed from gray papers. Four papers differing in reflectance depicted a central rectangle overlying a bipartite background. The rectangle was 2x1 cm and consisted of two adjacent squares 1 cm on a side. The background consisted of two adjacent squares 2.5 cm on a side. Table 5 lists the stimulus reflectances. Negative values of e indicate that stimuli 1 and 3 violated constraint iii. Constraint iii is satisfied if the reflectance of c in stimulus 1 is increased by 5 percent and in stimulus 3 by 8 percent. Since the value of e is undefined, stimulus 7 also violated constraints iii and iv. Constraints iii and iv are satisfied if the reflectance of c in stimulus 7 is increased by 13 percent. The negative values for α indicate that stimuli 2, 4, 6 and 8 violated constraint i. The values of α greater than 1 indicate that stimuli 9 and 10 violated constraint ii. The values of α and e indicate that stimulus 5 satisfies constraints i through iv.

Procedure. The procedure was similar to that in Experiment 1. Transparency was first illustrated by showing subjects a Polaroid filter that could be rotated from clear to opaque. Subjects were then shown computer generated pictures of surfaces arranged as in Fig. 3b. The 10 stimuli were mounted on pieces of black cardboard and presented by means of a Gerbrands tachistoscope. Subjects were instructed to report whether the center region.d and c were seen as transparent. They were told to judge a stimulus as transparent only if both background regions, a and b, could be seen through regions d and c respectively. If only region a could be seen through region d or only region b through region c, then a subject was told to judge the stimulus as not transparent. The subjects were told to make their judgments based upon their immediate visual impression. The exposure duration was 1.5 secs. Four computer generated pictures of surfaces arranged as in configuration II were presented as practice stimuli. Two of the practice stimuli produced a perception of transparency and 2 did not. To familiarize a subject with the stimuli, the 10 stimuli were presented in a preliminary trial during which no judgments were made. The stimuli were presented in a different random order to each subject.

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Subjects. Fifteen volunteers with normal or corrected to normal vision served as subjects. They were naive concerning the purpose of the experiment.

Results.

Table 5 shows that the perception of transparency occurred infrequently when

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Insert Table 5 about here

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either constraints i or ii were violated except for stimulus 10. The reason for the 6 transparency judgments of stimulus 10 is not clear. In contrast, the perception of transparency occurred frequently with violations of either constraints iii or iv. Stimulus 5 which satisfied constraints i through iv was judged transparent by 13 subjects. Stimulus 1 which violated constraint iii was judged transparent by 14 subjects. Stimulus 3 which also violated constraint iii was judged transparent by 10 subjects. It fails to differ significantly from stimulus 5 [t(14)=1.38, p>.05] but differs significantly from stimulus 1 [t(14)=2.26, p<.05]. The smaller number of transparency judgments with stimulus 3 we believe is due to stimulus 3 failing to satisfy constraint ii in terms of lightness. Non risulta dalla tabella Lightness is a nonlinear function of reflectance and the magnitude relation in constraint ii can be satisfied or violated independently by lightness and reflectance. Matching the lightnesses to Munsell values showed that the lightness difference between a and b on stimulus 1 equals the lightness difference between c and d. On stimulus 3 the lightness difference between c and d is approximately .75 of a Munsell step greater than the lightness difference between a and b. This is consistent with our suggestion that the important variable in satisfying constraint ii is lightness and not reflectance or luminance. Table 5 also shows that stimulus 7 which violated both constraints iii and iv was judged transparent by 14 subjects. The results, therefore, indicate that violations of constraints iii and iv fail to affect the perception of transparency.[3]

FILTER MODEL

The question may be raised: Since constraints i and ii are not wholly ecologically representative, why do they predict the occurrence of transparency as well as they do? The luminances of the areas d and c in Fig. 1 are the result of stimulating the retina by the light reflected from the episcotister and from the surfaces A and B behind the episcotister. The resulting addition of luminances is known as additive color mixture and is given quantitatively by Talbot's law. Additive color mixture occurs in some natural scenes as, for example, with clouds of dust. Many common occurrences of transparency, however, are in terms of subtractive rather than additive color mixture. When an object is viewed through a liquid, mist, or glass, subtractive color mixture occurs. The luminance of the overlapping area in subtractive color mixture is the result of the light intensity reflected by the background surface and transmitted by the transparent medium plus the light intensity reflected by the transparent medium.

What are the relations among image intensities when transparency occurs in terms of subtractive color mixture? The physical situation is depicted in Fig. 5a. We will assume an achromatic surface viewed in neutral illumination through a transparent medium that is nonselective for wavelength. In Fig. 5a, a is the

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Insert Fig. 5 about here

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reflectance of surface A, b the reflectance of surface B, f the reflectance of filter F, and t the transmittance of the filter. Fig. 5b illustrates the pattern of reflectance and transmittance assumed to occur. The apparent reflectances of regions d and c are equal to

$$(5)\quad d=f+(t^2a)/(1-fa)$$

$$(6)\quad c=f+(t^2b)/(1-fb)$$

Solving equations 5 and 6 for t and f yields

$$(7)\quad t=\sqrt{(c-bcd+bd^2-d)(b-a-abc+a^2c)/(b-a+abd-abc)^2}$$

$$(8)\quad f= (bd-ac)/b(1+ad)-a(1+bc)$$

Order and magnitude constraints for the perception of transparency with subtractive color mixture can be derived from equations 7 and 8. Since the perception of transparency occurs when t is restricted to values between 0 and 1, equation 7 implies (v) $(c-bcd+bd^2-d)(b-a-abc+a^2c)>0$ and (vi) $(b-a+abd-abc)^2>$

$(c-bcd+bd^2-d)$ $(b-a-abc+a^2c)$. Since the reflectance of the filter, f, is also restricted to values greater than or equal to 0 and less than 1, equation 8 implies (vii) if $bd>ac$ then $b(1+ad)>a(1+bc)$ and vice versa if $bd<ac$ and (viii) the absolute difference $|b(1+ad)-a(1+bc)|$ must be greater than the absolute difference $|bd-ac|$. Constraints v and vii insure that t and f are positive while constraints vi and viii insure that t and f are less than 1. An additional constraint is that t+f must be less than or equal to 1.

What is the relationship between the equations derived from the episcotister and the filter models? Equations 1 and 2 are clearly not equal to equations 5 and 6. For example, if a=.5, b=.3, and t=.7, and e and f=.2, d and c are equal to .41 and .27 from equations 1 and 2, while d and c are equal to .47 and .36 from equations 5 and 6. The order and magnitude constraints, however, defining the boundary conditions for solutions of the two sets of equations, appear to be closely related. Equations 5 and 6 of the filter model imply constraints i and ii derived from equation 3 of the episcotister model, and equations 1 and 2 of the episcotister model imply constraints v and vi derived from equation 7 of the filter model.[4] Although we have not been able to demonstrate it mathematically, a computer search of the solutions of equations 5 and 6 of the filter model has failed to find any solutions which violate constraints iii and iv derived from equation 4. Similarly, a computer search of the solutions of equations 1 and 2 of the episcotister model has failed to find any solutions which violate constraints vii and viii derived from equation 8 of the filter model. The variables were incremented by .02 within the bounds for each set of equations and the calculations carried out to 4 decimal places. What is suggested is that the solution sets of equations 1 and 2 and equations 5 and 6 are the same or very nearly the same.

The physical occurrences of transparency involve both color addition and color subtraction and set the normative conditions for the perception of transparency. If perception is to be adaptive, it must satisfy these conditions except in unimportant ways. This does not mean, however, that the visual system solves equations 1 and 2, and 5 and 6. The visual system may utilize heuristics to judge transparency which in the main agree with physical reality. Constraints i and ii derived from Metelli reflect order and difference relations that occur _both_ with additive and subtractive color mixture. The two constraints are, therefore, ecologically valid indicators of physical transparency and can serve as a basis for adaptive behavior. The constraints with additive and subtractive color mixture are, of course, not always the same. In the case of hue, for example, yellow plus blue yields white with additive color mixture while yellow plus blue yields green with subtractive color mixture. Beck (1972, 1975) presented demonstrations showing that hue transparency occurs with subtractive color mixture.

EXPERIMENT 3

We have indicated that the equations describing transparency with additive and subtractive color mixture are not quantitatively equal. Transparency judgments based on Equation 3, for example, will not be quantitatively correct with subtractive color mixture. This is, however, not very important because in general one is not able to make quantitatively accurate judgments of transparency. Transparency estimates appear to be based not on physical luminance or reflectance values but on lightness values. Metelli's equations 1 and 2 describing transparency assume that transparency is determined by the physical luminance or reflectance values. Equal increments of reflectance, however, do not represent equal increments of lightness. For example, the lightness difference between two papers that have reflectances of 80 percent and 90 percent is .45 of a Munsell step, while the difference between papers having reflectances of 5 percent and 15 percent is 1.82 Munsell steps. Since the visual system does not have direct information about reflectances, it is likely that transparency judgments will vary linearly not with reflectance difference but with lightness

3

difference. Thus, to predict quantitative judgments of transparency, one must introduce a psychophysical function, such as the Munsell value scale, which describes how lightness varies as a function of reflectance. The aim of Experiment 3 was to determine whether transparency judgments vary linearly with reflectance difference or with lightness difference.

Method

The stimulus consisted of 3 intensity regions arranged to depict two overlapping rectangles as shown in Fig. 6a.

Insert Fig. 6 about here

The stimulus color of region a was a Munsell value of 1 (1.2 percent reflectance) and of region b a Munsell value of 8 (59.1 percent) and of region c a Munsell value of 4 (12 percent). The stimulus is ambiguous and can be seen as the upright rectangle overlying the diagonal rectangle or of the diagonal rectangle overlying the upright rectangle.

The Munsell papers were pasted on a matte black background. The background was cut away so that only the stimulus figure was visible. The stimuli were supported by a stalk fitted into a wooden base located at eye level 5 feet from a subject. The illumination came from a projector using a bulb having a color temperature of 2900K. The light passed through a 1-62 Corning filter which converts the illuminant to C. I. E. illuminant C(6500K). Subjects viewed the stimuli monocularly through a viewing tube that limited visibility to the immediate stimulus surround. An electrically controlled shutter limited viewing time to 2 seconds. Subjects were allowed to view a stimulus for as many two-second periods as they wished, but were urged to make their judgments upon their immediate visual impression.

Perchè
prima
1½ m.?

Subjects were first acquainted with the phenomenon of transparency through

?

examples. The test stimulus was presented together with 10 other stimuli made up of colored Munsell papers.[5] Subjects judged the chromatic stimuli only with respect to whether they were seen as transparent or not. Following the presentation of the chromatic stimuli, subjects were instructed that the next stimulus would be achromatic, and that they would judge the stimulus not only with respect to whether it appears transparent but also with respect to how transparent it appears. They were told that a surface can vary in transparency. Differing degrees of transparency were described by asking subjects to think about mixing ink with water or milk with water. Adding milk or ink to the water decreases the transparency of the mixture. Subjects were asked to judge whether they saw transparency or not. If a subject reported seeing transparency, the subject was then asked whether the upright rectangle or the diagonal rectangle was seen as the Fig 6 overlying surface. Subjects were asked to estimate the transparency of the overlying surface from near zero percent (nearly completely opaque) to near 100 percent (nearly completely transparent). Following the transparency judgment, subjects were asked to try to see the three regions as coplanar and to match the lightness of the regions to an 18 step Munsell value scale. The Munsell scale was placed on a shelf to the left of a subject and illuminated by an Easel lamp which simulated C. I. E. illuminant C. Subjects were allowed to view the stimulus without time limit while matching the stimulus to the Munsell grays.

Subjects. Eleven subjects served in the experiment. They all had normal or corrected to normal vision, and were naive about the purpose of the experiment.

Results and Discussion

In Fig. 6a, a represents the reflectance of the top surface T, and b the reflectance of the bottom surface B. The transparency of the top surface in the area of overlap is represented by α. According to Talbot's law, the apparent reflectance of region c is equal to

$$(9)\ c=\alpha b+(1-\alpha)a$$

where α and $(1-\alpha)$ represent respectively the proportions of which the apparent reflectance c is made up of the reflectances of surfaces B and T. Solving Equation 9 for α, yields

$$(10)\quad \alpha=(c-a)/(b-a)$$

If the upright black surface is seen as transparent, the perceived transparency calculated in terms of reflectance is .19 and in terms of Munsell value .43. The mean of subjects' lightness matches of regions a, c, and b were Munsell values of 3.1, 5.5 and 9.2. The transparency estimate when these values are substituted in equation 10 is .39. The mean of subjects' transparency estimates is 41.4 with a standard deviation of 5.1. Thus, one must introduce into equation 10 lightness values rather than reflectances to accurately predict quantitative transparency judgments.

The finding that the perception of transparency is determined not by the physical reflectances, but by lightness values, argues that the phenomenon of transparency is not based on Talbot's law. In fact, if one sets up an episcotister, judgments of transparency would be inaccurate. Rather, the perception of transparency appears to be based on the lightness values which are a nonlinear function of reflectance. What is the theoretical justification for using the Munsell values of regions a, b, and c in equation 10? A justification may be given based on the hypothesis that the perceived transparency is a function of the relative similarity of the lightness of region c to the lightness of the underlying region b and to the lightness of the overlying region a. The perception of transparency is the result of encoding the lightness of region c as the lightness of the underlying region b modified by the lightness of the overlying region a. The more similar the lightness of c is to the lightness of a, the less the perceived transparency, and the more similar the lightness of c is to the lightness of b, the greater the perceived transparency. The Munsell value scale is based on direct estimates of lightness differences and reflects lightness similarities. If M(a), M(b), and M(c) are the Munsell values of the regions a, b, c, the relative similarity of lightness c to lightness a is given by the difference, d1, [M(c)-M(a)] divided by the difference, d2, [M(b)-M(a)] (Fig. 6b). The equation for perceived transparency has the same form as Equation 10, but with Munsell values substituted for reflectances:

$$(11)\quad \alpha=M(c)-M(a)/M(b)-M(a)$$

Partial Transparency. The perception of transparency with a three-part stimulus is anomalous. One does not perceive a transparent surface through which other objects and surfaces are seen. Rather, one perceives a surface which is in part transparent and in part opaque. Metelli (1974a) has called this special kind of transparency "partial transparency." As pointed out above, a model based on Talbot's law and color addition requires the reflectance of the overlapping region c to lie between the reflectance of the a region and the reflectance of the b region. The similarity algorithm we have proposed for judging the degree of transparency also requires that the lightness of the overlapping region c lies between the lightness of the a region and the lightness of the b region. In contrast, a model based on a filter and subtractive color mixture allows the reflectance of the overlapping region to be greater than the reflectances of the nonoverlapping regions. This occurs, when the reflectance of the top surface is greater than the reflectance of the bottom surface. Equation 6 gives the reflectance of the overlapping region, c, when F and B in Fig. 5a are interpreted to be the two overlapping surfaces. It is of interest to note that there is a physical interpretation with additive color mixture in which the intensity of the overlapping region is greater than that of the nonoverlapping regions. This occurs if B and T in Fig. 6 are two projected rectangles of light. Partial transparency, as pointed out, is not ecologically representative and appears to occur because of a preference by the visual system for minimizing the complexity of the perceptual interpretation. The perception of transparency in Fig. 7 both simplifies the shapes and minimizes the lightness

l'aggiunta
della 3a dim.
non
semplifica

changes. Fig. 7 shows examples of a three-part stimulus in which the reflectance of the overlapping region is below, and above that of the nonoverlapping regions. ?

Insert Fig. 7 about here

Nineteen of 26 subjects judged the stimulus shown in Fig. 7a transparent but only 6 subjects judged the stimulus shown in Fig. 7b transparent. Thus, judgments of transparency do occur when the reflectance of the overlapping region fails to lie between the reflectances of the nonoverlapping regions. Le [illegible]

EXPERIMENT 4

Metelli has called the perception of transparency "complete transparency" when a transparent film is perceived to overlie two opaque surfaces differing in reflectance. Equation 3 gives the degree of transparency in the Metelli model for complete transparency. We believe that with complete transparency, as with partial transparency, the degree of perceived transparency will not be correctly predicted when physical reflectances are substituted in equation 3. One possibility is that substituting lightness values for reflectances in equation 3 correctly predicts the perceived degree of transparency. The argument for this is that the estimate of transparency is based on the reduction of apparent contrast. ? The perception of the degree of transparency is assumed to be a $\frac{p-q}{a-b}$ function of the similarity of the lightnesses of regions d and c relative to the similarity of the lightnesses of regions a and b (Fig. 2). If the lightnesses of the regions d and c are equal, i.e., their contrast *e non?* is zero, then the degree of perceived transparency is zero. As the lightness difference between the regions d and c approaches the lightness difference between the regions a and b, the perceived degree of transparency goes to 100 percent. *No, solo se $0<T<1$* This equation, ? however, can not be correct without further restriction. Consider stimulus 9 in Table 6. The lightness difference between d and c is nearly equal to that between

la restrizione c'è: la trasp. deve essere equilibrata
(v. esempio di Romanini)

$\alpha = 1$ è accettabile soltanto se $a \geq p$ e $b \leq q$

(e comunque porta a + indebitamento)

V. triangolo di Bernardino

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a and b. Subjects' mean lightness match of region a was a Munsell value (M.V.) of 7.8, b a M.V. of 6.5, c a M.V. of 2.7, and d a M.V. of 3.9. Stimulus 9 was arranged as in configuration I and could be seen as either surface D overlying surface B, or as surface B overlying surface D. Substituting lightness values in Equation 3 gives a transparency of .96 when D is seen to overlie B, and .99 when B is seen to overlie D. Transparencies of .96 and .99 imply that the lightness of region d is close to that of region a and the lightness of region c is close to that of region b. This is clearly not the case. Table 7 shows that the mean judged transparency was .38 when surface D was seen overlying surface B and .59 when surface B was seen overlying surface D. The reason the formula is incorrect is that although the lightness difference d-c is nearly equal to the lightness difference a-b, the lightnesses of d and a and of c and b are not close to each other. It is not clear what formula relates the perceived degree of transparency to lightness values in the case of complete transparency. The main aims of Experiment 4 were to determine (a) whether subjects are able to make reliable judgments of transparency in the case of complete transparency, and (b) whether a formula can be developed in terms of lightness values which will predict the perceived degree of transparency.

È vero ma va rove lo scambio? Forse la contrast reduction ?

?? unbalanc. transp.

Invece sì

?

Method

Stimuli. Twenty-eight computer generated stimuli were mounted on white cards. Six stimuli strongly violated constraints i and ii and in pretesting were judged as not transparent. These served as catch stimuli. Seventeen stimuli were arranged as in configuration I (Figs. 2a and 3a) and 5 stimuli as in configuration II (Fig. 3b).

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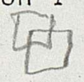

Procedure. Two independent groups of subjects made stimulus judgments. One group of 10 subjects matched the lightness composing a stimulus to a chart of Munsell grays. The second group judged whether a stimulus appeared transparent, and if transparent, the degree of transparency.

Questi dati non ci sono nella tab. 7 né altrove

In the lightness matching task, subjects were asked to match the lightness of the different regions composing a stimulus with the lightnesses on a Munsell Chart ranging from 1 to 9.5 in .5 steps. Subjects were told that none of the Munsell values might seem like a perfect match, but they should select the gray which appeared to be the best match. Subjects were first given a sample stimulus not used in the experiment and asked to match the lightnesses of the regions to the Munsell values. Subjects proceeded through 22 noncatch stimuli at their own pace. The stimuli were presented using two different random orders.

?

In the transparency estimation task, the instructions were similar to those with Set 2 in Experiment 1 with the following differences. For configuration I stimuli, subjects were first asked whether the overlying surface appeared transparent. If they said that the overlying surface did not appear transparent, the trial was concluded. If they reported the overlying surface transparent, they were then asked whether the rectangle D was seen to overlie the square B (D/B), or whether the square B was seen to overlie the rectangle D (B/D) (Fig. 3a). For configuration II stimuli, the center sequare is always seen to overlie the background square. Subjects were therefore, only asked to judge whether the center square appeared transparent (Fig. 3b). The criteria for judging a stimulus transparent was the same as with Set 2 in Experiment 1. As in Experiment 3, differing degrees of transparency were explained by asking subjects to think of mixing ink with water or milk with water. A visual example of the continuum from transparency to opaque was demonstrated by rotating crossed polaroid filters from clear to opaque. Subjects estimated the degree of transparency on a scale from 0 to 100.

The stimuli were exposed for 5 seconds in a Gerbrands tachistoscope. A subject initiated a trial by pressing a switch and was allowed to view a stimulus for as many times as he wished. Before beginning the experiment, 10 practice stimuli were presented. Six of the practice stimuli were arranged as in configuration I and 4 as in configuration II. The 28 stimuli were presented randomly. Two different random orders were used.

(22 + 6 non catch? stimuli)

Subjects. Ten volunteers with normal or corrected to normal vision served as subjects in the lightness experiment. Twenty-six different volunteers with normal or corrected to normal vision served as subjects in the transparency experiment.[6] All subjects were naive as to the purposes of the experiment.

RESULTS

Table 6 lists the 22 noncatch stimuli, their reflectances, and the values of α and e when a stimulus was seen as D/B and when a stimulus was seen as B/D. Table 7 presents the number of transparency judgments of each stimulus, and the mean transparency estimates and their standard deviations. A Roman numeral II following a stimulus indicates that the stimulus arrangement was that of configuration II.

Ma bisognare confrontarla con la trasparenza calcolata!

Insert Tables 6 and 7 about here

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alcuni in una versione altri nell'altra

solo in una versione

No

only in one of the two versions

Stimuli 1 through 8 in Table 6 satisfied constraints i through iv. Six were with configuration I and 2 with configuration II. Four of the configuration I stimuli (stimuli 1 through 4) satisfied the constraints when a stimulus was seen as D/B, and 2 (stimuli 5 and 6) when a stimulus was seen as B/D. The configuration II stimuli (stimuli 7 and 8) were always seen with the center square overlying the background square and are listed under D/B in Table 6. The mean number of transparency judgments of these 8 stimuli is 23.8 with a SD of 2.4. Stimuli violating constraints iii and iv were also judged transparent. The value of e remains the same and does not depend on whether a stimulus is seen as D/B or B/D. Stimuli 9 through 13 violated only constraint iii, and stimuli 14 and 15 violated only constraint iv. Stimuli 16 (and II) through 18 violated both constraints iii and iv. The mean number of transparency judgments of the 10 stimuli violating either constraints iii or iv is 22.1 with a SD of 2.3.

Il numero [illegible] di trasparenza non compare nella Tabella successiva

Comparisons of stimuli which violated constraints only as D/B or B/D need to be made with care. Other factors, such as the violations of other constraints and the proximity of c in lightness to d or to b may affect judgments. ? As in earlier experiments, Tables 6 and 7 show that violations of constraints i and ii decreased the number of transparency judgments. Three stimuli violated only constraint i. Stimuli 5 and 6 violated constraint i with the arrangement D/B, and stimulus 2 violated constraint i with the arrangement B/D. The mean number of transparency judgments is 2.0 with a SD of 2.0. Stimulus 3 violated only constraint ii. This occurred with the arrangement B/D. The number of transparency judgments is 1.

S.D. alte

Table 7 shows that subjects were able to make relatively consistent estimates of transparency. Correlation coefficients were computed between the predicted and obtained transparency estimates for stimuli in which 5 or more subjects judged a stimulus as transparent. The correlation of the obtained transparency

Con che formula? Munsell?

~~No~~

estimates with those predicted by Equation 3 is .62 for the 8 stimuli satisfying constraints i through iv. The hypothesis that transparency varies linearly with α requires the intercept to be 0 and the slope 1. The intercept of the regression equation is .28 and the slope .66. In addition to the 10 stimuli noted above which violated only constraints iii and iv, stimulus 19 violated constraint iii only when seen as D/B and stimulus 20 violated constraint iii only when seen as B/D. The correlation between the predicted and obtained transparency estimates (n=19 when D/B and B/D are counted separately) is .28. The intercept of the regression equation is .36 and the slope is .21. Thus, the results show that α fails to predict the degree of perceived transparency.

The stimulus relations underlying the perception of transparency may be quite different than the criteria used to judge the degree of transparency. We hypothesized that transparency depends on central visual processes checking whether the lightnesses in a pattern satisfy the order restrictions of constraint i and the magnitude restrictions of constraint ii. Judgments of the degree of transparency may be based on other, not necessarily even consistent, stimulus relations. ? For configuration I stimuli, it is possible subjects attended to the lightness relations between regions b, c, and d in making transparency estimates. ⑦ The estimation of transparency would then be predicted by an equation similar to equation 11. An equation analogous to equation 11 is given by equation 12. ?

Cr. paragrah pag. 24

$$(12)\quad \alpha = \frac{\overset{q-p}{|c-d|}}{\overset{q-p+q-b}{|c-d|+|c-b|}}$$

The equation assumes that surface D is seen to overlie surface B. If surface B is seen to overlie surface D then the numerator is $|c-b|$. The rationale for this equation is: (a) If c equals d in lightness then transparency is 0; (b) The greater the difference in lightness between c and d the greater is the perceived transparency; (c) The degree of perceived transparency is normalized so that it lies between 0 and 1 by dividing the absolute difference $|c-d|$ by the absolute difference $|c-d|+|c-b|$. If the lightness of c is between the lightnesses of b and d, equation 12 reduces to equation 11. The correlation (n=25) between predicted and obtained transparency is .67 when mean lightness values are substituted in equation 12 and .69 when reflectances are substituted. The slopes are .39 and .40 and the intercept values .37 and .36 respectively. The results show that we do not as yet have a good understanding of the factors controlling the judgment of transparency with complete transparency.

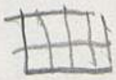
Insofar?

Transparency is never predicted

30

General Discussion

Non necessaria



Perceptual transparency is a function of the stimulus information indicating that the overlying surface is not opaque and transmits as well as reflects light. Transparency is indicated by the alteration in image intensities produced by the overlying surface, the image distortions occurring because of light refraction, and the cues provided by figural configuration, depth, and motion. The finding in Experiment 3 that the perception of transparency is a function of lightness indicates that transparency is not, as suggested by Metelli (1974a, b), the result of splitting a stimulus luminance into the luminance of the background surface and the luminance of the transparent surface, i.e., the reverse of color fusion. In fact, constraints iii and iv which are based on the physical variables of reflectance or luminance appear not to be implemented by the visual system. The visual system appears only to be able to make order and relative distance judgments of lightnesses.

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prima altri

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equil

How do the cues deriving from the pattern of intensities relate to other stimulus information affecting the perception of transparency? The other variable that has been systematically studies is figural configuration. Metelli (1974b) has identified three main figural conditions for perceiving transparency: figural unity of the transparent layer, continuity of the boundaries in the transparent region with the boundaries of the nontransparent regions, and stratification of the transparent region into two overlapping layers. Our observations suggest that figural cues are primary and that if the figural configuration indicates the possibility of transparency then the pattern of lightness relationships are checked to see if they are consistent with transparency.

no

Transparency will be seen if the pattern of lightnesses satisfies constraints i and ii. If more than one stratification of the surfaces satisfies the constraints, then instructional sets or subsidiary principles determine what is seen. One such principle is that the overlapping region tends to the region from which it deviates least in lightness.

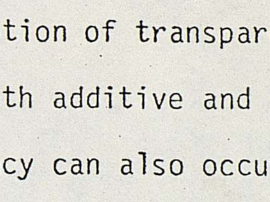
form an unit with (Petter)

If the figural cues for transparency are strong enough, then transparency may be seen even when the pattern of lightness relationships is incorrect. A striking example of this is described by Metzger (1955). Metzger showed that if a disk is made to rotate slowly about a point, two intersecting circles on the disk will become separated in depth. There is a splitting of the intersecting region into two planes based on two kinds of contour movements. One plane is defined by contours which move into each other, and the other plane by contours which are displaced over the retina. An observer sees a moving circle rotating around a stationary circle. What is of interest is that the cues for seeing overlapping circles are so strong that the perception of transparency occurs for color combinations that strikingly violate both additive and subtractive color mixture. The present study shows that transparency can also occur with stationary stimulus patterns when the pattern of lightnesses are incorrect. For example,

Color

Musatti

two planes are seen
one resting and the other moving with respect to it.



qpab quale trasparenza?

the stimulus order cdab with configuration I evoked judgments of transparency despite the violation of the order constraint by the pattern of lightnesses. When transparency occurs in such cases, the hues and lightnesses of the overlapping region may not appear correct. One needs to distinguish between the perception of transparency and color scissioning. We use "color scissioning" to refer to perceiving the color in the intersecting area as being composed of the base color and the overlying transparent color. Transparency can occur with and without color scissioning.

? Where? Colori [illegible] come con Metzger

When does color scissioning occur? Metelli (1974a) explains color scissioning as a splitting of the stimulus luminance into the luminances of the background surface and of the overlying transparent surface. We have argued that color scissioning is not the reverse of Talbot's law of color fusion. Rather, it is a higher-order more cognitive encoding of the structural information in a stimulus. We hypothesize that color scissioning is the result of an encoding of a stimulus in terms of the color of an opaque surface and the color of a transparent surface overlying the opaque surface. Encoding in terms of a perceptual schema such as overlying planes of colors appears to require sensory support. Sensory support can occur in various ways. Phenomenological observation suggests that all colors can be described using the color names "red," yellow," "green," "blue," "black" and "white." For example, orange can be described as a combination of a red color and a yellow color. Color scissioning can therefore occur in which an orange stimulus color is seen as a red through a yellow or vice versa. Another way of providing sensory support may be in terms of contrast colors at the boundaries of the transparent and the nontransparent regions, or flecks of the nontransparent color may leak through the transparent medium. Transparency with color scissioning occurs when sensory support leads to the visual system encoding the overlapping color as the opaque underlying color

[illegible] il grigio come base attraverso il verde

?

è il caso di Metzger

33

modified by the color of the transparent surface. When such an encoding is not induced in the visual system, the perception of transparency occurs without color scissioning, i.e., one has impression of transparency but the colors in the overlapping region are wrong.

Sta il fatto che per risolvere il sistema di 2 equazioni

$$p = \alpha a + (1-\alpha)t$$
$$q = \alpha' b + (1-\alpha')t'$$

le incognite devono essere due, cioè si deve avere $\alpha = \alpha'$ e $t = t'$.

Come si deve procedere per stabilire se queste condizioni presenti?

~~[illegible]~~ La soluzione è semplicissima se ci riferiamo al modello dell'episcotista. In questo caso α è l'ampiezza del settore vuoto e t il colore dell'episcotista o più esattamente la sua riflettanza. È chiaro che l'uno e l'altro possono variare soltanto fra 0 e 1. Che cosa significa allora se si ottengono l'uno o/e l'altro dei due valori fuori dai limiti ammessi? Semplicemente che quei valori di a, b, p, q non si possono ottenere con un episcotista, ma per ottenere a su p e b su q occorrono due episcotisti, o in altre parole occorrono due diversi α e/o 2 diversi t.

Kubovy Pomerantz
Perceptual Organization

Reference Note

1. Brill, M. Physical Foundations of the Perception of Achromatic Transparency. RLE Progress Reports: PR NO. 117, M.I.T., 1976, 315-320.

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Footnotes

1. Metelli (1975) suggests that the possibility of seeing a surface through a black transparent color when e=0. The density of the transparent color varies inversely with α.
2. Edge contrast increased the lightness difference between regions c and d. A 1 percent difference in reflectance corresponds to a lightness difference of .08 of a Munsell step. When the stimulus was matched so that only regions c and d were visible, the lightnesses of the two regions were nearly indistinguishable. When viewed normally, the lightness difference between regions c and d was between .25 and .5 of a Munsell step.
3. It should be pointed out that the value of e can change greatly with small changes in reflectance. For example, if a=.15, b=.28, c=.47, and d=.35, e=2.75. If c is decreased to .45 and d increased to .36, e=.83. This makes it further unlikely that the visual system takes into account to the value of e.
4. We are indebted to Dr. Seymour Haber of the Natural Bureau of Standards for these proofs. For a related mathematical treatment see Brill (Note 1).
5. The results with the chromatic stimuli will not be reported in this paper. In general, they showed that the perception of transparency occurs as readily with subtractive color mixture as with additive color mixture.
6. Twenty-nine subjects were run. One subject was dropped because he consistently called the catch stimuli transparent. Two subjects were dropped because they misunderstood the instructions. They thought that a stimulus to be reported transparent had to be seen as transparent when surface D is seen overlying surface B <u>and</u> when surface B is seen overlying surface D.
7. There are two possibilities if a subject's transparency estimates are based on attending to 3 of the lightness values in a stimulus. A subject may

e perché dovrebbe considerarne
solo 3? e non 4?

Footnotes (cont.)

attend to the lightness values of regions b, c, and d or to the lightness values of regions c,d, and a. For configuration I stimuli, the overall pattern makes it seem likely that subjects would attend to regions b,c, and d. For configuration II stimuli, the two alternatives are equally likely. We decided, therefore, to test the hypothesis with configuration I stimuli.

39

Alcuni effetti

.59 .96 .35 .23

Esper. 3

— Tab I Risultati della presentazione ~~collettiva~~ individuale a 10 soggetti esperti di 24 dischi (Fig   ) in lenta rotazione (1 giro al sec) corrispondenti alle 24 permutazioni delle quattro tonalità di grigio componenti i dischi a ~~Nella prima colonna~~ 10 soggetti esperti. Nella prima colonna sono le frequenze dei casi in cui è stata descritta la trasparenza delle regioni PQ nella regione AB (trasparenza completa). Nella seconda colonna sono indicate le frequenze della trasparenza completa invertita (regioni AB trasparenti sulle regioni PQ). Nella 3ª colonna i casi di trasparenza parziale, con la indicazione della regione trasparente e della regione vista per trasparenza (p. es $\frac{P}{A}$ = P trasparente su A) Nella quarta colonna sono indicate le frequenze dei casi di non trasparenza. Nella 5ª colonna le osservazioni. I numeri in parentesi indicano i casi in cui il soggetto ha visto due o tre forme di trasparenza.

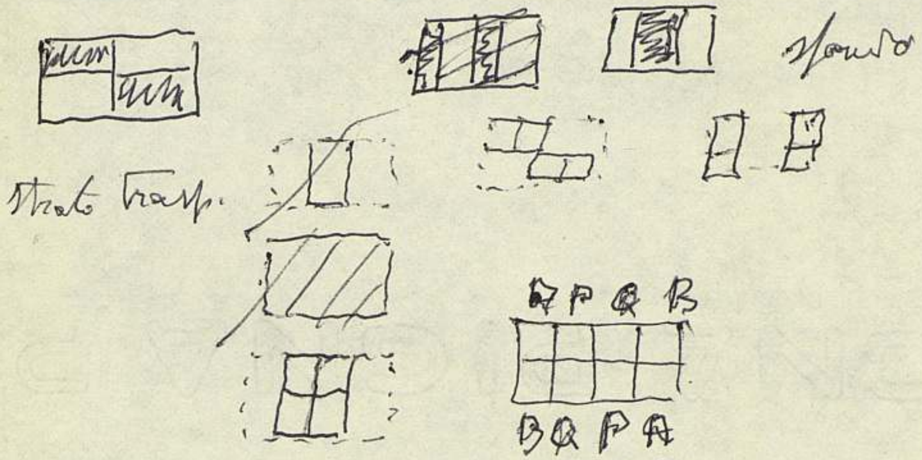
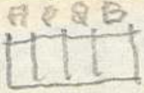
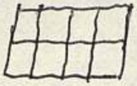


Fig. 8

Il secondo esperimento dà risultati complessi e non confrontabili esattamente con quelli di BPJ. Pur trattandosi di una condizione figuralmente neutra (Fig 8) le condizioni di trasparenza completa sono frequenti, in quanto si presentano sotto 3 forme diverse, e cioè a) la sezione riguarda i quadrati centrali PQ e QP (Fig. 10) b) ~~i quadrati~~ i due rettangoli sfasati BP e PA oppure QB e BQ (Fig. 11) c) i due rettangoli laterali AB e BA; e altrettante sono le forme di trasparenza parziale. [V. Tab.]

Nel complesso ~~si hanno~~, su 12 situazioni ce ne sono 8 che danno luogo alla percezione di varie forme di trasparenza e 4 che vengono percepite generalmente come X





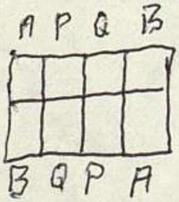
Posizione APQB

Chiarezza crescente

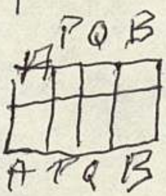
[illegible]

bqpa	6	apqb	apqb	✓3
qbpa	7	apbq	paqb	9
pbqa	16	aqbp	qapb	15
qpba	8	abpq	pqab	10
bpqa	14	aqbp	aqpb	12
bapq	22	qpab	abqp	21
pabq	~~9~~18	qbap	qbap	17 +
qabp	19	pbaq	pbqa	–20
bqap	5	paqb	apbq	2
bpaq	13	qapb	aqbp	11
baqp	4	pqab	abpq	1
qpab	23	bapq	pqba	24

1°



~~BQPA~~



1) riflettanze dei colori
Munsell usati

2) riflettanze dei CBS impiegati per
rifare  con minore
differenza di chiarezza

Forse i risultati più interessanti si sono ottenuti con il disco fatto ruotare lentamente. Siccome si tratta di una configurazione che riprende quella di Metzger (   ) citata da BP e J conviene anzitutto mettere in evidenza il fatto che, mentre nel caso di Metzger veniva forzata un tipo di trasparenza contrario alle leggi della fusione fra tonalità cromatiche, nulla di simile avviene quando anziché tonalità cromatiche si usano ~~differenti di chiaro~~ grigi di differente chiarezza. In questo caso le ~~situazioni che~~ permutazioni che non danno trasparenza in quiete non la danno neppure in movimento

---

X scacchiere opache ●. Ciò dimostra che contrariamente a quanto affermano BP e J cp. le condizioni spaziali, che in questo caso sono neutre, non sono ~~quelle che determinano~~ primarie nel determinare l'impressione di trasparenza.

● In alcune configurazioni si determina la percezione di ~~più forme visive~~ più strutture diverse che danno luogo alla trasparenza.

Tesi sostenute da B., P. e J.

1. La teoria di Wr. pone dei vincoli che dovrebbero avere validità generale ✓

3. I vincoli riguardanti α tengono, non così quelli riguardanti t

Esperimenti

2. La teoria di Wr. afferma che non c'è trasparenza quando non sono osservati i vincoli ✓

4. I vincoli riguardanti α tengono solo se trasgrediti in misura notevole (non p.es. [se $\alpha = 0$] se $\alpha = 1$)05

5. Le condizioni figurali influiscono sulla frequenza della trasparenza (⊕ e ⊞)

Esperimenti ○

6. (p.10) Se le condizioni figurali suggeriscono fortemente la trasparenza, si percepisce trasparenza anche se i rapporti di intensità la escludono <cioè anche contro i vincoli>.

7. Eccezioni ai vincoli si hanno più facilmente con la configurazione ⊕ che suggerisce più fortemente la trasparenza

Vedere

p.13

Vedere Esp.

6a Nella figura 9 p.14 le violazioni crescono col ~~co~~ diminuire della ~~differenza~~ fra percentuali ~~fra~~ cui differiscono le differenze tra a e b da

5

un lato e p e q dall'altro $|p-q| \leq |a-b|$
(~~#~~ 19 violazioni quando la percentuale è 4, e 4 violazioni quando la percentuale è 17).

Vedere

7. ~~La~~ Se la configurazione trasparente è invertibile prevale la versione in cui c'è meno differenza (o più rassomiglianza) fra le due superfici che diventano trasparenti (v. Petter)

8. Il modello del filtro è diverso dall'episcotister perché agisce secondo il modello sottrattivo però dà risultati corrispondenti.

De Pos

9. Inserendo stime della chiarezza al posto della riflettanze ~~si ottiene con~~ nella equazione della trasparenza parziale, si ottiene una misura della trasparenza vicina alla stima data dai soggetti.

già discusso

10 La trasparenza parziale è anomala (v. 24)

11. Possibilità della tr. parziale quando la regione o corrispondenze centrale è più chiara delle due regioni laterali. Vedere

12. La previsione della trasparenza completa non è data dalla formula $\frac{p-q}{a-b}$ neppure sostituendo le chiarezze alle riflettanze

Esperim.

12a ~~a~~ La formula non vale per $\alpha = 1$

p. 26 se $p \neq a$ e $q \neq b$ (v. diagramma di Remondino)

Tab. 6-7

[Le comparazioni di cui caratteristiche di identità sono comprese ff. e sono quasi tutte fuori del triangolo di T., quindi di trasparenza non equilibrata, quindi per esse non valgono le equazioni]

La correlazione fra trasparenza prevista e ottenuta è .28.

Vedi nostri esperimenti

B P e I usano anche un'altra formula che dai risultati migliori ma non tali da poter fondare una previsione.

Ingiustificati

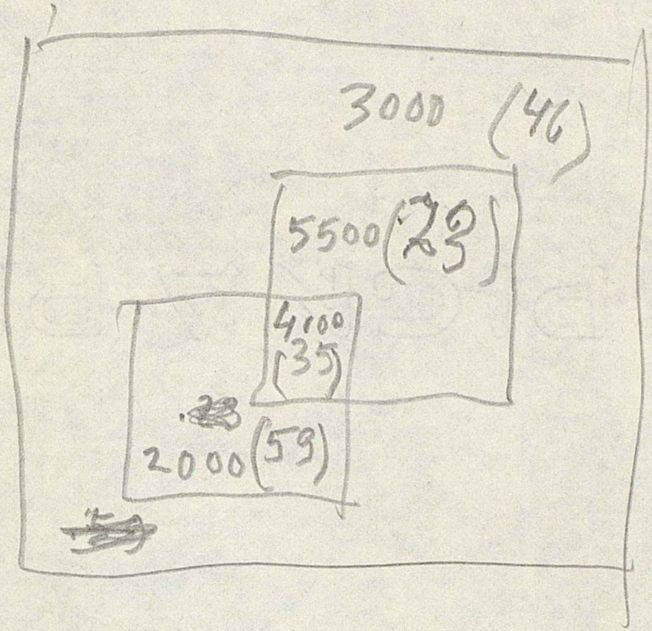


Fig. 5