THE PROBLEM OF PAST EXPERIENCE IN BECK'S MODEL OF PERCEPTUAL TRANSPARENCY

S.C. Masin

The problem of perceptual transparency, i.e. of perceiving one color through another, dates back to the debate between Helmholtz (1867) and Hering (1880). The existence of a genuine perception of «seeing through» is now well established (Fuchs, 1923). As far as I know, there are only two modern theories as to the factors that give rise to such a perception. They are Metelli's (1970, 1974a, 1974b, 1975, 1978) and Beck's (1972, 1975) theory.

Fig. 1 shows four adjacent surfaces A, B, P, and Q whose reflectance is a, b, p, and q respectively. In this paper only transparency of objects having achromatic colors will be considered.

According to Metelli's theory, the perception of transparency is contingent upon the values assumed by a, b, p, and q. When transparency is perceived, in the phenomenal field only two surfaces are present: the bicolored ground and the overlying disk. Basing himself on G.M. Heider's thesis (1933), Metelli states that the color of surfaces P and Q (stimulus color) splits into two colors: that of the ground and that of the transparent layer (the disk in Fig. 1). He assumes that perceptual scission in perceptual transparency quantitatively follows the opposite of Talbot's law. Accordingly the reflectances p and q, relative to the stimulus color, are equal to

$$p = \alpha a + (1-\alpha)t, \text{ and} \quad (1)$$

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

It follows that

$$\alpha = \frac{p-q}{a-b}\,,\ (a \neq b),\ \text{and} \qquad (3)$$

$$t = \frac{aq-pb}{(a+q)-(b+p)}\,,\ (\alpha \neq 1), \qquad (4)$$

where a is the reflectance of surface A and b the reflectance of surface B. The parameters α and t (both varying between 0 and 1) are respectively the degree of transparency and the reflectance corresponding to the color of the transparent layer.

Equations (1) and (2) are said to represent the law of additive color mixture. This means that the colors corresponding to p and q are obtained whenever an episcotister is rotated in front of surfaces A and B (Fig. 1). The sectors of the episcotister have a reflectance equal to t and an overall area equal to $1-\alpha$ (in this case it is assumed that the area of the sectors varies between 0 and 1). For this reason, equations (1) and (2) are also said to be based on an episcotister model (Beck, 1978). However the (1) and (2) formulas have been deduced independently from the episcotister model, which is not the model of M's theory

Beck (1972, 1975) maintains that transparency may also occur in terms of subtractive color mixture. He (Beck, 1978) claims that the episcotister model may be replaced by a canonical filter model, which would be in accordance with the subtractive color mixture model, without altering in the least equations (1) and (2); consequently distinguishing experimentally between the two models would be impossible.

Beck argues as follows. Let the disk in Fig. 1 be an achromatic filter through which surfaces A and B are looked at. If m is the transmittance of the filter and r its reflectance, then the stimulus colors p and q are equal to

$$p = ma+r,\ \text{and} \qquad (5)$$

$$q = mb+r. \qquad (6)$$

He maintains that equations (5) and (6) are reducible to equations (1) and (2). To show this two assumptions are needed. First it is assumed that the aforementioned filter is equivalent to a canonical filter. The canonical filter is a filter made up of clear points that transmit all the incident light (as if they were tiny holes), and opaque points whose reflectance is R_0. The reflectance corresponding to clear points is a for the points on surface A and b for points on surface B.

transmittance and reflectance

Secondly, let us consider on the canonical filter a minimal area as wide e.g. a receptive field or a retinal receptor. If the receptive unities of the retina integrate the light coming from the minimal area, as Beck (1978, p. 266) proposes, then, by Talbot's law, the reflectance corresponding to its color is

$$p = ca+(1-c)R_0, \qquad (7)$$

if the filter is on surface A, and

$$q = ca+(1-c)R_0, \qquad (8)$$

if the filter is on surface B, where c is the proportion of clear points in the minimal area - or, by extension, in the entire filter - and 1-c is the proportion of opaque points.

From Beck's demonstration that equations (5) and (6) are equivalent to equations (1) and (2), as far as an achromatic filter is equivalent to a canonical filter [1], it would follow that Metelli's equations (3) and (4) describe only the cases in which the relations between the reflectances a, b, p, and q are corresponding to the superimposition of an achromatic filter on surfaces A and B (Fig. 1). In other words, equations (3) and (4) would describe only those cases of transparency that occur in everyday experience, where physically transparent objects overlap opaque objects. The sketchy theory proporsed by Beck «is that the perception of transparency depends on the visual system encoding a stimulus color as a given color plus a deviation due

Beck's brilliant idea of having recourse to a canonical filter in order to prove the identity of subtractive and additive color mixture when only achromatic colors are involved is open to criticism. From the physical point of view ~~a common filter or~~ a given canonical filter ~~can be considered~~ corresponds to a filter of equal overall transmittance. But from this point of view also an episcotister is a filter of a given transmittance to the presence of an overlapping color film, i.e., a prototypical color plus a correction (Beck, 1972)» (Beck, 1978, p. 267). Every theory of schema with correction, both relative to pattern recognition (Woodworth, 1938; Attneave, 1955, 1957; Evans, 1967) and perception (Beck, 1972, 1978), involves the notion of past experience, since a schema requires a repeated contact of the organism with the everyday environment to be formed ([2]). Beck's demonstration is tended to render his theory compatible with that of Metelli. o il contrario?

In everyday life, not only physically transparent objects overlap opaque objects but also a lot of transparent objects xhatx ixxthxx overlap other transparent objects that in turn overlap opaque objects. Since Beck's theory pertains to the cognitive approach based on the notion of schema — which implies past experience as a main determiner of pattern recognition and perception the canonical filter model must apply to these cases as well. Fig. 2 represents a bicolored ground (surfaces A and B) on which two achromatic rectangular filters are superimposed: a greater rectangular filter (GR), which determines the proximal surfaces P_1 and Q_1, and a smaller rectangular filter (SR), which determines the surfaces P_2 and Q_2.

Let the proportion of clear points of SR be c, and the reflectance of opaque points be R_0. Let the proportion of clear points of GR be c_1 and the reflectance of opaque points be R_1. Receptive unities of the retina integrate the light coming from clear points (i.e. directly from the ground), from opaque points of GR, and from opaque points of SR. ~~If e.g. GR is between the ground and SR, and from opaque opaque points of SR.~~ If e.g. GR is between the ground and SR, then according to the theory of probability, the proportion of clear points in the superimposition region (surfaces P_2 and Q_2 in Fig. 2) is now $c \cdot c_1$ ([3]).

But from a psycho-physiological point of view, things are completely different: the canonical filter gives rise to an additive color mixture exactly as the episcotister. It is therefore a truism that both processes can be described by the same formulas

In Beck's model, the degree of transparency must be (under the same conditions) a monotone function of the proportion of clear points, as it would depend on a subtractive color mixture process. Even if we do not know this function, it must be that the degree of transparency corresponding to $c \cdot c_1$ is less than that corresponding to c or c_1. Consequently, when two filters are superimposed, the superimposition region must be always less transparent, with respect to the ground underneath, than the region superimposed only on the ground (surfaces P_1 and Q_1). Yet a transparency effect newly discovered, which never seems to occur in everyday life, may be considered a counter-example that does not fit this conclusion.

An experiment was conducted using a stereoscope. Fig. 2 shows the kind of stimulus presented to the subjects. It is a model composed of six surfaces. When shown to the subject, surfaces P_1 and Q_1 are perceived as a single rectangle (greater rectangle, GR). The same for surfaces P_2 and Q_2 (smaller rectangle, SR). With respect to the bicolored ground (surfaces A and B), GR and SR were sited in the stereoscope at a different distance: SR was before GR, and both were in front of the bicolored ground. To repeate, GR was at a distance from the ground, and SR – enclosed in GR at a proximal level – was before and at a distance from GR. If only GR is present and the reflectances a, b, p_1, and q_1 (Fig. 2) are chosen in such a way that the values of α and t are included in the interval $[0,1]$, then GR is perceived as a transparent surface at a distance from the ground.

What happens when SR is also present? If the reflectances p_2 and q_2 are chosen in such a way that α for SR not inclosed by GR is less than α for GR, then the region where SR and GR superimpose (in the phenomenal field) is perceived as less transparent than the region of GR, protruding under SR, superimposed on the ground. Moreover, the degree of transparency of SR is the same as that of another comparison rectangle, on the same background, whose reflectances are the same as those of SR. That is, the phenomenal splitting of the stimulus color of the surfaces P_2 and Q_2 is not influenced (except for a slight color addition due to chromatic contrast when the difference of lightness between A and B is high) by the surfaces P_1 and Q_1 inclosing them (e.g., the splitting of the color P_1 does not influence the splitting of the color of P_2 or Q_2) (4). These results are not easy to be explained in terms of Beck's theory.

Let us now make α for SR greater than α for GR. In this case a paradoxical (5) effect ensues. Two overlapping rectangles some distance apart, and both above the ground, are perceived. But the region where they superimpose is perceived much <u>more</u> transparent than the protruding region of GR. That is, the ground is perceived much more clearly through SR, which is before GR, than through GR, which is underneath. These results seem as well to be inconsistent with Beck's view, at least as it stands now.

It is of interest to examine how the effect now reported is interpreted within the gestalt approach. In general, a gestalt is characterized by three main points: 1) the proximal stimulus conditions (as Metelli's theory is limited to achromatic colors only, in this case the conditions are the reflectances <u>a</u>, <u>b</u>, <u>p</u>, and <u>q</u> of surfaces A, B, P, and Q; or better, the retinal stimulations corresponding to these areas; cfr. Masin, 1976); 2) the internal state (since, according to the gestalt theory, there is an isomorphism between the gestalt in the physiological field and the gestalt in the phenomenal field, the internal state of the physiological gestalt is reflected in the phenomenal experience; and one axpect of the internal state is the phenomenal appearance of scission colors); 3) and the process (i.e., the mechanism or law by which the internal state is produced; in Metelli's theory of transparency the process of perceptual scission is what causes the internal state, and consequently the scission colors). The machanism or law by which a phenomenon occurs may be hypothesized when the external conditions and the internal state (the percept) are known. Now the aforementioned effect is such that the splitting of the stimulus colors relative to SR seems to be independent of GR inclosing SR (figural condition), except for the addition of a slight effect due to chromatic contrast.

Such an effect is explainable with difficulty by Beck's theory. If it is true that we learn that colors are changed by the interposition of physical filters, and that two or more overlapping filters change colors more than a sole filter; than a situation in which cues are present that permit to detect two overlapped filters should give as a result a greater color modification (and consequently a lowered transparency) than when only one filter is detected. As regards gestalt theory, the aforesaid paradox is not an obstacle (inasmuch as the theory makes no prediction as to the number of perceived filters), but introduces a problem; that is, when, how, and why a condition, that usually produces the appearance of overlapping layers, does engender as in this event the perception of superimposed surfaces through the superimposition region of which <u>only one</u> transparency color is perceived? In other words, why in this case is the phenomenal field so articulated? From the more restricted standpoint of the theory of perceptual transparency, there is no difficulty; being the splitting of p_2 and q_2 a translocal effect that crosses over, as it were, the region corresponding to GR. That is, given <u>a</u>, <u>b</u>, <u>p</u>, and <u>q</u>, α is again given by equation (3).

There are other phenomena that probably pose Beck's canonical filter model with some problem. For instance partial transparency (Metelli, 1974a, 1975), and inclompete transparency with anomalous scission (Masin, 1978). To conclude, I would like to stress that the theoretical and experimental arguments reported above must not be understood as a complete desproof of Beck's view. They only suggest that the interesting theory proposed by Beck does not explains some phenomena of perceptual transparency, and that it will do perhaps only when it will be broadened further.

Notes.

(1) It is of importance to establish what impinges the eye, XXXX i.e., which is the proximal stimulation. The results attained by Beck seems to lead to the consequence that the proximal stimulation is the same in both cases, of fusion and filtering. The reason is that fusion of two lights occurs both in the case of the canonical filter and in the case of the episcotister: the light transmitted (corresponding to a or b) and the light reflected (corresponding to t in the socalled episcotister model, and to R_0 in the canonical filter model). Thus, it remains to be established if the acting on the eye by the canonical filter is the same as that of a normal homogeneous filter. As a matter of fact, the proximal stimulation produced by an episcotister may be considered equivalent to the proximal stimulation produced by four adjacent differently colored surfaces.

(2) Here the wording «past experience» should not be understood as concerning only practice, but also in a phylogenetic sense (i.e. it is not unplausible that a schema is given innately). Beck's theory does not specify the exact mechanism by which the schema and the prototype are formed.

(3) The proportion of opaque points pertaining to GR is $c\cdot(1-c_1)$, and the proportion of opaque points pertaining to SR is $(1-c)(1-c_1)+c_1(1-c)=1-c$. Consequently, the reflectance corresponding to the stimulus color relative to the superimposition region is

$$p_2=cc_1a+(1-c)R_0+c(1-c_1)R_1, \qquad (9)$$

if the superimposition region is on surface A, and

$$q_2=cc_1b+(1-c)R_0+c(1-c_1)R_1, \qquad (10)$$

if the superimposition region is on surface B.

Beck's argument, which we XXXXXX referred to above, does not touch in the least the question whether Metelli's equations describe correctly transparency phenomena. Accordingly, there is also no hint in Beck's argument on the basis of which to say that the equations derived from the canonical filter model describe correctly or incorrectly transparency phenomena. That is, we cannot say that XXXXXXXX equations (9) and (10) express Beck's theory because he never told us that equations (7) and (8), also based on the canonical filter model, should be considered as the right equations about perceptual transparency. In spite of this, equations (9) and (10) seem to imply a conclusion of great moment for Beck's theory.

(4) The effect has also other interesting aspects but they are in a way accessory to the argument of this paper, which is primarily theoretical. A research is in progress in which it is studied extensively together with akin phenomena (e.g., cfr. Metelli, 1967).

(5) As much as our expectation as to the perceptual result is based on our knowledge about the behavior of physically transparent objects in the everyday environment.

References.

F. ATTNEAVE, Effect of familiarization with a class prototype on identification of shapes. American Psychologist, 1955, 10, 400-401.

F. ATTNEAVE, Transfer of experience with a class-schema to identification-learning of patterns and shapes. Journal of experimental Psychology, 1957, 54, 81-88.

J. BECK, Surface color perception. Ithaca, Cornell Univ. Press, 1972.

J. BECK, The perception of surface color. Scientific American, 1975, 233 (2), 62-75.

J. BECK, Additive and subtractive color mixture in color transparency. Perception & Psychophysics, 1978, 23, 265-267.

S.H. EVANS, A brief statement of schema theory. Psychonomic Science, 1967, 8, 87-88.

W. FUCHS, Experimentelle Untersuchungen über die Anderung von Farben unter dem Einfluss von Gestalten. Zeitschrift für Psychologie, 1923, 92, 249-325.

G.M. HEIDER, New studies in transparancy, form and color, Psychologische Forschung, 1933, 17, 13-56.

H. HELMHOLTZ, Physiologische Optik. Leipzig, Leopold Voss, 1867.

E. HERING, Uber die Theorie des simultanen Kontrastes von Helmholtz. 4. Mitteilung. Archiv für die gesamte Physiologie, 1888, 43, 1-21.

S.C. MASIN, Transparency as a chromatic scission phenomenon and photoreceptor theory. Italian Journal of Psychology, 1976, 3, 405-413.

S.C. MASIN, A contribution to the theory of perceptual scission in phenomenal transparency. Italian Journal of Perception, 1978, 5, 169-189.

F. METELLI, Zur Analyse der phänomenalen Durchsichtigkeitserscheinungen. In R. Mühler and J. Fischl (eds.), Gestalt und Wirklichkeit, Berlin, Dunker und Humboldt, 1967.

F. METELLI, An algebraic development of the theory of perceptual transparency. Ergonomics, 1970, 13, 59-66.

F. METELLI, Achromatic color conditions in the perception of transparency. In R.B. MacLeod and H.L. Pick (eds.) Perception. Ithaca, Cornell Univ. Press, 1974a, 96-116.

F. METELLI, The perception of transparency. Scientific American, 1974b, 230 (4), 90-98.

F. METELLI, On the visual perception of transparency. In G.B.F. D'Arcais (ed.) Studies in perception, Martello, Milano, 1975, 445-487.

F. METELLI, La percezione visiva della trasparenza. In CNR Ist. di Psicol. (ed.) Problemi attuali di psicologia. Roma, Bulzoni, 105-144.

R.S. WOODWORTH, Experimental psychology. New York, Holt, 1938.

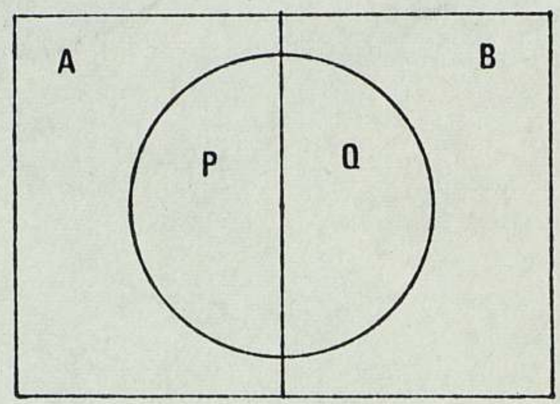

Fig. 1

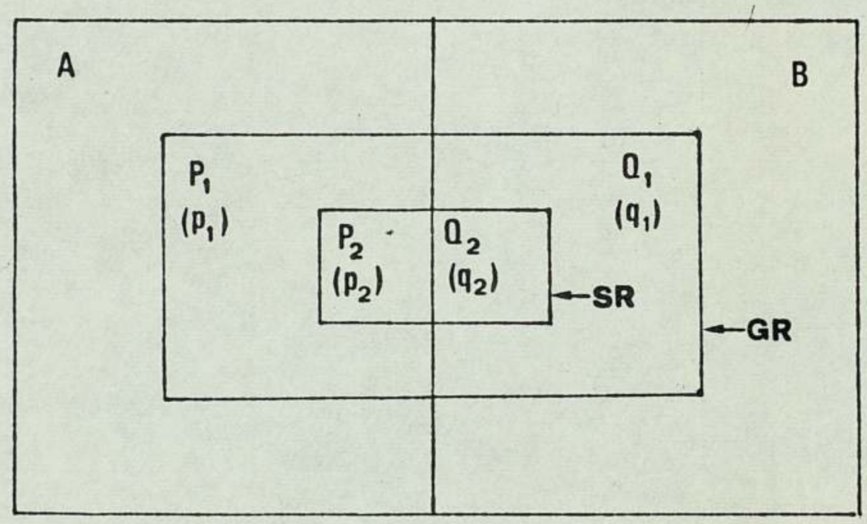

Fig. 2