BALANCED AND UNBALANCED, COMPLETE AND PARTIAL TRANSPARENCY

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ABSTRACT

Beck, Pradzny, and Ivry's interpretation of Metelli's theory of phenomenal transparency is ~~incorrect~~ reexamined here. There are no constraints because the theory considers only balanced transparency, and nothing is asserted against the existence of forms of unbalanced transparency. Experiment 4 proves that conditions of intensity are primary for complete balanced transparency and cannot be overcome if figural conditions strongly suggest transparency. [The algebraic deduction that in partial transparency, the intensity of the transparent region must be intermediate between the other two regions, is not disproved by Beck et al.'s experiments.] The equation $\alpha=(p-q)/(a-b)$ does not require further restrictions because the cases quoted by Beck et al. regard non-balanced transparency. Experiment 1 proves that figural conditions cannot be considered primary and thus the cause of the perception of transparency. Contrary to the results obtained by Beck et al. in their Experiment 4, a series of experiments with experienced subjects, where estimation of transparency was compared with predictions calculated with the α formula, gave satisfactory results.

Beck et al.'s thesis, according to which $\alpha \neq \alpha'$ hinders transparency while $t \neq t'$ allows it, is confirmed. Experienced subjects and simple instructions appear to yield clearer results.

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Beck, Pradzny, and Ivry (1984) in their paper "The perception of transparency with achromatic colors" start from an exposition of the theory of transparency proposed by the senior author of this paper, which however lacks an essential part.

The theory is as follows. The starting point is G.M. Heider's theory (1933), restated by Koffka (1935), according to which transparency is a phenomenal scission, in which a stimulation—that, if isolated, gives rise to a single color—gives rise in this case of scission to the perception of two colors; that is, the color of the object seen through transparency and the color of the transparent layer. Heider and Koffka's experiments also demonstrated that scission colors are such that if fused, when transparency is not perceived, they give rise to the color seen in isolation (that is, to the reduction color).

Heider and Koffka's results allow a quantitative interpretation. Talbot's law, which permits a quantitative description of chromatic fusion, also provides one for chromatic scission as well. In other words, if Talbot's law for the fusion of the two colors[1] is expressed by $\alpha a+(1-\alpha)b=c$ (where a and b are the reflectances of the two colors which are fused, c is the reflectance of the fusion color, α and $(1-\alpha)$ are the proportions in which the two colors are mixed), then the same formula reads, so to speak, backwards. That is, $c=\alpha a+(1-\alpha)b$, will describe the scission of color c into the two colors a, seen through transparency, and b, perceived as transparent; α and $(1-\alpha)$ are the proportions into which color c splits when giving rise to colors a and b.

The typical situation to which the theory refers is the transparency obtained using an episcotister. If an episcotister (that is, a disc lacking a sector) rotates at fusion speed before a bicolored ground, the perceptual result is a gray transparent disc, through which the colors of the background are visible (Figure 1). Figure 1a indicates the symbols of the four resulting regions, that is A and B are parts of the bicolored ground which are directly visible, while P and Q are regions where a transparent disc T and parts of the underlying background are perceived. But if part of one of the regions where scission is perceived is isolated with a pierced screen, scission disappears and a single fusion color p, in the P region, or q, in the Q region, is perceived through the hole.[2]

The situation can be described by the following two equations

$$p = \alpha a + (1-\alpha)\ t \qquad (1)$$

$$q = \alpha b + (1-\alpha)\ t \qquad (2)$$

where a, b, p, and q are the reflectances of the respective regions (Figure 1 a), t is the virtual reflectance of the transparent layer T, and α and $(1-\alpha)$ are the proportions into which the p and q colors split in giving rise to the color of that part of region A (respectively B) seen through transparency, and to the transparent layer T.[3]

From the system of two equations with two unknowns, the values of α and t can be obtained, that is

$$\alpha = (p-q)/(a-b) \qquad (3)$$

$$t = (aq-bp)/[(a+q)-(b+p)]. \qquad (4)$$

However, one must keep in mind—which Beck et al. failed to do—that the deduction of Equations 3 and 4 is valid only in the case of the episcotister, where the αs and the ts are the same in Equations 1 and 2.[4]

If a figure like Figure 1 is constructed selecting the two grays p and q at will, Equations 1 and 2 become

$$p = \alpha a + (1-\alpha)\, t \qquad (5)$$

$$q = \alpha' b + (1-\alpha')\, t' \qquad (6)$$

and then, as there are four unknowns (α, α', t, t'), the system becomes indeterminate and Equations 3 and 4 can no longer be deduced from Equations 1 and 2. In other words, only when $\alpha=\alpha'$ and $t=t'$ is the above mentioned deduction lawful, that is in the case of *balanced* transparency, where the degree and the color of the transparent layer are equal in the P and Q regions.

Beck et al. interpret limitations relative to α ($0<\alpha<1$) and t ($0<t<1$) as true constraints, namely as insuperable limits, thus putting the validity of the theory to the test. In fact ~~there is nothing of that~~

sort: the conditions studied concern only balanced transparency. If transparency occurs outside the aforesaid limits, it is a matter of unbalanced transparency, and the theory does not assert anything about the possible existence of forms of non-balanced transparency.

It is interesting to consider more closely what happens if these limits are surpassed. It has been noticed in preceeding papers that $\alpha>1$ and $\alpha<0$ give rise to results devoid of sense, and the same is the case for $t>1$ and $t<1$.[5] Results of this type are absurd. It is then natural to ask if the premises which give rise to these results are at fault.

In obtaining results from the two initial equations psychological equality was supposed between α and α', and t and t'. The most reasonable hypothesis, when results are absurd, is that the premiss must be wrong. That is, every time the system of two equations with two unknowns yields an absurd result, the premiss, that is $\alpha=\alpha'$ and/or $t=t'$, must be erroneous.

On the basis of this hypothesis, $\alpha<0$ or $\alpha>1$, or $t<0$ or $t>1$, only means that $\alpha\neq\alpha'$ and/or $t\neq t'$, or in other words that it is incorrect to solve the system of two unknowns and therefore the results are devoid of meaning.

The hypothesis suggests a concrete expectation. If there is transparency when $\alpha>1$ or $\alpha<0$, $\alpha\neq\alpha'$, that is transparency is unbalanced, since in the two regions there is a different degree of transparency. If there is transparency when $t>1$ ot $t<0$, $t\neq t'$, that is in the two regions there is a different color, or in other words T will be lighter than T', or viceversa (Figure 2).

It may perhaps be useful to go back to the example of the episcotister, where α corresponds to the empty sector of the episcotister, and t to the episcotister's reflectance. $\alpha<0$ and $\alpha>1$ means that the opening of the episcotister should be less than 0° or greater than 360°, which is absurd. Equally absurd, for the aforesaid reasons, is $t<0$ or $t>1$. Since with the episcotister the unknowns are p and q, this means that there are certain values of p and q that, when a and b have given values, cannot be obtained with an episcotister. These values of p and q could be obtained by setting two episcotisters, one in place of T and the other in place of T' (Figure 2), with different values for α and t in each episcotister. Therefore, what cannot be obtained with α and t, can be obtained with α, α', t, and t', that is by carrying out, if

(Fig. 2 about here)

it were possible, a form of non-balanced transparency using two episcotisters.

Summarizing, our theory does not give rise to constraints, besause it only indicates the limits of balanced transparency, and does not deny the possibility of forms of non balanced transparency beyond these limits.

Furthermore the preceeding hypothesis, interpreting results beyond the limits as cases of unbalanced transparency, suggests the possibility that results of α beyond the limits indicate a form of transparency unbalanced in degree, whereas results of t beyond the limits indicate a form of transparency unbalanced in color.

EXPERIMENTS

Some of the statements and conclusions in Beck et al.'s paper suggest or require a series of experiments.

In doing these experiments, we decided to differ from the above Authors on the following points:

a) Beck et al. followed tradition using naive subjects. But we were conscious of the considerable difficulty of giving a phenomenological description in this type of experiments. Therefore we had recourse to a more limited number of expert subjects, used to this type of experiments, accustomed to the difficulty of giving an objective description of what they saw, and used to distinguish between complete and partial transparency, which are easily confused by naive subjects.

b) Instead of limiting the task of the subject to describing one form of transparency, subjects were invited to describe every form of transparency; and were questioned every time the description did not appear sufficiently clear. Besides the above difference between complete and partial transparency and the possible forms of inversion, different forms of complete transparency (see Experiment 2) also appeared with the same type of display, along with variations in the order of lightness of the grays.

c) Subjects were free to observe the figure as long as they needed and had it in front of them when they gave their description. If, during observation, a change appeared (inversions are quite common during observation), subjects were also requested to describe the new form of transparency, seen successively.

EXPERIMENT 1

The purpose of the experiment was to test Beck et al.'s (1984, p 412, 421) thesis that figural conditions are primary and are the necessary clue for perceiving transparency.

Method

Subjects. Eight experienced subjects took part in the experiment. They required no explanations or preliminary experiments, since they were already used to this task. They were only told to describe transparencies, if any.

Displays. The configuration was the simplest possible and by no means suggested transparency (Figure 3). Four gray rectangular regions, 3 x 5 cm wide, and with different reflectances were juxtaposed (Figure 3 a). The grays were respectively No. 9.5, 7, 4.5, 2 of the Munsell series, corresponding to .03, .16, .43, .90 reflectance respectively. Displays were 12, corresponding to 12 permutations only because, since the figure was symmetrical, the other 12 were useless, in that they corresponded to the same figures with the rectangles in the inverse order.

Figures were attached to pieces of brown cardboard which formed a frame 2 cm wide. Each display is symbolized by 4 lower case letters indicating the order of the reflectance from the lowest to highest, as was done by Beck et al. The order of the grays in the displays was APQB.

Procedure. The figures were presented in succession to each subject at a distance of about 50 cm. There was no time limit. The subjects observed the figures for as long as they felt they had something to describe. Their task was to describe the form or forms of transparency, if any, and also to indicate any changes during observation. The descriptions of subjects were recorded and subsequently summarized in a table.

Results

Results have been collected in Table 1, where the number of cases of complete transparency (transparency on two regions of the background), partial transparency (transparency on one region of the background only), and cases of non trasparency appear. Numbers in parenthesis indicate cases where a subject gave a second description.

It is interesting to stress that in Experiment 1 every subject perceived at least one case of complete transparency.

Cases of partial transparency were very frequent. One display only gave rise to impressions of non-transparency. The subject's answers can be reconstructed from the table. For example, A/P means that the region A was perceived as transparent on the region P. Table 1 about here

Results are evident: in a figurally neutral situation (that is, in a configuration which, when drawn linearly, has nothing to suggest transparency) complete or partial transparency is perceived rather frequently. Therefore, figural conditions cannot be considered primary, and be the cause of the perception of transparency.

EXPERIMENT 2

Method

Subjects. Ten experienced subjects (including the 8 subjects from Experiment 1) took part in the experiment. They did not require any explanations or preliminary experiments.

Displays. The purpose was the same as in Experiment 1.

The displays are more complicated than those of Experiment 1, but drawn linearly (Figure 4). The configuration does not suggest transparency in any way. Eight gray regions are juxtaposed as in a checker board, with two lines of 4 squares 3 x 3 cm, of which the second line is the inverse of the first. The order of grays in the first line is the same as in the displays of Experiment 1. In this case also 12 displays were used since the figures were symmetrical. As before, the order of symbols corresponds to the order of reflectances, from the lowest to the highest. The order of grays was APQB (first line) and B'Q'P'A' (second line). Colors are the same as in Experiment 1.

Procedure. The procedure was the same as in Experiment 1.

Results

Results are collected in Table 2. In this case the entry is more complicated because complete transparency appears in three different locations. That is, a) the four central squares appear transparent (Figure 4 a); b) the four lateral squares appear transparent (Figure 4 b); c) the couples AP (left) and A'P' (right) appear transparent (Figure 4 c).

It should however be noticed that, when transparency appears in different forms, the functions of gray squares change. While in the form (a) of transparency, where the central four squares are transparent, P and Q in both lines of squares indicate the regions where perceptual scission takes place and transparency is perceived, this is not true for the other forms of transparency. In the case (b), where the outer squares are transparent, A and B assume the functions of P and Q. In the case (c), where the couples AP and A'P' are perceived as transparent, A and P, and A' and P', assume the functions of P and Q.

Averages therefore have not been calculated, as there is no relation between these results and those obtained by Beck et al.

General results are again very clear: there are 4 figures where *all* subjects perceived complete transparency, and 2 figures where no subject perceived transparency. Cases of partial transparency are spread among the other displays.

In this experiment, where displays are figurally neutral, the cases of transparency outnumber the results of experiments where figural factors are at work.

EXPERIMENT 3

This is a repetition of Beck et al.'s (1984) Experiment 1, with slight variations in the reflectances (N.C.S papers's reflectances .23, .35, .46, and .59 versus .22, .34, .47, .59 of Beck et al.'s Experiment 1). The aim was to test results using experienced rather than inexperienced subjects.

Method

Subjects. The subjects were the same as those who took part in Experiment 2.

Displays. The displays are figurally the same as those used by Beck et al. An example of the displays can be seen in Figure 5 where the letters symbolizing the different regions also appear. Twenty-four displays were used corresponding to the 24 permutations of 4 colors.

Procedure. The procedure was the same as that described for Experiment 1.

Results

In Table 3 our results are given in detail as before and are compared with those of Beck et al. The table (line 1) reads as follows: (1) order of reflectance: $a<b<p<q$; (2) complete transparency: 6 cases; (3) inverted complete transparency: 2 cases (5 cases of double response); (4) partial transparency: 2 cases (1 case of double response); (5) non transparency: 0 cases; (6) description of cases of double response: 5 cases of complete and of inverted complete transparency, and 1 case of complete and of partial transparency; (7) Beck et al.'s results: 15 cases of complete transparency (%); (8) $\alpha = .306$; (9) $t = .4$.

Taking into account the different tasks given to subjects, there is a fairly good agreement between our and Beck et al.'s results in the first half of the table. The few cases of non transparency in Beck et al.'s results are explained by cases of invertion and partial transparency in our subjects' responses, where there was no case of non transparency.

In the second part of the table, Beck et al.'s subjects describe almost only cases of non transparency. There are however very patent cases, as in Displays 21 and 22, and 23, where several of Beck's subjects described complete transparency, but where not one of our subjects described a case of complete transparency, but only inversions or partial transparencies. In other words, exceptions are not found where experienced subjects are used, and especially when subjects are asked to describe every form of transparency.

EXPERIMENT 4

The purpose of this experiment was to test the effect of a situation where some non chromatic factors (such as form and motion) strongly favour the impression of transparency. The new factor characterizing out experiments concerns the (apparent) motion of the transparent layer with respect to the figure seen through transparency, or viceversa. This configuration is similar to that in which Metzger (1955), when using different *colors* instead of different shades of gray, obtained anomalous transparency with colors.

Method

Subjects. The same 10 subjects of Experiments 2 and 3 took part in this experiment.

Displays. Discs rotating slowly (2 rotations per second) were used as displays. The configurations consisted in a circle whose center corresponded to the rotation center, and which was intersected by a smaller circle lying partly on the top of the first, and partly on a circular ring (Figure 6). When the disc is rotated, the centered circle and the ring are perceived at rest, while the small non centered circle is perceived as moving either on the top of or below the ~~big circle.~~ circular ring.

The displays were constructed from the same papers used for Experiment 3. Twenty-four discs were used corresponding to the order of colors in Beck et al.'s displays, so as to make the comparison easier. The diameter of the discs was 30 cm, the diameter of the centered circle 10 cm, and the diameter of the eccentric circle 6 cm.

Procedure. The procedure was the same as before.

Results

Table 4 about here

The most interesting result is that in 6 displays subjects were unanimous in not perceiving transparency. This proves that not even the most coercive non chromatic conditions succeed in creating the impression of transparency, when intensity conditions are against it. In two other displays, cases of non transparency were respectively 9 and 6. In the other displays cases of total and partial transparency are very frequent, as was expected, given the presence of very powerful factors favouring transparency. Cases where the eccentric circle was perceived as below instead of on top of the centered circle were classified as inverted transparency.

An important point is the remarkable correspondence of results in very different conditions. The cases of non transparency correspond exactly to those where Beck et al. found a majority of cases of non transparency. Another important point is the absence of cases of complete transparency in Display 23 where, on the contrary, all subjects perceived partial transparency, while Beck et al. report the inexplicable result of 13 cases of complete transparency. These were probably all cases of partial transparency that inexperienced subjects, forced by an unnatural task,[6] interpreted as complete transparency.

It has to be stressed that on the whole there were fewer descriptions of complete transparency in our experiments, while partial transparencies were frequent.

EXPERIMENT 5

The purpose of this experiment was to test the assertion made by Beck et al. (1984) that conditions $t<0$ and $t>1$ do not hinder transparency, contrary to what happens when $\alpha<0$ and $\alpha>1$.

Method

Subjects. The same 10 experienced subjects were used.

Displays. Forty displays were constructed, that is 10 were $\alpha<0$ while t was between 0 and 1; 10 where $\alpha>1$ while t was between 0 and 1; 10 where $t<0$ while α was between 0 and 1; and 10 where $t>1$ while α was between 0 and 1. Figurally, the displays correspond to Beck et al.'s (1984) Figure 5.

Procedure. The procedure was the same as that described for Experiment 1.

Results

Results are collected in Tables 6 to 9. From Table 6 it appears that there are no cases of complete transparency ($\alpha < 0$). The great majority of subjects respond "non transparent". There are some cases of inversion and of partial transparency.

Table 7 ($\alpha > 1$) is characterized by a great number of invertions. As has been said, in cases of invertions α changes and therefore these are not cases where $\alpha > 1$. There are also some cases of partial transparency. Only 2 cases out of a hundred (10 displays x 10 subjects) are described as complete transparencies. These are likely to be cases of inexact descriptions. So it seems that transparency is excluded when $\alpha \neq \alpha'$ ($\alpha < 0$, $\alpha > 1$).

In Tables 8 and 9 ($t < 0$, $t > 1$) the results are completely different. Cases of non-transparency are the exception instead of the rule, and all displays give rise to some cases of transparency. In Table 8 there are three cases of non-transparency, all about the same display, which otherwise is judged as transparent by 4 subjects. Nothing different appears in Table 9 where cases of non-transparency are 6, all with regard to a display other subjects judged as transparent. The results therefore confirm Beck et al.'s thesis.

We may conclude that unbalanced transparency with t≠t' does occur. There is however some doubt that in this case unbalanced transparency with regard to color is somewhat of a hindrance, given the low number of cases of complete transparency.

DISCUSSION

In their paper, Beck et al. (1984) set forth a series of theses, some of which will be discussed in this section. Apart from theses regarding the theory, that have been discussed at the beginning, the above Authors maintain:

a) that if figural cues strongly suggest transparency, contradicting indications of the intensity conditions can be overcome (Beck et al., 1984, p. 411-412, 421). This point is contradicted by the results of our experiments. In particular, the results of Experiment 4 demonstrate that when, besides figural conditions, motion also favors transparency, transparency is not perceived if intensity conditions are against it.

b) Figural conditions affect the frequency of transparency (Beck et al., 1984, p. 411-412). Our experiments confirm this thesis, demonstrating the strong difference between results of Experiment 1, where figural conditions did not suggest transparency, and Experiments 3 and 4, where displays suggested transparency.

c) Figural conditions are primary (Beck et al., 1984, p. 412, 421), that is they are a necessary cue for perceiving transparency. The results of Experiment 1, and 2 where this cue is not present, proves that this thesis is not supported by facts.

d) When two different "versions" of transparency are possible, the version where there is greater similarity between the two regions concurring to give rise to the transparent layer occurs more frequently (Beck et al., 1984, p. 412-414). The assertion is correct, but this fact has been known since 1960 (see Petter, 1960; Morinaga, Noguchi, and Osihi, 1962).

e) The violation of "constraints" III and IV does not hinder the perception of transparency (Beck et al., 1984, p. 421 - Exp. 2, p. 414-415). Our results confirms this thesis. According to our hypothesis this means that the visual system admits transparency when there is a different lightness in the P and Q regions.

f) While the algebraic deduction evidences the necessary condition that in partial transparency the region where transparency appears must be intermediate in reflectance between the other two regions. Beck et al. (1984, p. 418) hold that there are situations where the intermediate region is (physically) brighter than the other two regions. This occurs if two projected rectangles of light are partially superimposed. However, it has yet to be verified whether transparency is perceived in this case. Beck et al. give as an example two figures (1984, Figures 7 a and 7 b). But Figure 7 a, where the majority of subjects perceived transparency, is a case of complete, not partial transparency (the white paper is also seen through transparency[7]) and only 6 out of 26 subjects judged Figure 7 b transparent, which is at odds with Beck et al.'s ~~therefore have so far failed to prove their~~ assertion.

g) According to Beck et al. (1984, p. 418) the equation $\alpha = (p-q)/(a-b)$ is not valid without further restrictions because, for $\alpha=1$, only when $p=a$ and $q=b$ there is maximum transparency, while in the other cases, when only the differences $(p-q)$ and $(a-b)$ are equal, only low transparency is perceived. But the above Authors did notice that only in the first case, when $p=a$ and $q=b$, is there balanced transparency (see Remondino, 1975), while in the other cases, where transparency is unbalanced, the formula is inadmissible because non deducible.

h) Beck et al. (1984, Exp. 3, p. 416-417) refer to a case of partial transparency where they asked the subjects to estimate the degree of transparency. While α's formula gives a result rather far from the average estimate, when the values of the estimated lightnesses are substituted in the above formula, they obtain a prediction which is very close to the estimated value of transparency. Substitution of reflectances with estimated values seems to be an arbitrary procedure, which however Beck et al. attempt to justify. In a preceeding paper (Metelli, 1982), the senior author of this paper, accepted the proposal that transparency is directly related to lightness instead of reflectance, and presented a formal deduction of the formula with lightness values.

i) The results obtained by Beck et al. (1984, Exp. 4, p. 418-421) using lightness values in predicting complete transparency [are not clear-cut] ~~constitute a failure~~. In Table 6 the Authors present 28 cases of transparency where they appear to have substituted lightness estimates for reflectances. Only 8 cases refer to balanced transparency with a correlation of .62 between estimation and prediction whereas, when they use all the data (balanced and unbalanced transparency) a much lower correlation (.28) is obtained. ~~Clearly, the results do not confirm expectations.~~ The above Authors use also another formula with results of the same order. Therefore, according to the above Authors, unlike the case with partial transparency, in complete transparency the α formula does not predict the degree of transparency. Our results, on the other hand, suggest cautious optimism.

In a research to be published shortly by Da Pos, Cavedon, and Izzinoso (1985), the relation between estimated and predicted transparency is studied. Experiments were done only in conditions of complete balanced transparency, using episcotisters. Expert subjects were presented with different situations of transparency, where the two colors of the ground, the color of the transparent layer and the degree of physical transparency were changed. The task of the subjects was to give a direct evaluation using numbers from 0 to 100 of the degree of transparency in every situation. These estimates were compared with the corresponding predictions of transparency obtained from the model formally deduced by Metelli, where Munsell values were used instead of reflectances.

Eight situations characterized by different combinations of ground (A and B) and color of the transparent layer (T) were considered. For every situation eight episcotisters of different degree of physical transparency were used. In Table ~~10~~ 9, $r_{\varepsilon\alpha^*}$, the correlation between experimental data, ε, and teoretical predictions, α^*, are presented. Also values of n (intercept) and m (slope) of the regression straight line are given.

As can be seen, the results appear to provide a very satisfactory confirmation of the theoretical model proposed by Metelli.

GENERAL DISCUSSION

As a conclusion of their paper, Beck et al. (1984) maintain that the perception of transparency is a function of stimulus information indicating that the overlaying surface is not opaque but transparent. We cannot accept this assertion because in our experiments transparency is perceived in stimulus-situations devoid of any information in this sense.

Notwithstanding the results of Beck et al.'s Experiment 3 and Da Pos et al.'s (1985) results with estimation of transparency, the scission notion would still seem to offer an adequate description of the process of transparency, even if scission took place at a higher level.

The most interesting result of Beck et al.'s study seems to be that transparency takes place in the form of non balanced transparency with regard to color

(Beck et al., 1984, p. 408, 421)—that is, when two regions of the transparent layer differ with regard to color—and not when two regions of the transparent layer ought to show a difference in the degree of transparency. This is the meaning of the assertion that, while the "constraints" regarding the degree of transparency, α, hold, "constraints" regarding color, t, can be violated without transparecy being hindered. We see no reason for asserting that "constraints" III and IV are based on the physical variable of luminance or reflectance (Beck et al., 1984, p. 421), as if "constraints" I and II were not. All four "constraints" can be expressed in terms of physical or psychological variables, according to the data used in the respective formulas.

There is no doubt that transparency also depends on figural as well as chromatic or intensity conditions. But for reasons indicated above we cannot agree with the above Authors when they assert that figural conditions are primary, namely that they are essential to perceive transparency. In fact, we proved that transparency is also perceived in cases where no figural conditions act in favor of transparency. But obviously transparency is more likely to be perceived when favored by figural conditions. However, figural conditions never become coercive. Indeed, in our experiments with displays illustrated by Figure 6, where transparency is favored by motion, there are displays which, notwithstanding the interfigural apparent motion of the two partially superimposed circles, do not give rise to the perception of transparency. The paradoxical case observed by Metzger (1955) does not occur when, in place of color differences, there are differences of intensity.

To assert that the phenomenon consists in encoding a color in the color of an opaque surface and in that of a transparent surface (Beck et al., 1984) means, in other words, that chromatic scission takes place. If on the other hand coding is intended as an intellectual activity, then the old hypothesis of unconscious judgments is revived, a hypothesis that we consider inacceptable.

Beck et al. (1984, p. 422) speak of necessary sensory support to this intellectual activity. But, while it is quite clear that we see red and yellow in orange, and red and blue in purple, ~~they forgot that~~ in their experiments with different shades of gray, we do not see white and black in gray. As for other supports, such as highlights, border contrast, color at the bounderies, or flecks of the non transparent color, they are only accidental factors, whereas the theory must take into account only necessary conditions.

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NOTES

1. Only achromatic colors are considered in this paper (white-gray-black) which can be described by only one number, the reflectance, which is the proportion of light reflected by a gray surface of a given shade.

2. Capital letters indicate regions, and small letters indicate the respective reflectances.

3. The above symbols (ABPQ) used in the preceeding papers (Metelli, 1970, 1974 a, 1974 b, 1975, 1982) have been changed by Beck et al. (1984) into ABDC. But we stick to our symbols for clarity. P and Q are the regions where transparency takes, or could take, place, while A and B are the background colors. P is the region where A is seen through transparency and Q is the region through which B is seen.

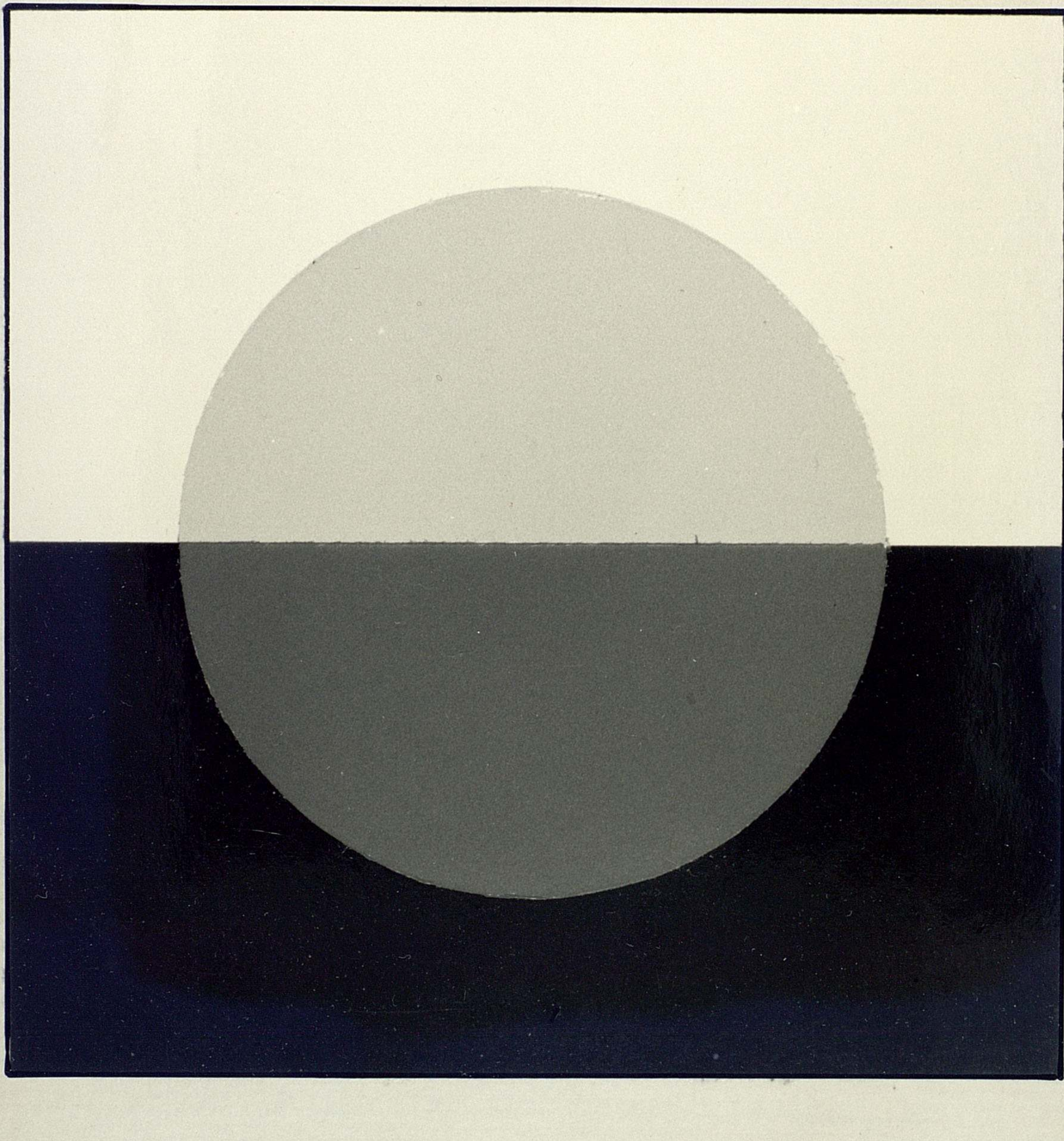
4. Because α is the lacking sector of the episcotister, and t is the color of the episcotister.

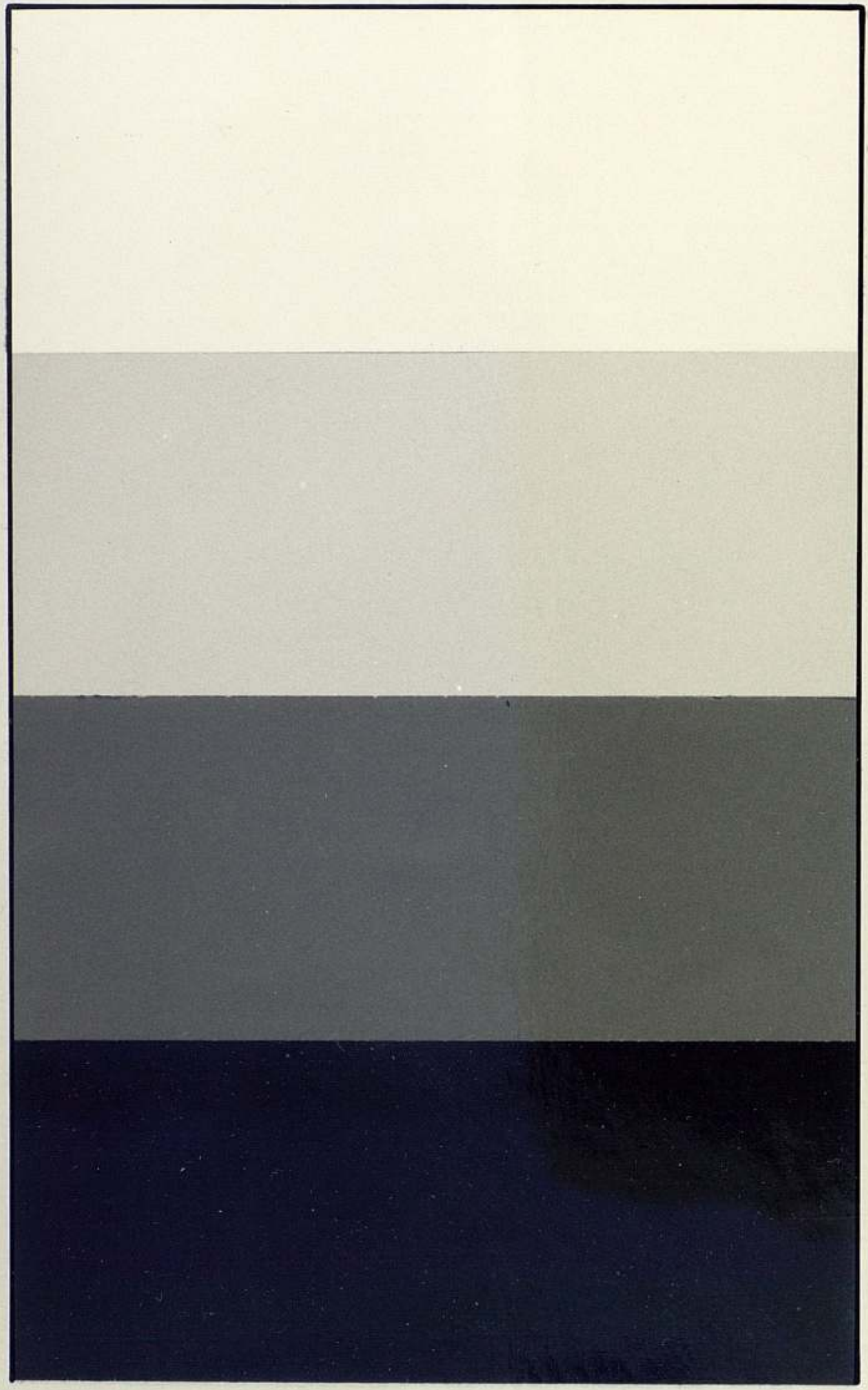
5. If $\alpha>1$, then $(1-\alpha)<0$. In this case, as in the case of $\alpha<0$, it appears from Equations 1 and 2 that either the transparent region or the region seen through transparency receives a negative quantity of color, which is devoid of meaning. Since t is a reflectance, $t>1$ or $t<0$ means

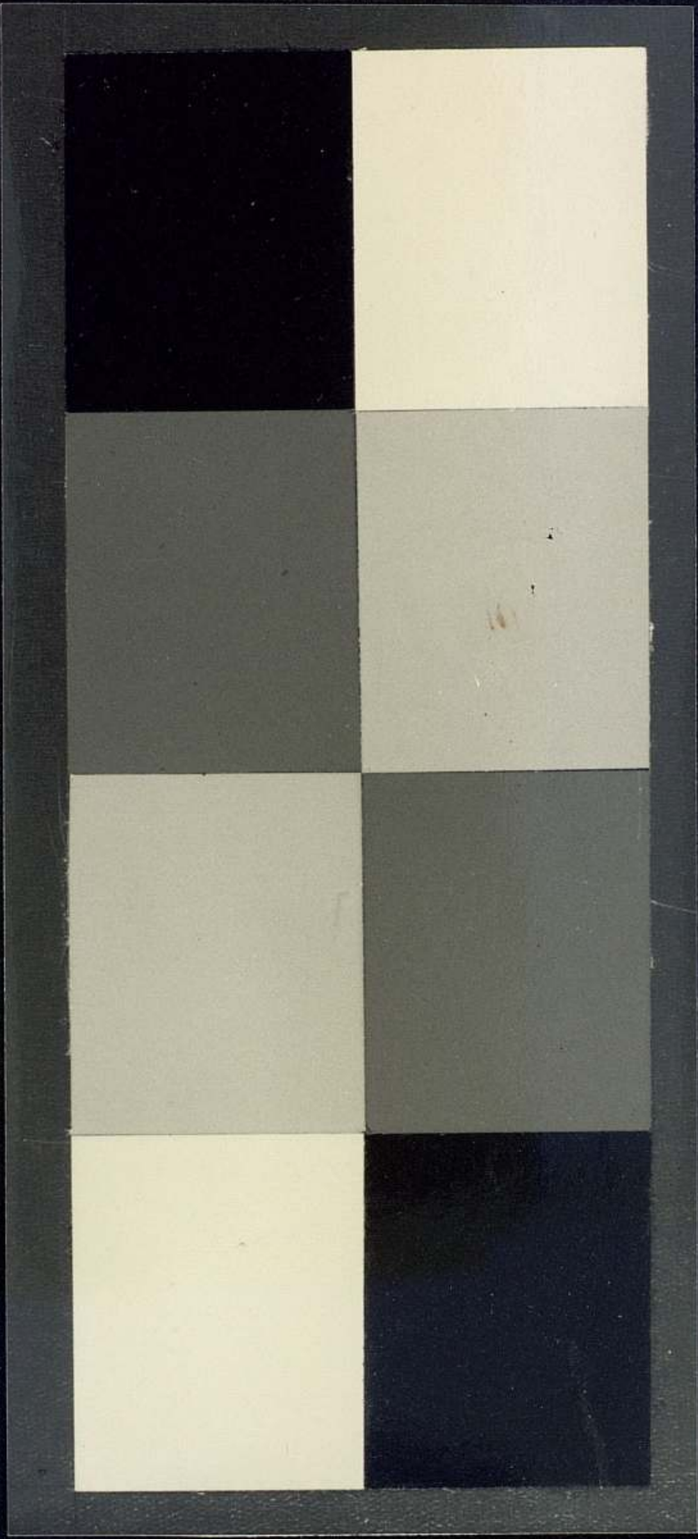
that a region would reflect or absorb more light than the quantity falling on it, which is equally absurd.

6. The task of Beck et al.'s subjects was to declare "non transparent" all cases of transparency (partial, inverse) except those localized in the QP regions (see Figure 5).

7. In this case, the color of the darker superimposed region is not intermediate between the two adjacent regions, but is intermediate between the ground and the transparent layer, whose color is not physically represented.







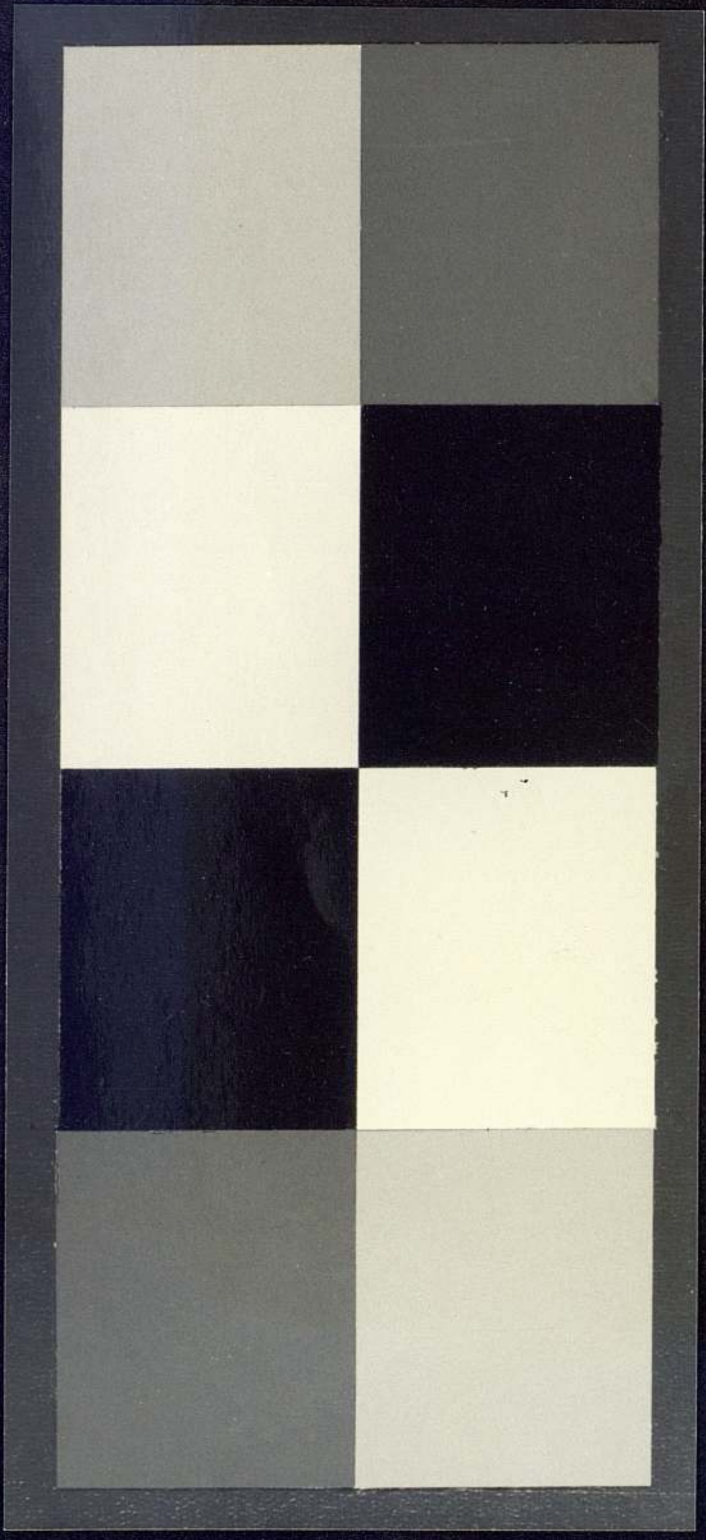


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FIG. 1 - 3a - 4a - 4b - 4c

NOTES

1. Only achromatic colors are considered in this paper (white-gray-black) which can be described by only one number, the reflectance, which is the proportion of light reflected by a gray surface of a given shade.

2. Capital letters indicate regions, and small letters indicate the respective relfectances.

3. The above symbols (ABPQ) used in the preceeding papers (Metelli, 1970, 1974a, 1974b, 1975, 1982) have been changed by Beck et al. (1984) into ABCD. But we stick to our symbols for clarity. P and Q are the regions where transparency takes, or could take, place, while A and B are the background colors. P is the region where A is seen through transparency and Q is the region through which B is seen.

4. In fact, Beck and al. found that unbalanced transparency about color ($t \neq t'$) is quite common, a result which has been confirmed by our experiments.

5. If $\alpha > 1$, then $(1-\alpha) < 0$. In this case, as in the case of $\alpha < 0$, it appears from Equations 1 and 2 that either the transparent region or the region seen through transparency receives a negative quantity of color, which is devoid of meaning. Since t is a reflectance, $t > 1$ or $t < 0$ means that a region would reflect or absorb more light than the quantity falling on it, which is equally absurd.

2

NOTES

1. Only achromatic colors are considered in this paper (white-gray-black) which can be described by only one number, the reflectance, which is the proportion of light reflected by a gray surface of a given shade.

2. Capital letters indicate regions, and small letters indicate the respective reflectances.

3. The above symbols (ABPQ) used in the preceeding papers (Metelli, 1970, 1974 a, 1974 b, 1975, 1982) have been changed by Beck et al. (1984) into ABDC. But we stick to our symbols for clarity. P and Q are the regions where transparency takes, or could take, place, while A and B are the background colors. P is the region where A is seen through transparency and Q is the region through which B is seen.

Experienced subjects (4) vedi foglio. In fact, Beck and al. found that cases of unbalanced transparency about color ($t \neq t'$) were quite common, a result which has been confirmed by our experiments

5 Unbalanced

4. Because α is the lacking sector of the episcotister, and t is the color of the episcotister.

5. If $\alpha > 1$, then $(1-\alpha) < 0$. In this case, as in the case of $\alpha < 0$, it appears from Equations 1 and 2 that either the transparent region or the region seen through transparency receives a negative quantity of color, which is devoid of meaning. Since t is a reflectance, $t > 1$ or $t < 0$ means

6. (Naive subjects

7. (minimization

that a region would reflect or absorb more light than the quantity falling on it, which is equally absurd.

8. The task of Beck et al.'s subjects was to declare "non transparent" all cases of transparency (partial, inverse) except those localized in the QP regions (see Figure 5).

7. In this case, the color of the darker superimposed region is not intermediate between the two adjacent regions, but is intermediate between the ground and the transparent layer, whose color is not physically represented.

(7) (7) However it has to be stressed that we never ~~that we never~~ intended to minimize the importance of figural con= ditions.

Here we used neutral figural conditions, but there are several necessary figural conditions(Metelli 1975, 1985). Our intention was only to show that figural cues are not necessary in order to perceive transparency.

~~However,~~ in this case it ~~would~~ have been better to use a group of naive subjects ~~also~~; but probably the dif= ference with the above results would not be crucial, be= cause naive subjects have to be pre-trained in order to teach them the task (see Beck p.409).

(6) (6) The above explanations are, ~~at~~ our opinion, ~~justified~~ sufficient to justified the use of expert subjects in this research. But there are other reasons speaking for the use of expert subjects in experimentation in perception, where phenomenological description is re= quired."Naive"subjects are by no means naive because, as they are asked to give a phenomenological descip= tion, they ~~already have, orconstruct~~ their interpre= tation or opinion about the phenomenon which is stu= died, and interpret instead of describing.

Phenomenological description is a difficult task, and only expert subjects are able to resist to temptation to say what they think, instead of saying what they see, or in general perceive.

(4) In fact, Beck and al found that unbalanced transpa= rency about color (t ≠ t') ~~are~~ quite common, a result which has been confirmed by our experiments.

However the concept of balanced transparency, clearly defined when referred already to physical measures (reflectances) could be interpreted differently if referred to perceptual measures, that is to estimations of lighness.

The first one who considered the possibity of predicting perceptual transparency starting from the perceptual estimations instead of from reflectancies was BECK (personal communication, 1980). The next step should have been the deduction of a new theory. BECK simply used the equation $p = \alpha a + (1-\alpha) b$ (which had been deduced for physical measures) with perceptual measures, i.e. estimations of lightness (giving however theoretical justifications). This was an arbitrary procedure, but the result was an excellent prediction of perceived estimated transparency.

The reason of this success was explained when the senior author of this paper deduced the equations for predicting the measure of perceived estimated transparency starting from estimated lightness of the surfaces involved in the phenomenon: the equations were formally identical to the equations which had been deduced for physical measures. So BECK's happy intuition was confirmed by the theory.

However the theory not only predicts the perceptual measure of partial transparency (the case of BECK's prediction) but also the perceptual measure of complete balanced transparency. And here our results seem to be quite different from BECK's and al (see BECK's and al p. 420-421 and point h of Discussion in the present paper)

Our conclusion is that, nowthstanding the formal equality of the equations, there are two different theories, one valid when we are working with reflectances, and the other when we are working with estimations of lightness.

NOTES ON TABLES.

1. CT= complete transparency; PT= partial transparency. Purpose of the experiment was to show that transparency is perceived even when there are no figural conditions favourable to transparency.

2. The purpose of the experiment was the same as in experiment 1. In this case, although there are no figural conditions favourable to transparency, there are very evident and constant impressions of transparency.

3. CIT= complete inverted transparency; CT= complete transparency; PT= partial transparency. The experiment was a repetition of Beck and coll.'s experiment 1, set 1. The purpose was to see if with experienced subjects more constant results are obtained. The hypothesis is confirmed: in cases of non-transparency subjects were very often unanimous.

4. CIT= complete inverted transparency; CT= complete transparency; PT= partial transparency. To the favourable conditions in experiment 3 apparent motion of the figure upon the ground is added. Notwithstanding the very favourable conditions there are several situations where subjects do not see transparency.

5. CIT= complete inverted transparency; NT= non-transparent; PT= partial transparency. With $\alpha<0$, $\alpha\neq\alpha'$. In this case results are generally negative, i.e. transparency is not perceived.

6. PT= partial transparency; TG= transparent ground. With $\alpha>1$, $\alpha\neq\alpha'$. Results are generally negative, i.e. transparency is not perceived.

7. CIT= complete inverted transparency; CT= complete transparency; NT= non-transparent; PT= partial transparency; TG= transparent ground. With $t<0$ ($t \neq t'$) while $\alpha=\alpha'$, unbalanced transparency is not uncommon.

8. CIT= complete inverted transparency; CT= complete transparency; PT= partial transparency; TG= transparent ground. With $t>1$ ($t \neq t'$) while $\alpha=\alpha'$, unbalanced transparency is not uncommon. Beck and coll.'s hypothesis is confirmed.

9. Results of experiments bY O.Da Pos, A.Cavedon and F.Izzinoso. a,b = colors of the ground; t = color of the episcotister; $r_{\varepsilon\alpha^*}$ = correlation between estimated (ε) and calculated (α^*) degree of transparency; n = intercept, m = slope of the regression line. The degree of transparency was calculated with α^* formula, using Munsell Values. Since the correlation is close to 1 and the values of the intercept and of the slope are negligible, it seems to be possible to predict the estimated transparency from the formula : $\alpha^* = (p^*-q^*)/(a^*-b^*)$, where p^* q^* a^* b^* are Munsell Values instead of reflectances.

TABLE 1

Experiment 1.

Displays	Order of reflectances	TRANSPARENCY complete	TRANSPARENCY partial	Non Transparent	Double Response Description	α	t
1	bqpa	8	(+2)	-	$2<^{CT}_{PT}$	.31	.4
2	baqp	1	7 (+1)	-	$1<^{CT}_{PT}$	1.08	-2.53
3	bqap	1	7	-	-	1.04	-2.53
4	qbpa	-	8	-	-	1.04	-2.53
5	qpba	-	2	6	-	.96	-2.53
6	bpaq	1	3	4	-	-1.08	.4
7	bpqa	-	1	7	-	- .31	.41
8	pbqa	-	2	6	-	- .96	.41
9	pabq	1	3	4	-	3.27	.4
10	qabp	-	-	8	-	-3.27	.4
11	bapq	1	7 (+1)	-	$1<^{CT}_{PT}$	-1.08	.4
12	pqab	1	7	-	-	- .92	.4

TABLE 2

Experiment 2.

Displays Order of reflectance		Complete Transparency a	b	c	Partial Transparency	Non Transparent
1	bqpa apqb	10	-	-	-	-
2	baqp abpq	3	1	-	6	-
3	bqap apbq	3	1	1	5	-
4	qbpa paqb	8	-	-	2	-
5	qpba pqab	5	-	-	5	-
6	bpaq aqbp	-	-	-	-	10
7	bpqa qapb	5	-	-	-	5
8	pbqa qapb	-	-	-	-	10
9	pabq qbap	-	10	-	-	-
10	qabp pbaq	-	3	-	1	6
11	bapq abqp	-	-	10	-	-
12	pqab pqba	-	-	10	-	-

TABLE 3
Experiment 3.

Displays Order of reflectances	T R A N S P A R E N C Y			Non Transparent	Double Response Description	Complete Transparency (BECK)	α	t
	complete	complete inverted	partial					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 abpq	6	2 (+5)	2 (+1)	-	$5<^{CT}_{CIT}$ $1<^{CIT}_{PT}$	15	1.08	-2.53
2 apbq	5	3 (+4)	2 (+1)	-	$4<^{CT}_{CIT}$ $1<^{CIT}_{PT}$	18	1.05	-2.53
3 apqb	10	-	(+1)	-	$1<^{CT}_{PT}$	18	.31	.4
4 baqp	3	4 (+1)	3 (+3)	-	$1<^{CT}_{CIT}$ $3<^{CIT}_{PT}$	18	-1.08	.4
5 bqap	7	1 (+2)	2 (+1)	-	$2<^{CT}_{CIT}$ $1<^{CIT}_{PT}$	21	1.04	-2.53
6 bqpa	10	(+1)	(+1)	-	$1<^{CT}_{CIT}$ $1<^{CIT}_{PT}$	21	.31	.4
7 qbpa	7	2 (+5)	1	-	$5<^{CT}_{CIT}$	21	.06	-2.53
8 qpba	8	1 (+4)	1 (+2)	-	$4<^{CT}_{CIT}$ $2<^{CIT}_{PT}$	18	.92	-2.53
9 paqb	4	3 (+2)	3 (+1)	-	$2<^{CT}_{CIT}$ $1<^{CIT}_{PT}$	18	.96	-2.53
10 pqab	6	1 (+4)	3 (+1)	-	$4<^{CT}_{CIT}$ $1<^{CT}_{PT}$	17	.92	-2.53

continuation of table 3.

11	aqbp	–	1	–	9	–	1	-1.04	.41
12	aqpb	–	–	–	10	–	2	- .31	.41
13	bpqa	–	–	1	9	–	–	-1.04	.41
14	bpqa	–	–	–	10	–	–	- .31	.41
15	qapb	–	–	–	10	–	–	- .96	.41
16	pbqa	–	–	–	10	–	1	- .96	.41
17	qbap	–	1	3	6	–	–	3.27	.4
18	pabq	–	–	4	6	–	1	3.27	.4
19	qabp	–	–	–	10	–	–	-3.27	.41
20	pbaq	–	–	–	10	–	–	-3.27	.41
21	abqp	–	9	1 (+2)	–	2< CIT / CT	3	-1.08	.4
22	bapq	–	–	4	6	–	6	-1.83	.4
23	qpab	–	–	5	5	–	13	- .92	.4
24	pqba	–	9	1	–	–	2	- .92	.4

TABLE 4

Experiment 4.

Displays	Order of reflectances	TRANSPARENCY complete	complete inverted	partial	Non Transparent	Double Response Description	Complete Transparency (BECK)	α	t
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	abpq	5	–	4 (+2)	1	1<CT/PT 1<PT/NT	15	.92	-2.53
2	apbq	5	1	3 (+4)	–	4<CT/PT	18	.96	-2.53
3	apqb	10	–	–	–	–	18	.31	.4
4	baqp	1	1	7 (+1)	1	1<CIT/PT	18	1.69	.79
5	bqap	2	1	5 (+2)	2	1<CT/PT 1<CIT/PT	21	.96	-2.53
6	bqpa	10	–	–	–	–	21	.31	.4
7	qbpa	7	1	2 (+1)	–	1<CT/PT	21	1.04	-2.53
8	qpba	7	1	3	–	–	18	1.08	-2.53
9	paqb	1	–	9 (+1)	–	1<CT/PT	18	1.04	-2.53
10	pqab	1	–	9	–	–	17	1.08	-2.53

continuation of table 4.

11	aqbp	–	–	–	10	–	1	-.92	.4
12	aqpb	1	–	–	9	–	2	-.31	.41
13	bpaq	–	–	–	10	–	–	-.92	.4
14	bpqa	–	–	–	10	–	–	-.31	.41
15	qapb	–	–	–	10	–	–	-1.04	.41
16	pbqa	–	–	4	6	–	1	-1.04	.41
17	qbap	–	7	2	1	–	–	-3.27	.4
18	pabq	–	9	1	–	–	1	-3.27	.4
19	qabp	–	–	–	10	–	–	-3.27	.41
20	pbaq	–	–	–	10	–	–	-3.27	.41
21	abqp	–	–	10	–	–	3	-.92	.4
22	bapq	–	1	7 (+1)	2	1<CIT PT	6	-.92	.4
23	qpab	–	–	10	–	–	13	-1.08	.4
24	pqba	–	–	10	–	–	2	-1.08	.4

TABLE 5

Experiment 5: α<0 , 0<t<1

Displays	Order of reflectances	TRANSPARENCY complete	complete inverted	partial	Non Transparent	Transparent ground	Double Response Description	α	t
1	aqbp	–	–	–	10	–	–	- .67	.33
2	qabp	–	–	–	10	–	–	-1.89	.45
3	abqp	–	6	1 (+1)	3 (+1)	–	1<CIT/PT 1<CIT/NT	- .22	.2
4	qapb	–	–	2	8 (+1)	–	1<PT/NT	- .59	.37
5	qpab	–	–	1	8 (+1)	1	1<PT/NT	- .83	.47
6	aqpb	–	–	–	10	–	–	- .65	.26
7	qabp	–	–	–	10	–	–	-3.16	.6
8	abqp	–	9	1 (+1)	–	–	1<CIT/PT	- .63	.36
9	aqbp	–	–	–	10	–	–	-1.50	.58
10	qapb	–	–	1	9	–	–	- .83	.71

TABLE 6

Experiment 5 : $\alpha>1$, $0<t<1$

Displays Order of reflectances		TRANSPARENCY complete	complete inverted	partial	Non Transparent	Transparent ground	Double Response Description	α	t
11	pabq	–	2	4	2	2 (+1)	1<PT/TG	1.67	.34
12	pabq	–	–	5	3	2 (+1)	1<PT/TG	2.06	.32
13	paqb	–	3	6 (+2)	1	–	2<CT/PT	1.39	.15
14	paqb	1	(+1)	9	–	(+2)	1<CT/CIT 2<PT/TG	2.87	.06
15	paqb	–	–	5	3	2 (+3)	3<PT/TG	1.59	.2
16	pabq	–	2	7	–	1 (+2)	2<PT/TG	1.76	.04
17	paqb	–	1	5	2	2 (+1)	1<PT/TG	3.17	.71
18	pabq	1	–	8	1	(+1)	1<PT/TG	1.71	.89
19	apbq	–	1	3	4	2 (+1)	1<PT/TG	1.71	.6
21	pabq	–	–	4	5	1	–	2.21	.9

TABLE 7

Experiment 5 : $0<\alpha<1$, $t>1$

Displays Order of reflectances		TRANSPARENCY complete	complete inverted	partial	Non Transparent	Transparent ground	Double Response Description		α	t
21	paqb	1	1	8 (+1)	-	(+1)	1<CIT/PT	1<NT/TG	.83	1.61
22	pqab	4	(+1)	6 (+1)	-	-	-		.56	1.22
23	qbpa	4	1 (+3)	2 (+1)	3	-	3<CT/CIT	1<CT/PT	.97	5.91
24	qbpa	6	2 (+2)	2 (+3)	-	-	2<CT/CIT	3<CT/PT	.90	1.56
25	pqab	-	-	10	-	-	-		.59	1.27
26	pqab	2	-	7	1	(+2)	1<PT/TG	1<NT/TG	.72	1.38
27	pqab	1	-	8 (+1)	1	-	1<CIT/PT		.38	1.16
28	paqb	6	(+1)	4 (+2)	-	-	1<CT/CIT	2<CT/PT	.89	1.31
29	paqb	2	(+1)	8	-	(+1)	1<CT/CIT	1<PT/GT	.83	1.5
30	paqb	4	(+1)	6 (+1)	-	-	1<CT/CIT	1<CT/PT	.89	1.31

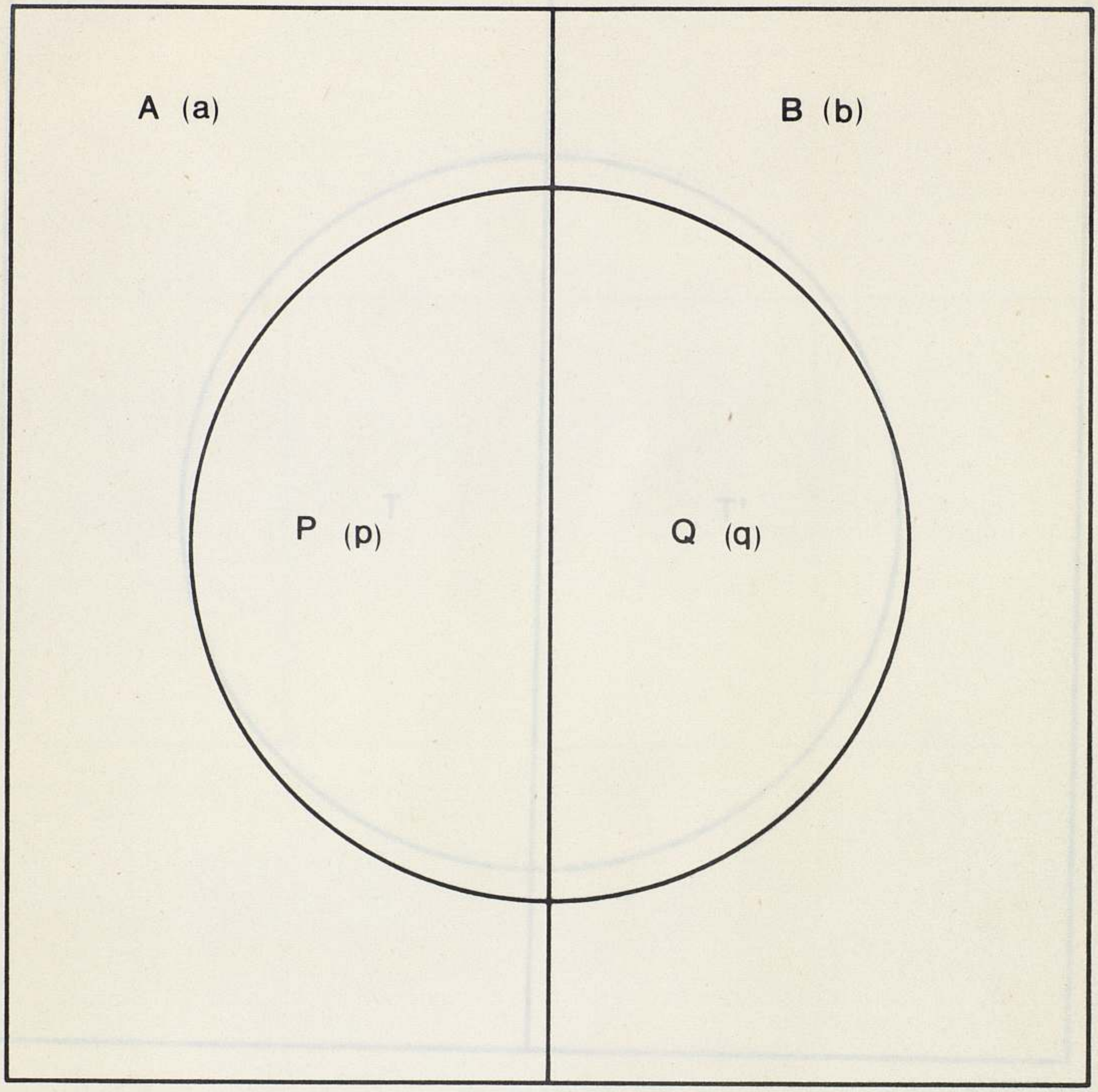
TABLE 8

Experiment 5 : $0<\alpha<1$, $t<0$

Displays Order of reflectances		TRANSPARENCY complete	complete inverted	partial	Non Transparent	Transparent ground	Double Response Description	α	t
31	apbq	3	(+3)	7	–	–	3< CT / CIT	.81	-.64
32	apbq	1	–	9 (+1)	–	–	1< CT / PT	.88	-.05
33	abpq	1	(+1)	8	1	–	1< CT / CIT	.36	-.04
34	apbq	3	(+2)	6	1	–	2< CT / CIT	.69	-.05
35	abpq	2	(+2)	7	1	–	2< CT / CIT	.52	-.48
36	abpq	1	1 (+1)	5 (+1)	3	–	1< CT / CIT 1< CIT / PT	.25	-.04
37	abpq	1	(+1)	9	–	–	1< CT / CIT	.68	-.9
38	abpq	4	(+4)	6	–	–	4< CT / CIT	.96	-.64
39	abpq	6	(+5)	4 (+1)	–	–	5< CT / CIT 1< CT / PT	.64	-.38
40	abpq	1	(+1)	9	–	(+1)	1< CT / CIT 1< PT / TG	.49	-.41

TABLE 9

	1 a=dark grey b=black t=white	2 a=medium g. b=dark g. t=white	3 a=medium g. b=dark g. t=black	4 a=white b=light g. t=black	5 a=white b=black t=dark g.	6 a=white b=light g. t=dark g.	7 a= medium g b= dark g. t= light g.	8 a=white b=medium g. t=light g.
r_{ε,α^*}	.92	.99	.95	.96	.94	.97	.95	.96
n	-.07	-.06	-.18	-.2	.14	0	.02	.06
m	1.22	1.11	1.09	1.1	.93	.98	.99	.93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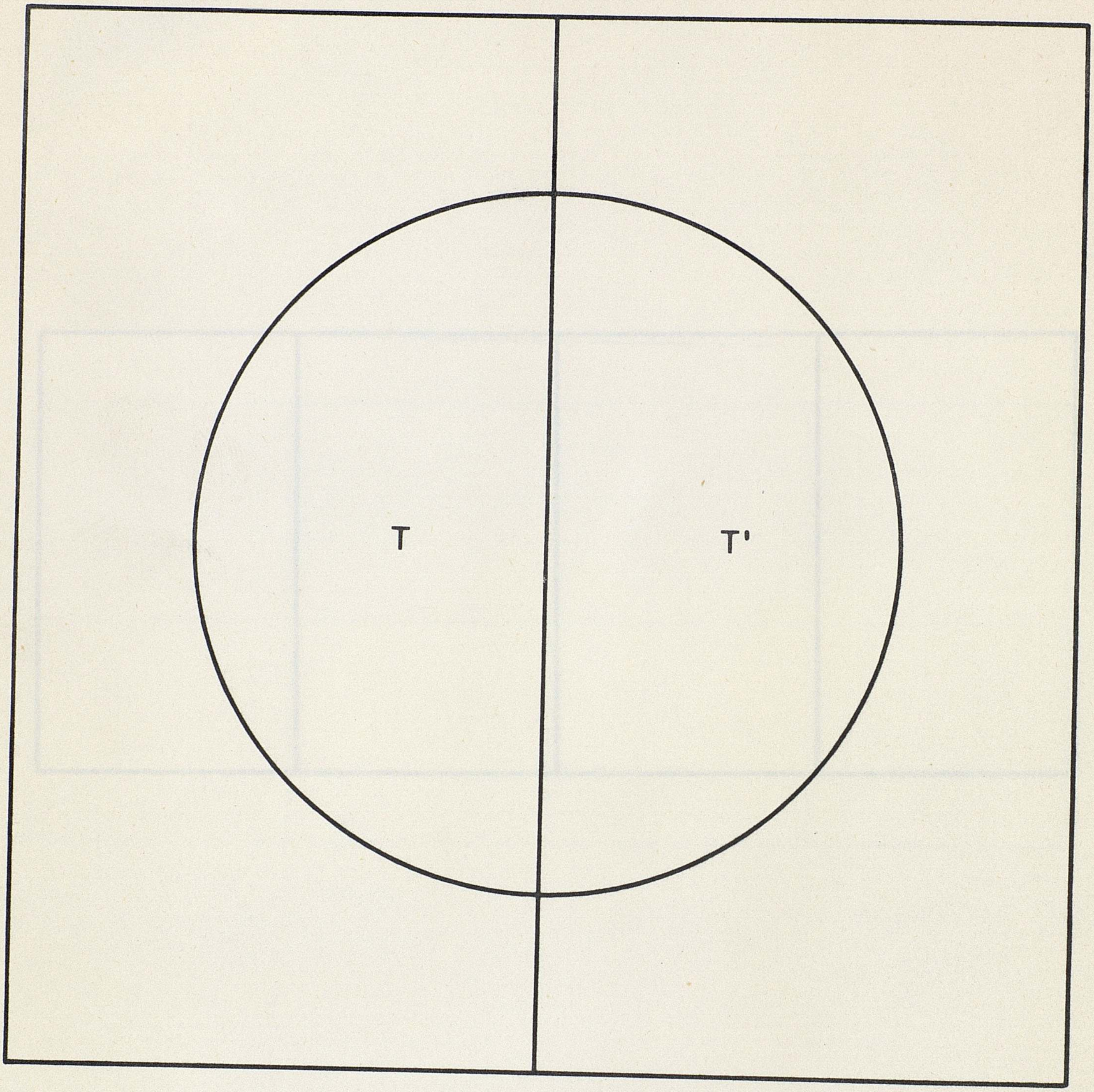
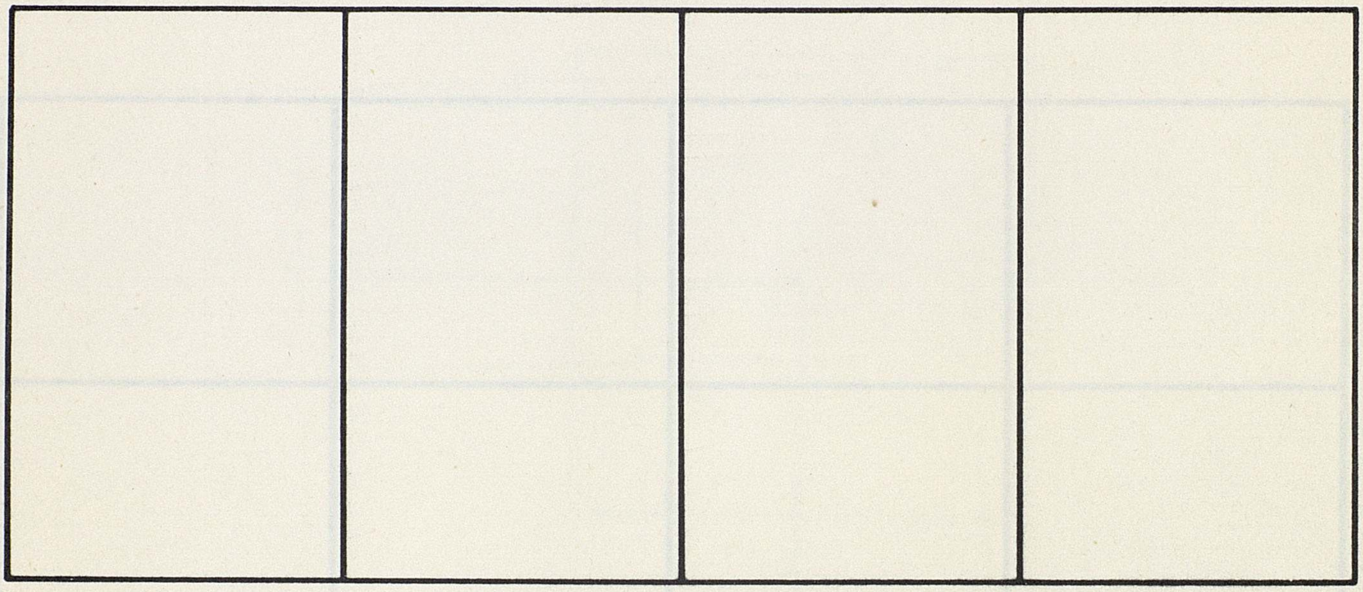
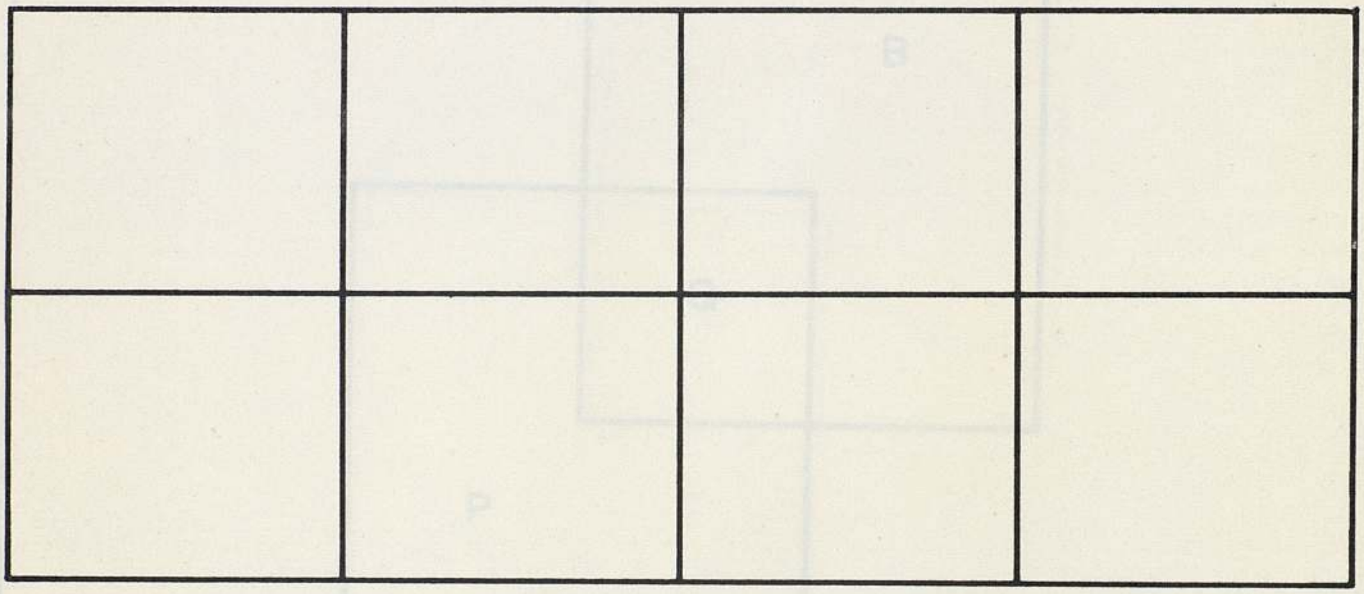
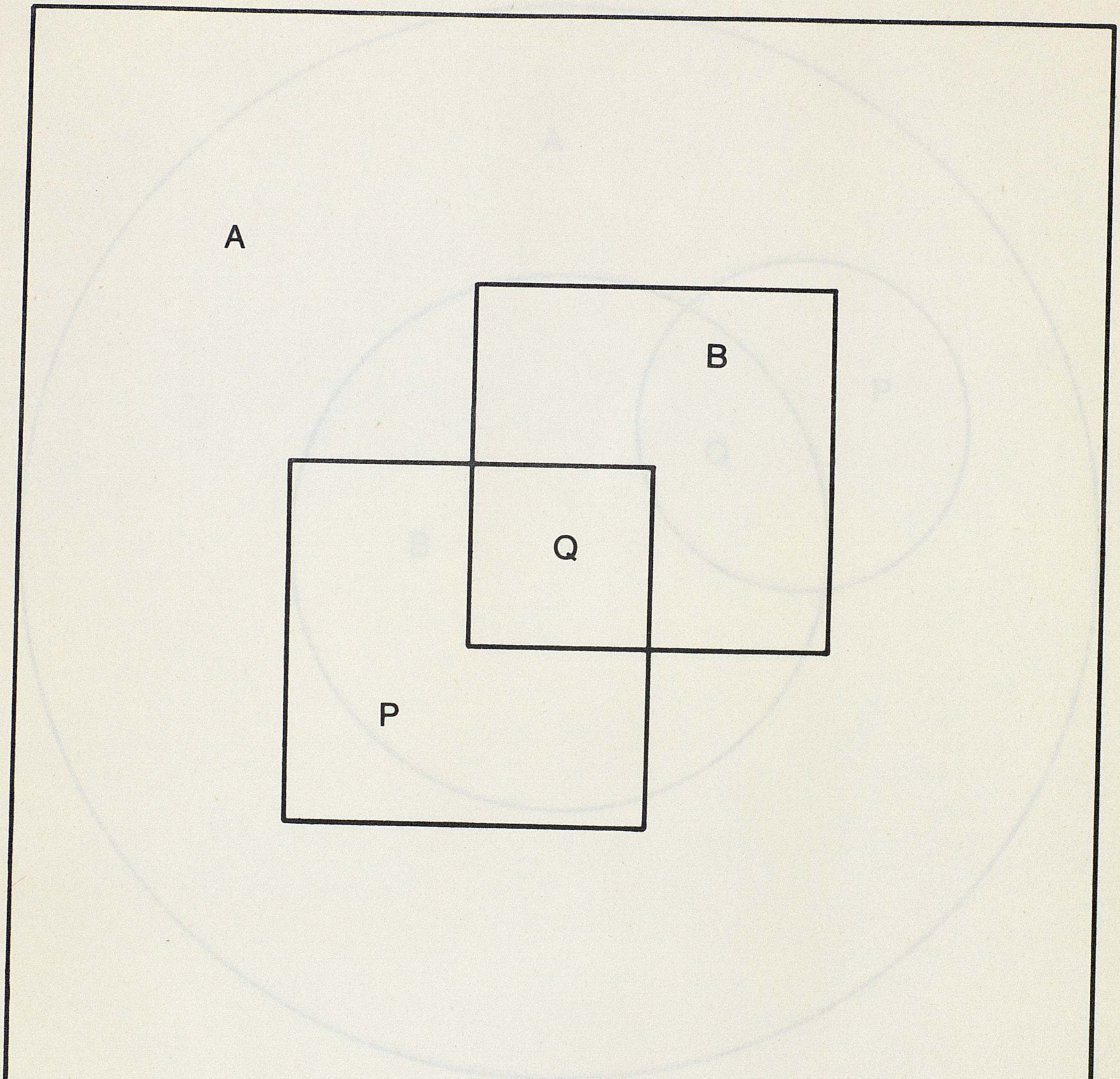
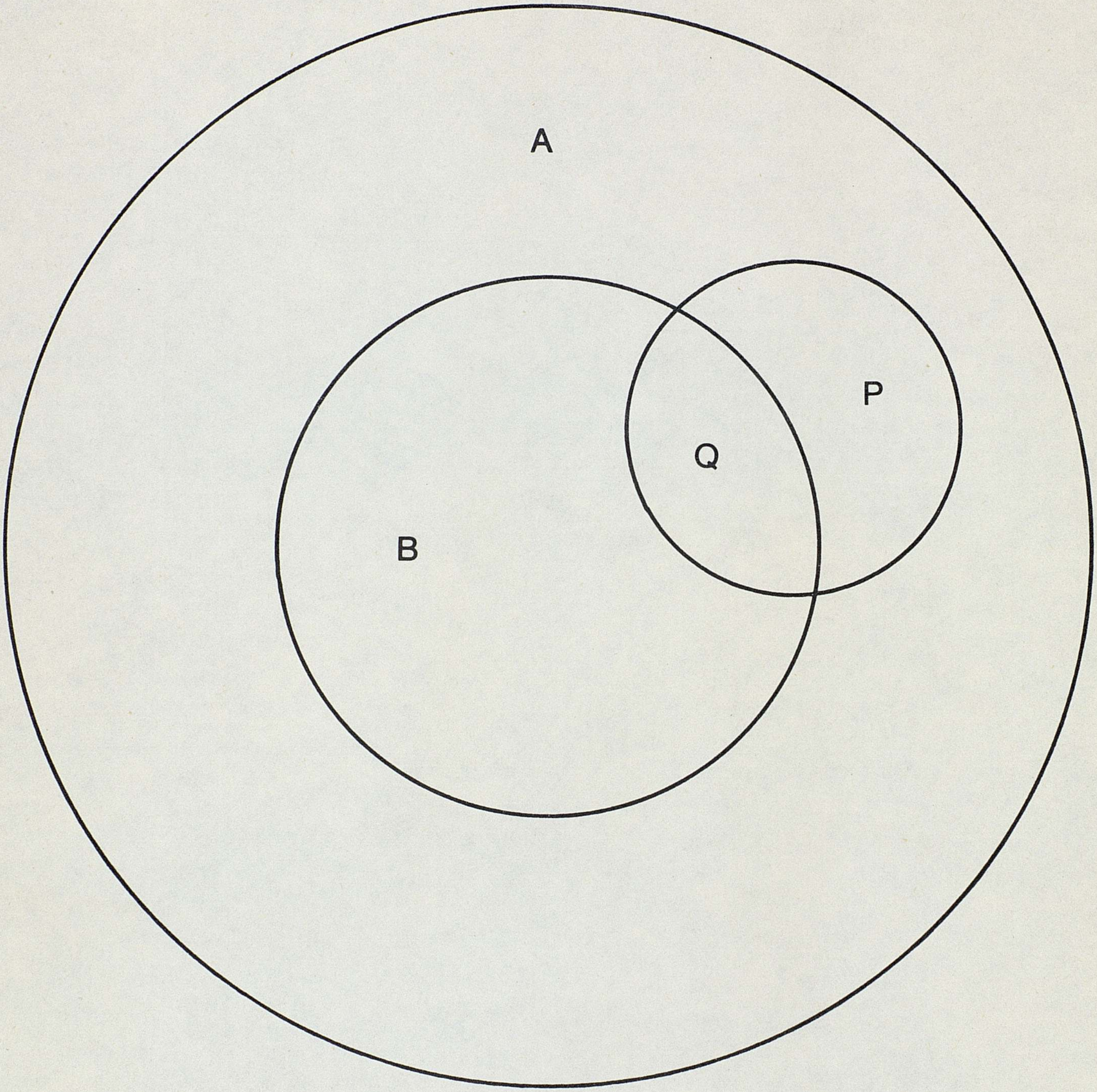
B (b)
P (p)
Q (q)


T
T'






A
B
Q
P


A
P
Q
B

Non balanced transparency is characterized by the fact that transparency is not perceived as uniform, but as ~~more~~ some regions of a display are perceived as more transparent than other regions of the same display. This effect may be imposed by the stimulus conditions which not allow that the transparent layer be uniform in the degree of transparency and/or in the color of the transparent layer, but it is also possible that non balanced transparency be perceived when objective conditions allow the perception of balanced transparency if the task given to the subjects favour an analytical attitude.

The above phenomenon is important, because it explains, till a certain point, the difficulties encountered in trying to measure, with the method of paired comparison, the degree of transparency perceived in a series of displays. ~~Analyzing the phenomenon through~~ From an experimental analysis of the phenomenon it resulted that subjects, confronted by the task of comparing two figures as to the degree of transparency, when taking an analytical attitude, perceive figures as divided in two halves and consider, in making the paired comparison, only one half of each figure.

Since in this case the degree of transparency perceived in the two halves of the figure is different, ~~the~~ the judgment of two subjects taking into account, one one half and the other the other half of the figure ~~may~~ can result contradictory.

An other result of the research is that, to the contrary of what has been asserted in ~~previous~~ classical and recent research the degree of lightness of the transparent layer, measured by the t coefficient (t being the measure of its albedo), has not an univocal effect on the degree of transparency perceived by subjects, but varies with the lightness of the ground: on a dark ground, a dark transparent layer appears more transparent than a light one, while on a light ground an opposite effect takes place.

26