What Does "More Transparent" Mean? A Paradox

Fabio Metelli

The perception of transparency may be studied for different purposes, but the main one seems to be that of describing the phenomenal aspects of transparency and of discovering the conditions that give rise to them. When possible, laws which allow predictions about the phenomenon ought to be formulated.

First of all, the conditions of the phenomenon have to be specified. Thus it becomes clear that, contrary to what seems self-evident, physical transparency is neither a necessary nor a sufficient condition for the perception of transparency; therefore a more precise and restrictive definition of perceptual transparency is needed. Physical transparency is present everywhere, as we always see objects through the (physically) transparent air. But under these conditions we do not perceive transparency. We perceive transparency only when the transparent object or layer is perceived, in addition to the objects seen through it (Metelli, 1974 a, p. 91).

We commonly speak of more or less transparent objects. The present discussion will be restricted to achromatic colors.[1] If we use various nonselective filters to cover a given black and white figure, we perceive various degrees of transparency, and transparency decreases as the density of the filters increases. The same result can be obtained without having recourse to physical transparency. By the

use of different shades of gray cardboard (Metzger, 1953, pp. 127-131), figures can be constructed which give rise to a clear impression of transparency (Figures 1, 2). With variation of the difference between the grays forming the central square, which is perceived as transparent, the degree of perceived transparency varies. The more similar the shades of gray in the central region, the greater the perceived opacity, and therefore the less the transparency of the square.[2]

All other conditions being equal, the degree of similarity of the grays of the central region is the stimulus condition giving rise to a greater or lesser "degree of transparency." But what is the meaning of this expression? How do subjects support their description of greater or lesser transparency?

Descriptions obtained are of three types. When transparency is greater: 1) One sees what is beyond more clearly.[3] 2) The transparent layer is less visible. 3) What is beyond is less altered by the superposition of the transparent object.

As with any comparison, the difference in the degree of transparency may become so small as to reach threshold value. But whether one uses a series of filters, or physically opaque models which give rise to perceptual transparency such as those described above, when differences in perceived transparency are not near the threshold, judgments of transparency are unanimous and are expressed with certainty. For example, no subject expresses doubt about the fact that

Kodak wratten filter 96 .20 is more transparent than wratten filter 96 .80 when each of these filters is superimposed on a different part of the same checker board; neither is there any doubt about the greater transparency of the transparent layer perceived in Figure 1 as compared with the transparent layer perceived in Figure 2.

If other conditions also differ, as for example the color of the transparent layer (Figures 3 and 4) or some feature of the surface perceived beyond the transparent layer, which may have a figure-ground organization (Figure 5), then the judgment may become more difficult and the threshold rise; but there are still cases in which differences in perceived transparency are strong, and in these cases the consistency of the judgments remains.

There is, however, a situation where subjects' judgments are contradictory, although the difference in transparency is evident. If the task is to compare the transparency of Figures 6 and 7 (and it has been established that subjects perceive a transparent layer or film covering the central region in both figures), we are faced with a disappointing result: some subjects assert that transparency is greater in Figure 6, some in Figure 7.

How are such contradictory results to be interpreted?

The first hypothesis to be considered, that the difference in transparency is below (or near) threshold can [redacted] easily be rejected: subjects do not show uncertainty or difficulty in expressing their

judgments, and judgments made by any given subject show a remarkable consistency.

Another hypothesis is that the same objective figure gives rise to different perceived figures, as often happens in experiments on visual perception. But in such cases sudden changes are experienced by subjects, who say that they are seeing "another thing" or another feature. And this does not happen in the present case.

Finally, the contradictory assertions of subjects may depend on an unclear definition of the task, so that subjects may be interpreting it in different ways. However, the task was the same when subjects were asked to compare the two transparent layers in Figure 1 and Figure 2, and in this case consistency of subjects' judgments shows that it was clearly enough [redacted] defined. It seems to have become insufficiently defined only when subjects were asked to compare Figures 6 and 7.

As has been noted above, when subjects are asked to specify what they mean when they assert that one film or filter is more transparent than another, they give three different reasons, which may be considered criteria for degree of transparency. If we compare the pair of transparent layers in Figures 1 and 2, these criteria yield the same result: in Figure 1 one sees more clearly what is "beyond," the transparent layer is less visible, and what is seen beyond is less altered by the superposition of the transparent layer.[4]

But when Figures 6 and 7 are compared, the three criteria give

different results: they do not indicate the same figure as being the more transparent. In Figure 6 one sees more clearly what is beyond, while in Figure 7 the transparent layer is less visible and what is seen beyond is less altered by the interposition of the transparent layer. Thus it seems that a clearer criterion for the degree of transparency has to be found, one which avoids such inconsistent results.

If we follow this line of reasoning, however, and make the task more specific by telling subjects to use the criterion of the visibility of the transparent layer in judging degrees of transparency, complete agreement of subjects is still not reached. In fact there is an impressive perceptual quality which is present in Figure 6 but lacking in Figure 7, namely the greater salience of the color-splitting phenomenon, which is more clean, more clear, and (in a sense) more beautiful. This aspect has to be disregarded if one wants to assert that there is more transparency in Figure 7.

The problem raised by the comparison of Figures 6 and 7 cannot, however, be considered settled by the preceding comments. There remains a problem of dimensionality in transparency. What has to be clarified is whether transparency is a unidimensional or a bidimensional phenomenon, that is, whether transparency can vary independently in degree and salience or prägnanz, just as color can vary independently in hue, brightness, and saturation.

Appendix

If the color of the transparent layer is held constant, the degree of transparency is measured by the index of chromatic scission $\propto$ (Metelli, 1970, 1974 b):

$$\propto = \frac{p - q}{a - b}$$

where p and q are the albedos of the splitting colors, while a and b are the albedos of the ground (black and white in Figures 1, 2, and 6).

It is clear that if p and q become more similar and a and b remain unchanged, $\propto$ decreases; this happens in Figure 2 (as compared with Figure 1) and, in fact, there is less transparency in Figure 2 than in Figure 1.

But $\propto$ also varies if (p and q remaining unchanged), a and b become more similar, that is, if the a - b difference decreases. In this case, since the denominator of the fraction decreases and the numerator remains unchanged, the value of $\propto$ increases, and since the color of the transparent layer is approximately homogeneous, the prediction is that the degree of transparency increases. Figure 6 differs from Figure 7 only with respect to colors a and b, which are more different in Figure 6, being white and black, while they are light gray and dark gray in Figure 7. Therefore, according to the theory of perceptual splitting, transparency should be greater in Figure 7.

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Footnotes

1. My current research has been confined to achromatic colors to avoid excessive complexity of conditions.

2. See Appendix.

3. The clarity of what is seen beyond is more striking, transparency is more "evident," "pronounced," "compelling."

4. That is, there is less difference between the protruding part of the ground or figure and the part of the ground or figure seen through the transparent layer.

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The perception of transparency may be studied for different purposes, but the main one seems to be that of describing the phenomenal aspects of transparency and of discovering the conditions that give rise to them. When possible, laws which allow predictions about the phenomenon ought to be formulated.

First of all the conditions of the phenomenon have to be specified. Thus it becomes clear that, contrary to what seems self evident, physical transparency is neither a necessary nor a sufficient condition for the perception of transparency: and therefore a more precise and restrictive definition of perceptual transparency is needed. Physical transparency is present everywhere, as we always see objects through the (physically) transparent air. But under these conditions we do not perceive transparency. We perceive transparency only when the transparent object or layer is perceived, in addition to the objects seen through it (1).

We commonly speak of more or less transparent objects. Restricting our argument to achromatic colors (2), if we use various non-selective filters to cover a given black and white figure, we perceive various degrees of transparency, and transparency decreases as the density of the filters increases. The same result can also be obtained without having recourse to physical transparency. Using different shades of gray cardboard (3), figures can be constructed which give rise to a clear impression of transparency (Fig. 1,2). Varying the difference between the grays forming the central square which is perceived as transparent, the degree of perceived transparency varies. The more similar the shades of gray in the central region, the greater the perceived opacity, and therefore the less the transparency of the square (4).

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(1) Metelli, 1974.

(2) My current research has been confined to achromatic colors to avoid excessive complexity of conditions.

(3) Metzger, Gesetze des Sehens, pp. 127-131, II^ Ed. Frankfurt and Main, 1953.

(4) See Appendix.

All other conditions being equal, the degree of similarity of the grays of the central region is the stimulus condition giving rise to a greater or lesser "degree of transparency". But what is the meaning of this expression? How do subjects support their description of greater or lesser transparency?

Descriptions obtained are of three types. When transparency is greater: 1. One sees what is beyond more clearly (1). 2. The transparent layer is less visible. 3. What is beyond is less altered by the superposition of the transparent object.

As with any comparison, the difference in the degree of transparency may become so small as to reach threshold values. But whether one uses a series of filters, or phisically opaque models which give rise to perceptual transparency such as these described above, when differences in perceived trasparency are not near the threshold, judgements of transparency are unanimous and are expressed with certainity. For example, no subject expresses doubt about the fact that Kodak wratten filter 96 .20 is more transparent than wratten filter 96 .80 when each of these filters is superimposed on different parts of the same checker board; neither is there any doubt about the greater transparency of the transparent layer perceived in Fig. 1 compared with the transparent layer perceived in Fig. 2.

If other conditions also differ as for example the color of the transparent layer (Fig. 3 and 4) or some features of the surface perceived beyond the transparent layer, which may have a figure ground organisation (Fig. 5), then the judgment may become more difficult and the thresold rise, but there are still cases in which differences in perceived transparency are strong, and in these cases the consistency of the judgements remains.

There is, however, a situation where subjects' judgements are contradictory, although the difference in transparency is evident. If the task is to compare Figs. 6 and 7 (and it has been established that the subjects perceive a transparent layer or film covering the central region in both figures) when they are asked in which figure there is grater transparency, we are faced with a disappointing result: some subjects assert that transparency is greater in Fig. 6, some in Fig. 7.

(1) The clarity of what is seen beyond is more striking, transparency is more "evident", "pronunced", "compelling".

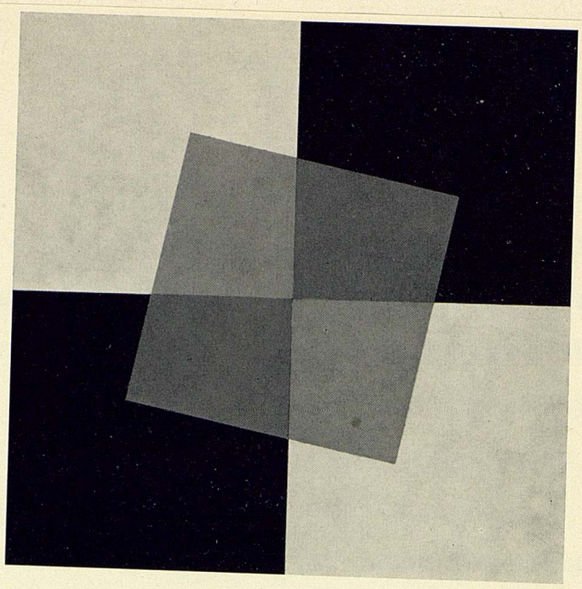

Fig. 6

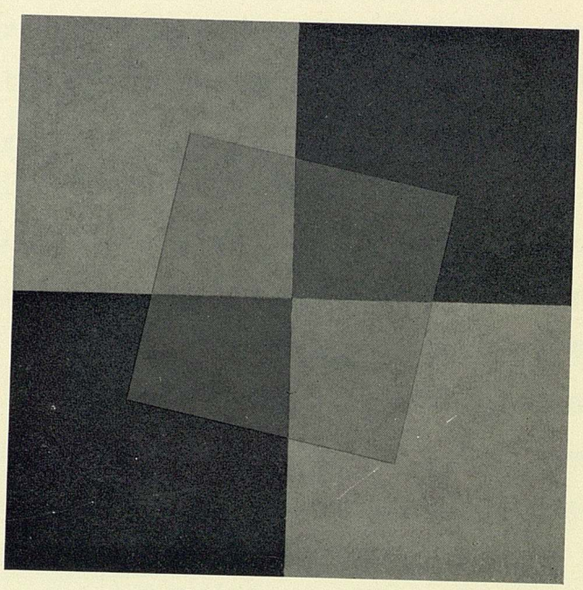

Fig. 7

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which may be considered criteria for the degree of transparency. Comparing the pair of transparent layers in Fig. 1, and 2, these criteria yield the same result: in Fig. 1 one sees more clearly what is "beyond", the transparent layer is less visible, and what is seen beyond is less altered by the superposition of the transparent layer (1).

But when Fig. 6 and 7 are comparend, the three criteria give different results: they do not indicate the same figure as being the more transparent. In Fig. 6 one sees more clearly what is beyond, while in Fig. 7 the tranpsrent layer is less

(1) That is, there is less difference between the protruding part of the ground or figure and the part of the ground or figure seen through the transparent layer.

How should such contradictory results be interpreted?

The first hypothesis to be considered, that the difference in transparency is below (or near) threshold, can be easily rejected: subjects do not show uncertainity or difficulty in expressing their judgement, and judgements made by any given subject show a remarkable consistency.

Another hypothesis is that the same objective figure gives rise to different perceived figures, as often happens in experiments on visual perception. But in these cases sudden changes are experienced by subjects who say that they are seeing "another thing" or another feature. And this does not happen in this case.

Finally the contradictory assertions of subjects may depend on an unclear definition of the task, so that subjects may be interpreting it in different ways. However, the task was the same when subjects were asked to compare the two transparent layers in Fig. 1 and 2 and in this case coincidence among subjects' judgements has shown that it was clearly enough defined. It seems to have become insufficiently defined only when subjects were asked to compare Fig. 6 and 7.

As has been noted above, when subjects are asked to specify what they mean when they assert that one film or filter is more transparent than another, they give three different reasons, which may be considered criteria for the degree of transparency. Comparing the pair of transparent layers in Fig. 1, and 2, these criteria yield the same result: in Fig. 1 one sees more clearly what is "beyond", the transparent layer is less visible, and what is seen beyond is less altered by the superposition of the transparent layer (1).

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However, if, following this line of reasoning, the task is made more specific by telling subjects to use the criterion of the visibility of the transparent layer in judging the degree of transparency, complete agreement of subjects is still not reached. In fact there is an impressive perceptual quality which is present in Fig. 6 but lacking in Fig. 7; namely, the greater salience of the color-splitting phenomenon, which is more clean, more clear and (in a sense) more beautiful. This aspect has to be disregarded if one wants to assert that there is more transparency in Fig. 7.

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APPENDIX

If the color of the transparent layer is held constant, the degree of transparency is measured by the index of chromatic scission α (1):

$$\alpha = \frac{p - q}{a - b}$$

where p and q are the albedos of the splitting colors, while a and b are the albedos of the ground (black and white in Figs. 1, 2, 6).

It is clear that if p and q become more similar and a and b remain unchanged, α decreases; this happens in Fig. 2 (as compared with Fig. 1) and in fact there is less transparency in Fig. 2 than in Fig. 1.

But α also varies if (p and q remaining unchanged), a

(1) See Metelli (1970, 1974b)

and b become more similar, that is, the a-b difference decreases. In this case, since the denominator of the fraction decreases and the numerator remains unchanged, the value of α increases and since the color of the transparent layer is approximately homogeneous, the prediction is that the degree of transparency increases. Fig. 6 differs from Fig. 7 only with respact of colors a and b which are more different in Fig. 6, being white and black, while they are light gray and dark gray in Fig. 7. Therefore according to the theory of perceptual splitting, transparency should be graater in Fig. 7.

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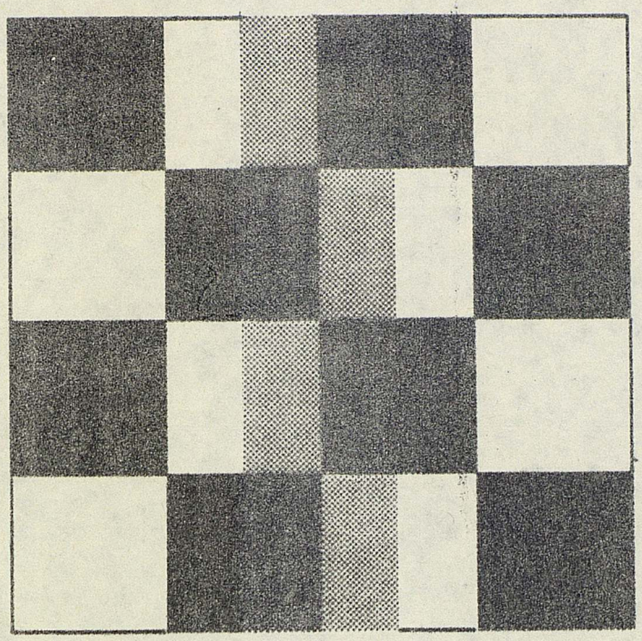

FIG. ~~8~~ 1

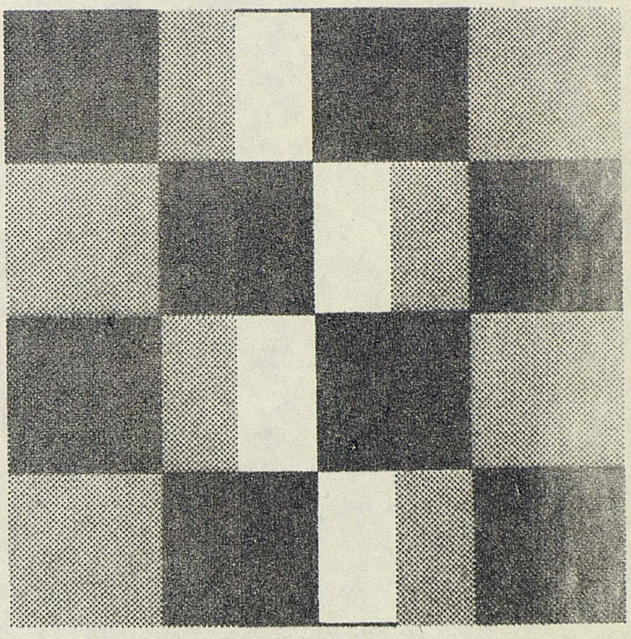

FIG. 9

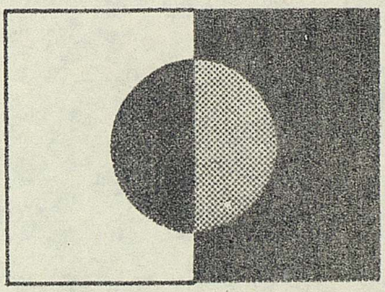

FIG. 9A

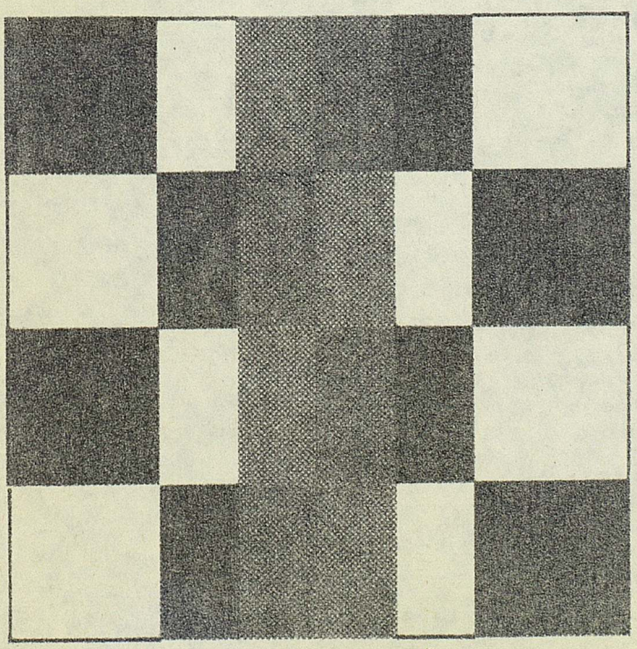

FIG. ~~10~~ 2

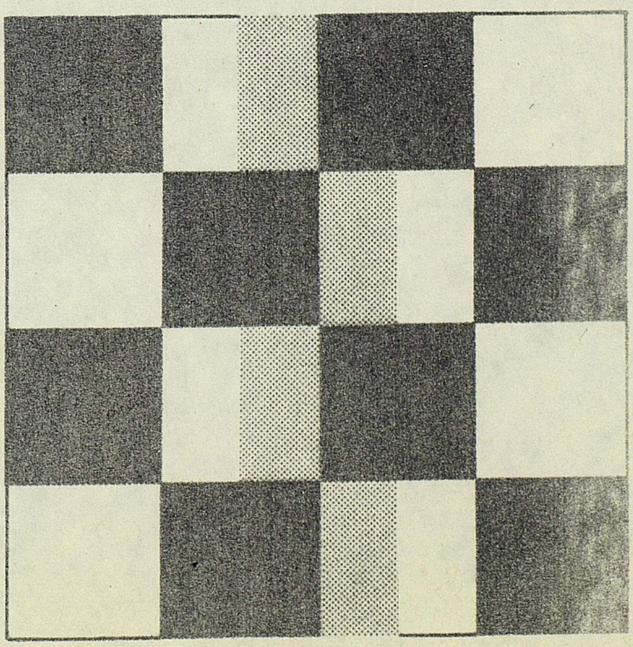

FIG. 11

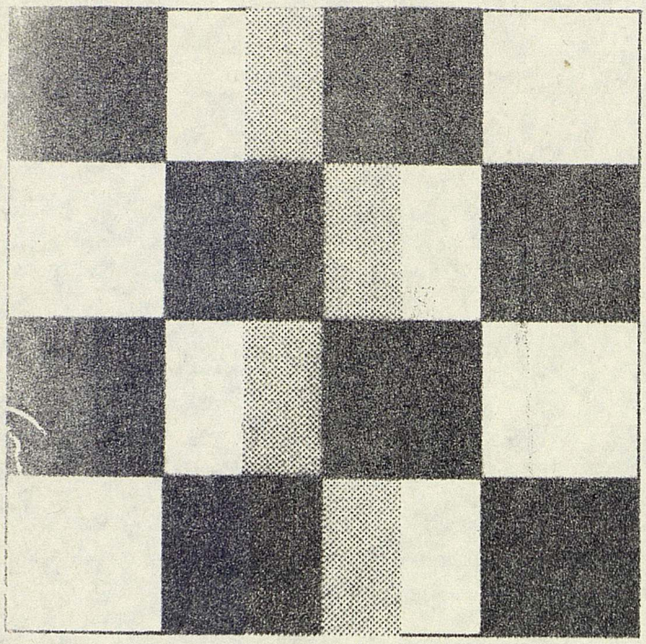

FIG. 10

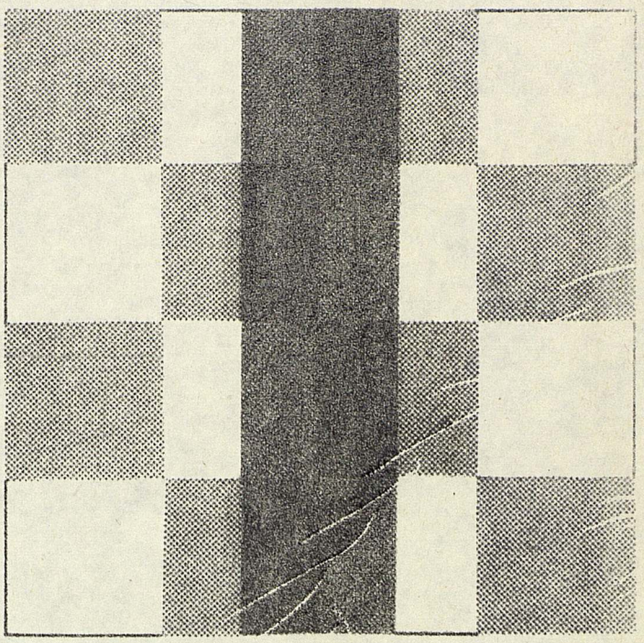

FIG. 11

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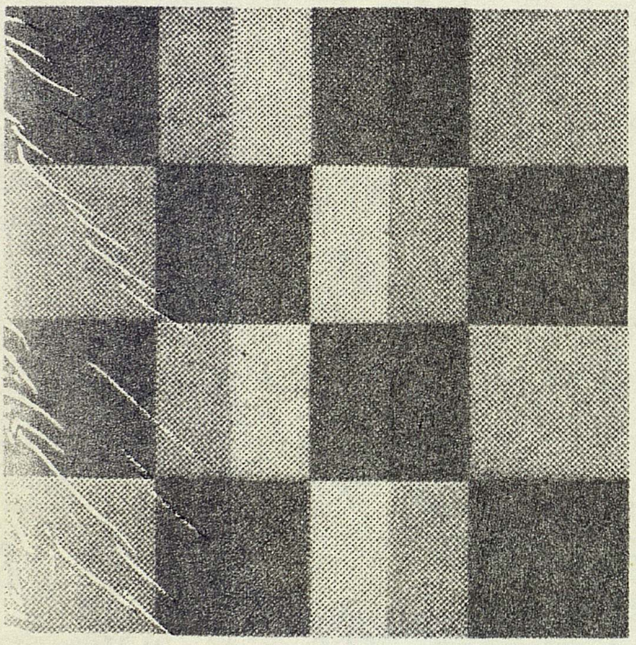

FIG. 12

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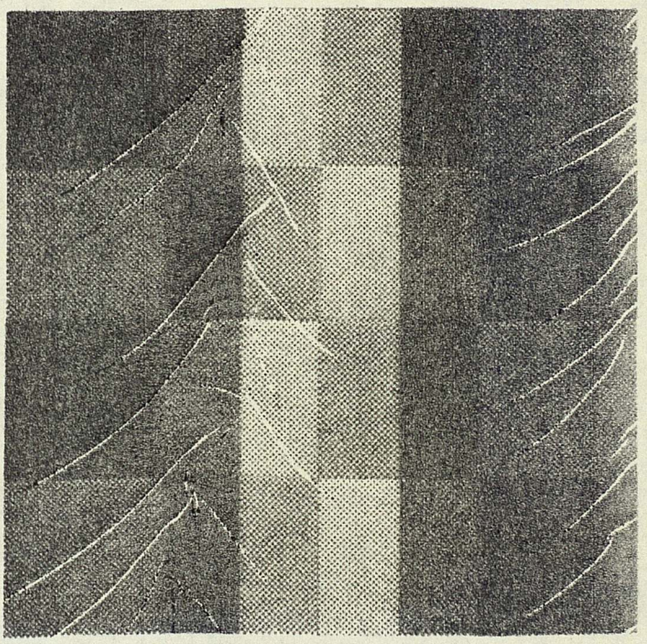

FIG. 13

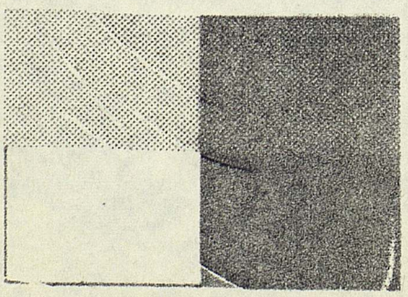

FIG. 14

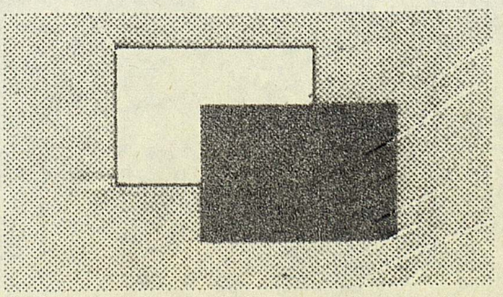

FIG. 15

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