

Contours and retinal disparity as determinants of localization in depth: the conditions of the perception of a hole.

Summary

The purpose of this experimental research has been to analyze the conditions determining or hindering the perception of a hole. A series of displays has been used, consisting in pierced screens of different forms and dimensions with behind, at a distance of about 40 cm, homogeneous or inhomogeneous surfaces of different color and illumination. Different results have been obtained according to the different experimental conditions. An objectively present hole is never perceived, independently from the form, size, color of the surface behind, if only the ground is homogeneous and entirely covered by the screen. In the case when the borders of the ground are visible to the subject, an objectively present ^{hole} ground is perceived only rarely. When the ground is inhomogeneous, all the subjects perceive the hole. Special effects have been however observed, due to inhomogeneity of the ground, for example, a transparent layer at the level of the pierced screen and a figure at the level of the ~~screen~~ ground. Finally it has been shown that under special conditions the paradoxical effect is obtained, of the perception of an objectively nonexistent hole.

When is a hole perceived as a hole, or more generally which are the conditions ~~and~~ determining or hindering the visual perception of a hole?

The problem has been treated in a preliminary note⁽¹⁾ where some situations were presented, in which the disappearance of a hole ~~and~~ other phenomena were described. In this paper the research is extended with the purpose of studying the effect action of other conditions, and the inverse effect of the perception of a physically non existing hole.

The research has been done with naive subjects.

Experiment 1

Display. A black pierced screen 27×35 cm with a rectangular hole 7×8 cm is placed before a white ground whose borders are covered by the screen and therefore are not visible to the subject. The part of the backward screen which is visible through the hole of the anterior screen is homogeneously illuminated and without shadows. The subject is at first at a distance of 3 m from the screen, then at 2,5 m.

border of the backward ~~side~~ surface

Subjects. The subjects taking part to the experiment were 22, they ~~did not know~~ not informed of the purpose of the experiment.

Results. No subject perceives the hole. The majority speaks of a piece of gray paper glued on the black background. The others speak of a painted figure ∇ at the level of the pierced ~~screen~~ screen.

(1) F. Melilli, O. da Pos, A. Carcedon

Experiment 1A

(3)

Display. The surface visible through the hole is red. The remaining other conditions are as for the experiment 1.

Subjects. 15 University students ⁽²⁾ not knowing the purpose of the experiment

Results. Not differing from Experiment 1. No subject perceives the hole.

(2) When there is no other indication, subjects taking part to the experiment are 15 University students, not knowing the purpose of the experiment, different from previous experiment, and Experiment 2.

Display. A black screen 150×60 with six holes 10×10 cm. Behind each hole, at a distance of 35 cm, is a surface of different color, respectively, yellow (1) green (2) blue (3) orange (4) red (5) light brown (6). The subject was at a distance of 2,5 m from the pierced screen.

Results. No subject says to see the holes. In this case also the majority of the subjects refers to see six squares of different colors glued on the black cardboard. Some subjects speak of figures drawn on the black cardboard, some others say to have the impression that colored papers are attached immediately behind the pierced screen. The descriptions vary slightly with the colors considered: The red has been seen more frequently before, than the yellow, the blue, the brown.

Experiment 3.

Display. A pierced screen, with a pierced square 10×10 cm hole before a homogeneous gray surface (Fig 4a). Below the hole on the black screen there are two other squares of the same size one of which is superposed to the screen (Fig. 4b) while the

Other is attached behind a hole second hole, equal to the first (Fig 4c). The squares are gray.

Results. No subject perceives the hole. Almost all the subjects () say to see three gray squares attached on a black cardboard.

Only one subject decides three squares painted on a black cardboard. Only two subjects observed that that the three squares could be attached immediately behind a pierced screen.

Hypota Experiment 4

Display

A black screen with three holes of different form and dimensions. (a circle whose diameter is 15 cm, a star and a rectangular hole $9 \times 1,5$ cm. Behind the pierced screen, at a distance of 40 cm is a homogeneous yellow background smaller than the black screen. The subject was at a distance of 3 m.

Results. No subject sees the hole. Almost all see three yellow figures glued on the black cardboard.

Comment - Observations

Other non systematic research allows us to assert that a hole is never perceived when behind a pierced screen there is a ground an homogeneous ground whose borders are covered by the pierced screen. The above effect is independent from the form of the hole and the color of the screen. The evidence of the effect, when other conditions are equal, is in inverse relations with the size of the hole. When the pierced screen is more lighter than the ground, other conditions being equal, the impression that at the place of the hole there is a figure of lined on the screen is more frequent. Then in this first series of experiments the conditions have been found making invisible an objectively present hole.

Experiment 5

(5)

Display A black pierced screen, as in experiment 1, is located before a gray homogeneous ground, uniformly illuminated; ~~whose~~ but its limits are beyond the pierced screen and visible to the subject (Fig. 5) ← ^{Fig. 5} Border of the background

Results. The results of the experiment are summarized in Tab. 1. Only one subject perceives a hole, the others perceive a figure. The figure is perceived upon the screen ^{by five subjects} ~~at the level of the screen~~ by three subjects, glued immediately under the pierced screen by two subjects.

Table 1

Pierced screen	Hole on the screen	Figure painted	glued under	Total
similar than the ground	1	9	3	15

Experiment 6

Display A₅ for Experiment 4 with the only difference that the ^{back} ~~grey~~ ground is greater than the pierced screen and is therefore visible to the subject. (Fig. 6)

Results. ~~see Table 2.~~ In this case, differently from Experiment 4, not all the subjects perceive a figure at the level of the pierced screen. Two subjects out of 15 perceive the hole, but one of them perceives it also in the two situations where no hole is objectively present. Besides three subjects describe the three squares glued at the back of the pierced ~~screen~~ ~~description~~

Table 2

Pierced screen	Hole	Figure under cover
greater than the ground	2	3

Experiment 7:

Display Before a gray ground homogeneously illuminated are three empty frames, respectively a rectangular c_1 an irregularly convex c_2 a symmetrically convex c_3 (Fig 4). The distance from the ~~gray~~ ground is 30 cm. The subject is at a distance of 3 m.

Results, see Table 2. Some subjects perceive the hole and others (when they perceive the figure) describe the gray figure attached immediately behind the black frame. This description is more frequent in the case of the two convex frames, when the gray central part is less easily perceived as "attached on" ~~the black peripheral part~~ ^{the black} ground.

(4) This variation has been suggested by R. Arnheim. The importance of the condition of ^{convexity} concavity for the organization of figure-ground organization has been shown by Kanizsa and Gerbino, who are quoting the preceding observations of Rubin (1921) and Arnheim (1954). In a configuration, like those constructed by Kanizsa, the regions whose contours have the character of convexity is perceived as figure, it may be hypothesized that, when the borders of the screen have the character of convexity, there is the tendency to perceive the region with the convex border as superimposed, favoring therefore the perception of a hole.

From Experiments 5, 6, 7 it results that in these cases also conditions favoring the perception of a hole are acting although the conditions favoring the perception of the figure prevail. Favorable to the perception of the hole appear: a) the identity or the chromatic similarity of the internal region of the hole and the external region including the hole and its border, having the tendency of becoming a perceptual unity (as in experiments 5 and 6) b) the convexity of the pierced screen.

Comment

Further non systematic research showed that when the ground is inhomogeneous all subjects perceive the hole. Besides it resulted that the more the ground is articulated, the more is the evidence of the jump in the depth and therefore the distance perceived between the ground and the pierced ^{screen}, especially if the same ~~fig~~ red paper has been used to obtain the pierced screen and the ground. The effect keeps its validity also with monocular vision. To the contrary to what happens in the situations of Experiments 1-4 (where the hole is not perceived), the more is the size of the hole, the less its evidence.

Results of Experiment 8 and non systematic observations show that the inhomogeneity of the region constituting the ground is the necessary condition for the perception of the hole; the retinal disparity and the mechanisms of accommodation, which act when this condition is present, give rise to the structuring of the field also in opposition to conditions that alone give rise to a different structuration.

— gray homogeneous background —

(7)

Table 2 (Figure 7)

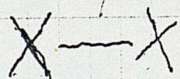
	Empty frame (hole)	Figure			Total
		upon	under	sampled	
C ₁	1	9	2	3	15
C ₂	2	4	4	5	15
C ₃	3	2	4	6	15

Experiment 8

Display Identical to that of figure 6, ^{but} the back ^{screen} surface is figured instead of homogeneous.

Results. All the subjects perceive the hole corresponding to the first square and the figures corresponding to the ~~two~~ other ^{two} squares

- hole -
- square glued on the screen -
- square glued under the screen -



Experiment 9

Display A black screen on which there is a rectangular hole 12x10 cm. The background, which ^{is} ~~is~~ are occluded by the screen is at a distance of 5 cm, red, with an ^(orange) rectangle ^{more} glued corresponding to the hole.

Results. See Table 3. Ten subjects describe, corresponding to the hole a red transparent layer, through which a red background with a white rectangle are seen. Three subjects on 15 do not perceive the hole. This result is then different from what is perceived with figured grounds.

Table 3

?

Experiment 10

~~which is also inside the~~

Display An open black box cm 32×187 . (Figure 8) The open side, directed towards the subject is closed with a pierced ~~pierced~~ screen (hole cm) occluding the box. The subject sees therefore only the pierced screen. The purpose of the experimental display was to obtain a hole of a particularly intense black. The subject is at first 2 m, then 1 m from the screen.

Results. See tab. 4. The number of subjects perceiving the hole grows with growing distance (5)
Table 5

Comment

The situations examined in the two preceding experiments show that there are cases intermediate to those observed in sections I and III. The inhomogeneities of the ground can give rise to special effects, as the omission between a transparent layer at the level of the pierced screen and a figure at the ground's level, and, however do not give rise, always and in every subject, to the perception of the hole. This is then the special case of the intense black screen which is an exception of the regular series of the results where the ground is homogeneous. The black hole is perceived as a hole by a non negligible number of subjects

Screen at 2 m from the subject	Screen at 1 m	Total
Hole uncertain Figure	Hole uncertain Figure	
1	2	13
9	—	15

Display. Background of dark grey card-board on which 5 stripes of paper of irregular form, ^{made of of different colors} stitching and crossing each other, are glued. Before, at 30 cm from the background are two rectangular frames, the left one empty, the right one with a ground equal to the background in color.
(5) In an analogous experiment I obtained the result that subjects at a greater distance perceive the hole with still greater frequency.

The colored strips are seen through the left (empty) frame (9) while they are glued on the ground inside of the right (full) frame. Thus there is continuity, in shape and color as if the right frame was empty. The illumination is compensating the difference in lightness due to the different spatial localization.

Procedure The subject, sitting with a head-rest⁽⁶⁾ at a distance of 3m. observes binocularly the stimulus-situations, at first for 10 seconds, and successively as long as he likes. After the first part of the experiment, the subject was asked to describe with the maximal precision what he saw. Successively, during the second presentation the subject had the opportunity of punctualizing, verifying, correcting his preceding description. (7)

Results. See tab. 6. It is interesting to note that all subjects at first perceive as empty, that is as holes, both frames. In the successive presentation only

Table 6

P	1 st presentation (10 seconds)		2 nd presentation (free)		Total
	Figure at the frame's level	Empty frame	Figure at the frame's level	Empty frame	
empty perceived frame	—	15	1	14	15
full frame	—	15	3	12	15

Three subjects "notice" that one of the two frames contains a layer superposed to the ground. One subject describes as full also the objectively empty frame.

(6) In order to avoid that movements of the head give rise to displacements between the figure contained in the full frame and the figures on the ground.
 (7) This procedure has been adopted because it was interesting to know in this experiment, what the subject perceived at first.

Experiment 12

10

Display. As the preceding experiment, except that the strips in-
sides of the frames (the left, insides "empty" as well as the right insides "full")
do not continue (neither for the color ^{nor} for the direction) the strips of the
ground.

Results. See Table 7. Differently from the preceding experiment
(Table 6) already after the first presentation two subjects per-
ceive as full the right frame; but one of them describes as full
also the ^{left} ~~right~~ frame. In the second presentation the number of sub-
jects describing as "full" the right frame increases. It has
however to be stressed that in this case also, the majority of the
subjects, also after a long observation perceive illusorily
an empty frame.

The conditions of experiments 11 and 12 give rise to the pa-
radoxical perception of a non existing hole. The effect seems to be
due to conditions of figural similarity giving rise to continuity and
spatial localization.

Table 7

	1 st presentation (10 seconds)		2 nd presentation (free)		
	Full frame	Empty frame	Full frame	Empty frame	Total
Empty frame	1	14	2	13	15
Full frame	2	13	8	6	14(?)

Concluding comment

When indexes of depth are lacking, a hole ^{to} and a surface superposed
to a screen (appeared perfectly equal). The apparently paradoxical
phenomenon appears obvious, considering that in the two cases the proxi-

mal stimulation is equal. It remains to be explained why instead of a hole, a figure is perceived in both cases. The effect can be explained in connection to the unilateral function of the contour (Koffka, page 195) which limits the included and not the external region.

In the present research conditions acting against the previously described action of the contour were introduced, i.e.:

a) The identity of the internal region of the hole and the region including the pierced screen. In this case a tendency takes place to perceive the region internal to the hole and the region external to the screen as a perceptual unity and therefore to perceive the hole.

But this unification is conflicting with the unilateral-including influence of the contour. From the results obtained this last factor appears much more stronger as the majority of the subjects perceived, in this case also, the figure instead of the hole. (8)

b) Another factor acting in this direction is the convexity of the borders of the pierced screen and therefore the concavity of the borders of the hole. The convexity, as has been shown by Kanizsa (1977) is a factor of figure. In the Experiment 7 the two factors a) and b) were acting together, and where the screen is reduced to a frame, they seem to show a greater tendency to perceive a hole. However the action exercised by the two above factors is less than that due to the function of the contour. The reduction of the dimensions of the screen to a frame does not seem to exercise any action on the phenomenon.

(8) This situation had been previously experimented (See Maffei, De Pui, Cavonius, et al.) with different results, probably because expert subjects were used (see the results of experiment 7, c1).

3) When the ~~action~~ of the contours is acts against factors of localization in the depth (accommodation, retinal disparity) the last one overcome, as a rule, the action exercised by the contours: when the ground is figured, the hole is perceived (see Experiment 8). When the action of bathoscopic factors is reduced, (so for example when there is a little figure on homogeneous ground, as in Experiment 9, a relevant number of subjects describes a phenomenal division into a transparent surface at the level of the screen and a figure at the level of the ground. This happens particularly if chromatic conditions favoring the phenomenal division are present.

4) A particularly interesting condition is given by a hole of extremely intense black, obtained with a box of black cardboard, with a hole in front of the subject. In this case the conditions are identical to those who gave ^{rise} without exception to the perception of a figure on the ground; what changes is only the lightness of the central region.*

5) In experiment 5 the action of the equality ^(color) of the inside surface corresponding to the hole and of the surface external to the hole was studied a condition which acted in the sense of analyzing the two surfaces favoring the perception of the hole. In this case the surfaces were homogeneous. In the experiments 11 and 12 the action of the two analogous figured surfaces is studied: in figural continuity ^(Exp. 11) and in absence of continuity (Exp. 12). From these experiments evidencing a further paradoxical effect (the perception of a non existing hole) it results that the action of figural homogeneity is greater than chromatic homogeneity, also in absence of continuity.

(73)

* As a matter of fact a figure of such intense black cannot be obtained and therefore in this case a change from color to illumination takes place. As it cannot be perceived as a surface, a relevant number of subjects perceives the region as a hole. The reason why at a lesser distance a lesser number of subjects perceives the hole, is not clear.