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New Gestalt Principles of Perceptual Organization: An Extension from Grouping to Shape and Meaning[1]

1. Introduction

Perceptual organization is a key issue of Vision Science challenging all its main approaches, be they computational, psychophysical, neurophysiological or phenomenological. It concerns the problem of why we perceive a world articulated in objects such as people, cities, houses, cars and trees, and not in differences of luminances, edges and bars, or in Wertheimer's (1923) words: *I stand at the window and see a house, trees, sky. Theoretically I might say there were 327 brightnesses and nuances of color. Do I have "327"? No. I have sky, house, and trees. It is impossible to achieve "327" as such. And yet even though such droll calculation were possible and implied, say, for the house 120, the trees 90, the sky 117 -- I should at least have this arrangement and division of the total, and not, say, 127 and 100 and 100; or 150 and 177.*

The problem of perceptual organization was first studied by Gestalt psychologists in terms of grouping (Wertheimer, 1912a, 1912b, 1922, 1923; see also Spillmann & Ehrenstein, 2004; Ehrenstein, 2008) by asking "how do individual elements group into parts that in their turn group into larger wholes separated from other wholes ('objects')?". Furthermore it was approached in terms of figure-ground segregation (Rubin, 1915, 1921) by asking why we perceive a configuration always in some implicit profile as something that is more pronounced and appears in front of the remaining parts of the visual field which recede and thus assume a "ground" character, even if the display is perfectly flat rather than an object in space?". Well-known 'principles of grouping': such as proximity, similarity, good continuation, closure, convexity, exhaustiveness, symmetry, *prägnanz* and past experience resulted from Wertheimer's study, whereas Rubin (1921) specified rules of figure-ground organization such as surroundedness, size, orientation, contrast, symmetry, convexity, and parallelism.

[1] Dedicated to the memory of Walter Ehrenstein, a great scientist, a kind man and a true friend. His memory will endure.

GESTALT THEORY
© 2010 (ISSN 0170-057 X)
Vol. 32, No.1, 11-78

Recently, Pinna & Reeves (2006) introduced the notion of "figurality" and some principles defining the phenomenal appearance of what is perceived as a figure within the three dimensional space and under a given illumination. More precisely, figurality is conceived to represent the integrated set of properties of a visual object, starting from grouping and figure-ground segregation principles, namely the color and the volume of the object with light and shaded regions, and the direction and the color of the light reflected by the object. The aim of this work is to investigate further forms of perceptual organization directly related and immediately consequent to grouping and figure-ground segregation.

Human perception is more than figural grouping and segmentation, it also extends to the organization of shapes and meanings (see also Boudewijnse, 2004). Each perceptual object is made up of element components grouped and segregated, but further appears as a shape related to other shapes that convey and signify one or more meanings related to other shapes and meanings, thus creating a complex net of perceptual shapes and meanings that is the complex world perceived in everyday life. By perceiving people, cities, houses, cars and trees, we perceive at least three main kinds of organization (forms): grouping/figure-ground segregation, shape and meaning. The ability and distinctiveness of the human visual system to organize the world through different kinds of forms, going from grouping to shape and to meaning subsumes the following questions. Are the forms of shape and meaning independent from the one of grouping/figure-ground segregation? How are the problems of grouping, shape and meaning mutually related? Can the forms of shape and meaning be considered as part of a perceptual organization process? What is a perceptual meaning? What are the main phenomenal rules governing the formation of shape and meaning? The answers to these questions aim primarily (i) to suggest a link between perceptual grouping, shape perception and visual meaning, (ii) to trace the visual shapes and meanings back to organizational processes similar to grouping, thus following the same phenomenological and epistemological basis inspired by Gestalt psychologists but, at the same time, going beyond the principles studied by them, (iii) to define the phenomenal underlying structure and principles ruling the formation of shapes and meanings, and, finally (iv) to delineate a new theory of perceptual organization based on this interrelated partition of forms. This perspective can widen the domain of Vision Science by including perceptual meanings usually considered parts of Cognitive Science, thus bridging the two domains of investigation.

2. Methods

In order to define appropriately the phenomenal continuum – from grouping to shape and to meaning – it is necessary to adopt at least two suitable methods. Firstly, a phenomenological free-report method (as used by Gestalt psychologists) is chosen, in which untutored, "naive" subjects are given a carefully chosen series of visual stimuli and asked to report anything they see. Secondly, the free-report method is supplemented by a quantitative one (magnitude estimation), where subjects are instructed to rate (in percent) the descriptions obtained in the phenomenological experiments.

2.1. Subjects

For each stimulus independent groups of 10 undergraduate students participated in the phenomenological and the scaling experiments as described in the next sections. Subjects were naive as to the purpose of the experiments, and all had normal or corrected-to-normal acuity.

2.2. Stimuli

The stimuli, composed of the figures illustrated and described in the next Sections, were presented on a computer screen with ambient illumination from a Osram Daylight fluorescent light (250 lux, 5600° K). The mean overall size of the stimuli was about 8x8 deg of visual angle. The stroke width was approx 6 arcmin. The luminance of the white background was 88.3 cd/m^2. Black contours had a luminance contrast of 0.94 (luminance value of 2.6 cd/m^2). Gray components had a luminance contrast of 0.45 (luminance value of 51.3 cd/m^2). The CIE chromaticity coordinates for the main colors used were: (purple) 0.30, 0.23 and (orange) 0.57, 0.42.

All conditions allowed for binocular viewing of stimuli displayed in frontoparallel plane at a distance of 50 cm from the observer. The head position of the observer was stabilized by a chin rest.

2.3. Procedure

Phenomenological experiments: The subjects' task was to report spontaneously what they perceived by giving, as much as possible, an exhaustive description of the main visual properties. Unless otherwise stated, different groups of 10 naive observers each described only one stimulus. This was done to avoid interactions and contaminations among stimuli. The descriptions reported in angled quotes (guillemets - « ») through the paper used similar phrases and words as those provided by the spontaneous descriptions of no less than 7 out of 10 subjects in each group but edited for brevity and representativeness. The edited descriptions were judged by three graduate students of linguistics, who were naive as to the hypotheses, to provide a fair representation of those provided by the observers. The descriptions are incorporated within the text to aid the reader in the stream of argumentations.

Scaling experiments: New groups of subjects were instructed to rate the accurate reflection (in percent) of the descriptions of the phenomenological experiments, i.e. the degree to which it captures the phenomenon being rated. An example of the task is: "please rate whether this statement is an accurate reflection of your perception of the picture, on a scale from 100 (perfect agreement) to 0 (complete disagreement)". Throughout the text, each description is followed by the result of the magnitude estimation (mean rating) compared to other possible phenomenal results.

In the two kinds of experiments, each stimulus was presented once to each observer. Observation time was unlimited. All the reports were quite spontaneous.

3. Two Forms of Perceptual Organization: From Grouping to Shape

3.1. The Form of Grouping

In Figs. 1a-b, «two large square shapes made up of rows (a) or columns (b) of small squares (100)» are perceived. In Fig. 1c, the small squares do not show any preferential direction of the inner organization, i.e. neither rows nor columns, but «a lattice of small squares (98)» is globally perceived. Under these conditions, the row or column organization can be induced through the visual attention but not as clearly as in Figs. 1a-b and it is easily reversible when the attention is switched to one or the other result.

The inner local organization of the small squares in rows or columns is due to the Gestalt grouping principle of *similarity* (Wertheimer, 1923) stating that, all else being equal, the most similar elements (in color, brightness, size, empty/filled, shapes, etc.) are grouped together. The outer global organization in large square shapes is due to the principle of similarity of shape and to the principle of *exhaustiveness*, according to which, all else being equal, all the components of a stimulus pattern tend not to be left out but included as parts of a grouped whole.

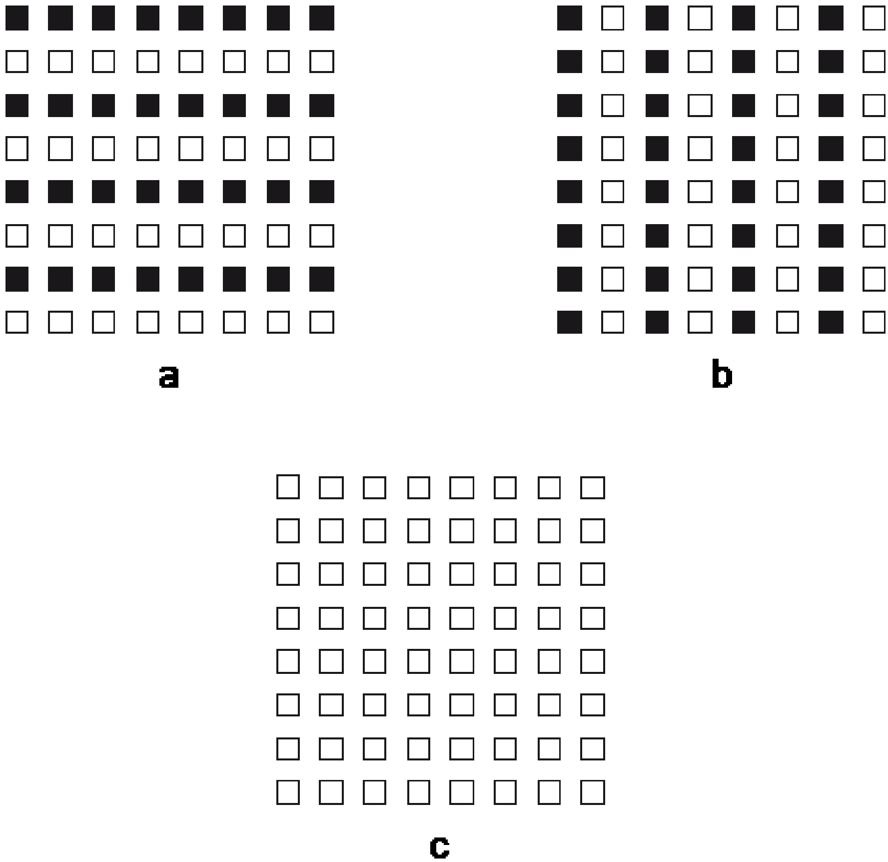


Fig. 1. Two large square shapes made up of rows (a) or columns (b) of small squares. In Fig. 1c, rows and columns are not perceived as clearly and stably as in Figs. 1a-b, but they appear reversible. *The Rectangle Illusion*: Both small and large squares appear similar to horizontal (a) and vertical (b) rectangles.

3.2. The Form of Shape: The Rectangle Illusion

On a closer observation of Fig. 1, naive subjects agreed to report more subtle and precise properties of the perceived shapes. The shapes of the small and large squares are not perceived isotropic (directional invariant) but with a clear directional symmetry (see also Pinna & Albertazzi, in press; Pinna & Reeves, 2009). «The inner organization in rows or column orients and elongates the shape of both the small and large squares in the same direction as the one of the perceptual grouping (87)». In other words, the perception of the rows distorts the squares by «widening the base of both the small and the large squares that appear like horizontal rectangles (89)». On the contrary, the column organization induces «a perceptual lengthening of the height of both small and large squares that appear similar to vertical rectangles (85)». Similarly to the whole deformation, «each small square appears distorted like a rectangle (81)». We call this effect "the rectangle illusion". These results emerge more clearly by comparing them with those of the control illustrated in Fig. 1c. These apparent deformations of the whole and local geometric shapes persist or are even stronger by zooming the focus of attention only on a small array of squares, e.g. the extreme 3x3 squares on the left or right upper side of Figs. 1a-b.

This effect can be related to Oppel-Kundt-like illusions, according to which an empty (unfilled) space looks wider than a space filled by some objects (Oppel, 1854-1855; Kristof, 1961; Da Pos & Zambianchi, 1996) and to Helmholtz's square illusion, where a square appears wider when it is filled with vertical lines and higher when filled with horizontal lines (Helmholtz, 1866). However, our effects show several important differences: (i) the whole shape distortion is induced by grouping and not by filled vs. unfilled space; (ii) the direction of the illusory distortion is the opposite of the one perceived in both Oppel-Kundt's and Helmholtz's square illusions, and (iii) the shape distortion involves both the small squares and the whole square shape.

The spontaneous descriptions suggest that the form of grouping can influence the form of shape: squares "become" rectangles. These results might depend on the *directional symmetry* that can be considered a principle of shape formation derived from the grouping by similarity but placed at a meta-level of perceptual organization. As a consequence the problems of grouping and shape appear different but phenomenally related. In Fig. 1, the perceptual results show how individual elements group into wholes separated from others. Grouping *per se* does not make any prediction about shape. The role of the gestalt principles is to define the rules of "what is or stays with what" i.e. the grouping and not the shape. The notion of 'whole' due to grouping is phenomenally different from the one due to shape. The form of grouping represents the groups of elements that assume the role of "parts" within a holistic percept. The form of shape is instead the result of a global perceptual process emerging parallel to or after the form of grouping and giving to the whole a unitary form along the boundary contours. This implies that grouping and shape formation can be considered as two complementary integrated processes of perceptual organization. This is not a literal or a fictitious distinction but a phenomenal necessity that can have consequences in terms of experimental phenomenology and neural circuitry.

The main purposes of the next sections are (i) to study the relationship between grouping and shape perception, (ii) to demonstrate that the form of grouping can influence the form of shape and *vice versa*, and (iii) to demonstrate that the directional symmetry is a second order tendency that polarizes the perception of the shape and that represents the basic principle of shape formation.

3.3. The Form of Figure-Ground Segregation

One cannot talk about grouping without also mentioning figure-ground segregation (Rubin, 1915, 1921, Ehrenstein, 1930, 1954). These principles complement Wertheimer's grouping laws. If we compare figure-ground segregation with grouping, it is reasonable to assume that the former must precede the latter (Palmer, 1999). In fact, the dot, line or square elements on which grouping acts must be already segregated as a figure from the ground, otherwise the visual system could not group: essentially it is the figures rather than the ground that allow for grouping. An exception to this rule is only to be observed in ambiguous pattern in which figure and ground reverse easily (see Fig. 1 in Spillmann & Ehrenstein 2004, p. 1574).

In Fig. 2, on a first observation, «a black regular six-pointed star (100)» is perceived, but after a closer observation it can also be perceived like «two overlapping shapes as illustrated in Fig. 2b and 2c (87)». «The two triangles of Fig. 2c can be easily reversed in their depth and amodal completion organization (100)». In Fig. 2d, the two overlapped shapes are not seen anymore but only «a regular six-pointed star is perceived (100)».

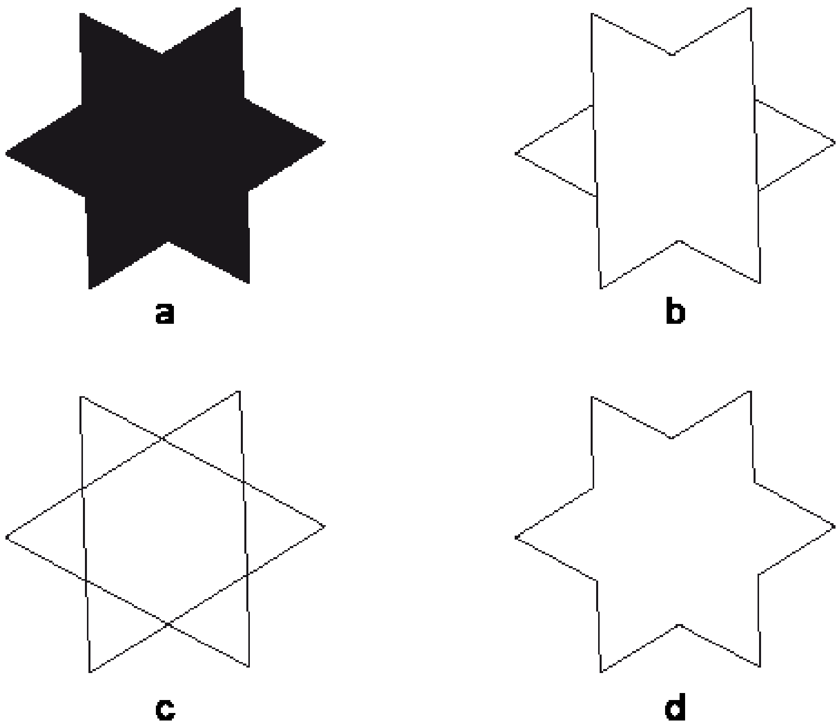


Fig. 2. A black regular six-pointed star (a) and other possible phenomenal alternatives (b-d).

According to Rubin (1915, 1921) the figures, perceived in each of the previous conditions, show the following properties: (1) they appear closer to the observer than the background implying that figure-ground segregation is related to depth perception; (2) their color appears denser than the color of the ground, which appears empty and diaphanous; and (3) they assume the shape traced by the contour and therefore the contour belongs only to the figure, but not to the ground on the other side of the contour ("border-ownership", see Spillmann & Ehrenstein 2004).

The different results perceived in Fig. 2 are likely due to the symmetry principle stating that, all else being equal, symmetrical regions tend to be perceived as figure. It implies that different levels or different kinds of symmetry elicit different phenomenal results as shown in Fig. 2b-c. The *prägnanz* principle can be also considered responsible for this kind of organization. In its history this principle has assumed three different but related meanings. It was considered as (i) a special phenomenal property belonging to certain gestalts but not to others. This property makes some objects appear as unique, preferred, singular and distinguished (*ausgezeichnet*). This is the case of the circle and the square (Wertheimer, 1912a, 1912b, 1922, 1923; Metzger, 1941, 1963, 1975a, 1975b, 1982). (ii) Wertheimer (1923) introduced a second interesting meaning, aimed at describing not only a property but also a process: *prägnanz* refers to a process bringing perception to a stable result and with the maximum of equilibrium. This is the case of *prägnanz* as a grouping principle (see also Metzger, 1963) directed to create the best Gestalt (*Tendenz zur guten Gestalt*; *gute Fortsetzung*) with an inner necessity and with the minimum of requiredness (*innere Gefordertheit*, Köhler, 1938). For the need to distinguish between the two meanings of *prägnanz* see Hüppe (1984). (iii) The third meaning is the most controversial (see Kanizsa & Luccio, 1986, 1989) and states that *prägnanz* refers to self-organization processes aimed at the formation of an ordered, singular (*Einzigartigkeit*), and distinguished (*ausgezeichnet*) outcome (Wertheimer, 1912a, 1912b, 1922; Köhler, 1920; Goldmeier, 1937; Rausch, 1952, 1966; Metzger, 1963, 1982). Pinna (1993, 1996, 2005a) introduced a fourth meaning, extending Kanizsa and Luccio's critiques (1986, 1989) to the third meaning. It states that a tendency toward *prägnanz* does not necessarily concern the *modal* realization of a singular perceptual result but usually implies the implicit, *amodal* formation of the most distinguished and singular result (*amodal prägnanz*). This idea is in agreement with the kind of organization beyond grouping that we called "form of meaning".

The question to answer in the next Section is: can grouping and figure-ground segregation influence shape perception?

3.4. The Illusion of the Distorted Seven-Pointed Star

In Fig. 3a «a black regular seven-pointed star is perceived (97)». However, after a prolonged observation along the boundary contours of the shape, it is perceived as «an irregular seven-pointed shape that does not appear symmetric, as illustrated for example in the summation of Fig. 3b, but crooked and unstable (95)». We call this effect "the illusion of the distorted seven-pointed star". A possible representation of the perceived result is illustrated in Fig. 3c where an intersected unclosed and twisted shape can be perceived. The perception of «irregularity prevails (87)» also under conditions like those shown in fig. 3d-f, where the result like the one illustrated in Fig. 3b is more easily predicted. These results are not expected in the light of any of the three meanings of the *prägnanz* principle. The shape distortion is weakened or even annulled in Fig. 3f, where the white dots stop the good continuation of the sides of the vertexes. This result underlines the role of the principle of good continuation that in these conditions wins against *prägnanz* and symmetry.

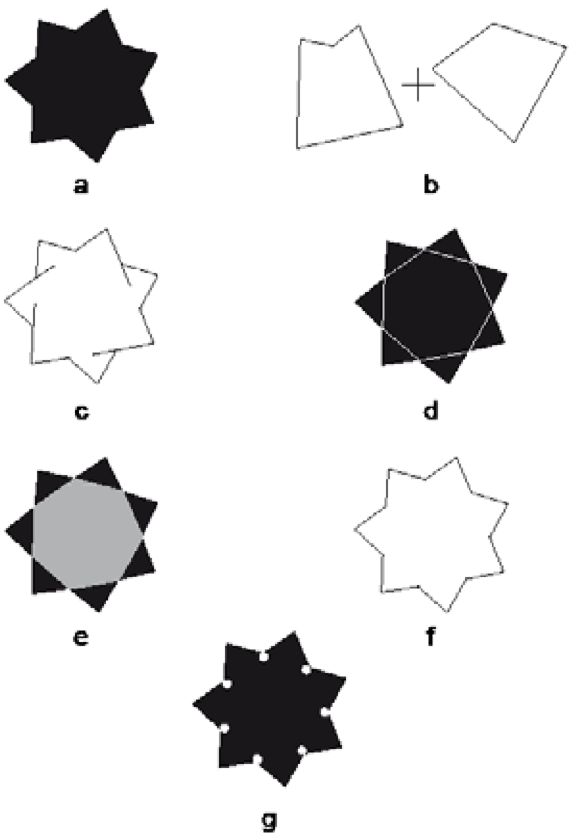


Fig. 3. *The Illusion of the Distorted Seven-Pointed Star*: The seven-pointed star appears distorted, irregular and asymmetric.

The good continuation induces locally in all the components a non-isotropic directional symmetry that creates the *ad infinitum* virtual rotation of the sides and then the irregularity of the star. In other words, the broken symmetry and irregularity likely depend on the directional symmetry induced by the good continuation of the vertex sides. This implies that the formation of the irregular star is a consequence of a shape formation process based on the results of the earlier grouping and figure-ground segregation processes.

3.5. The Grouping Diamond Illusion

In Fig. 4, the inner organization of elements influences the form of shape of both the elements and the whole. In Fig. 4a, the small and the large composite squares are rotated of 35° and the similarity principle, pitted and winning against proximity, groups the components in «columns along the diagonal of the whole square (100)». As a consequence «the inner and the whole squares appear like diamond shapes (88)». We call this effect "the grouping diamond illusion". It is related to the square-diamond illusion (Schumann, 1900), according to which a square rotated by 45° is perceived larger and like a diamond-shaped or rhombic figure. This effect is clearly enhanced by the grouping of the components along the diagonal of the whole shape. To perceive the difference in strength of the diamond effect induced by grouping compare Figs. 4a and 4b.

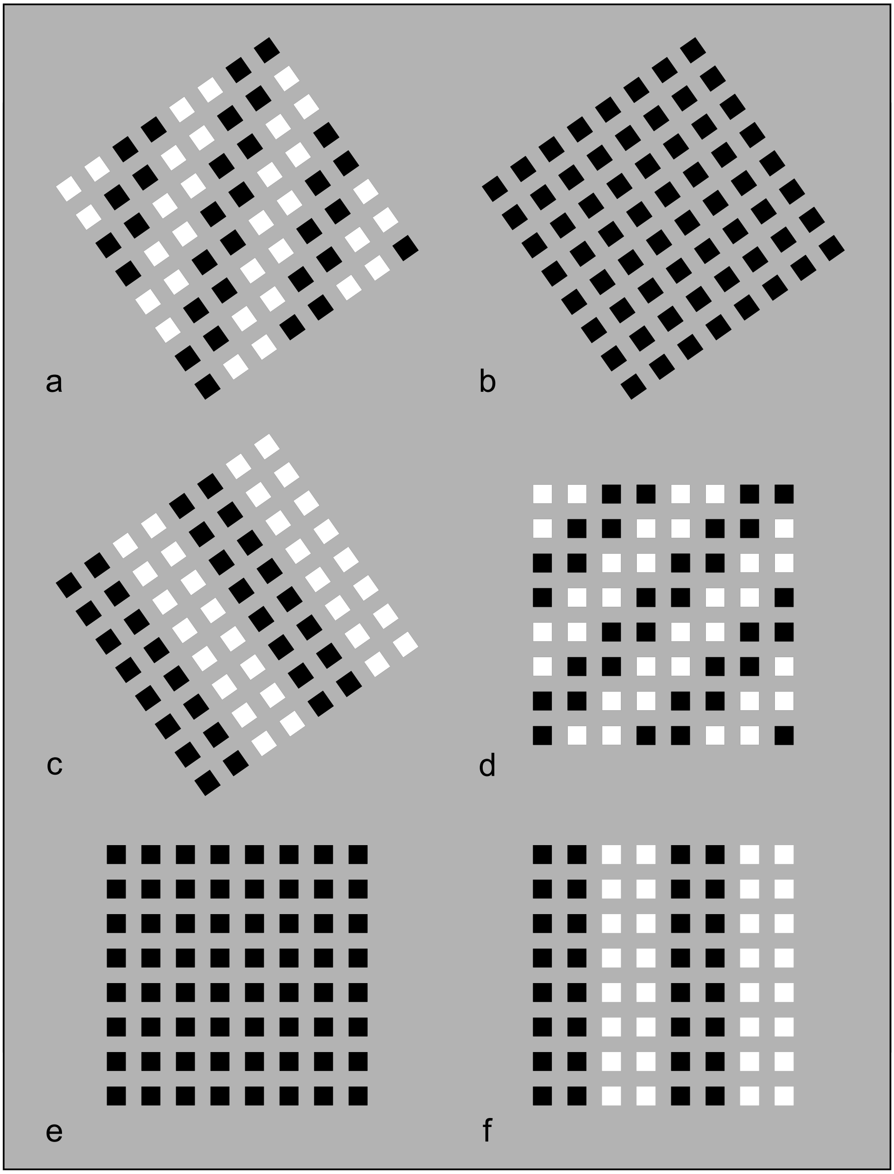


Fig. 4. *The Grouping Diamond Illusion*, see also p. 22

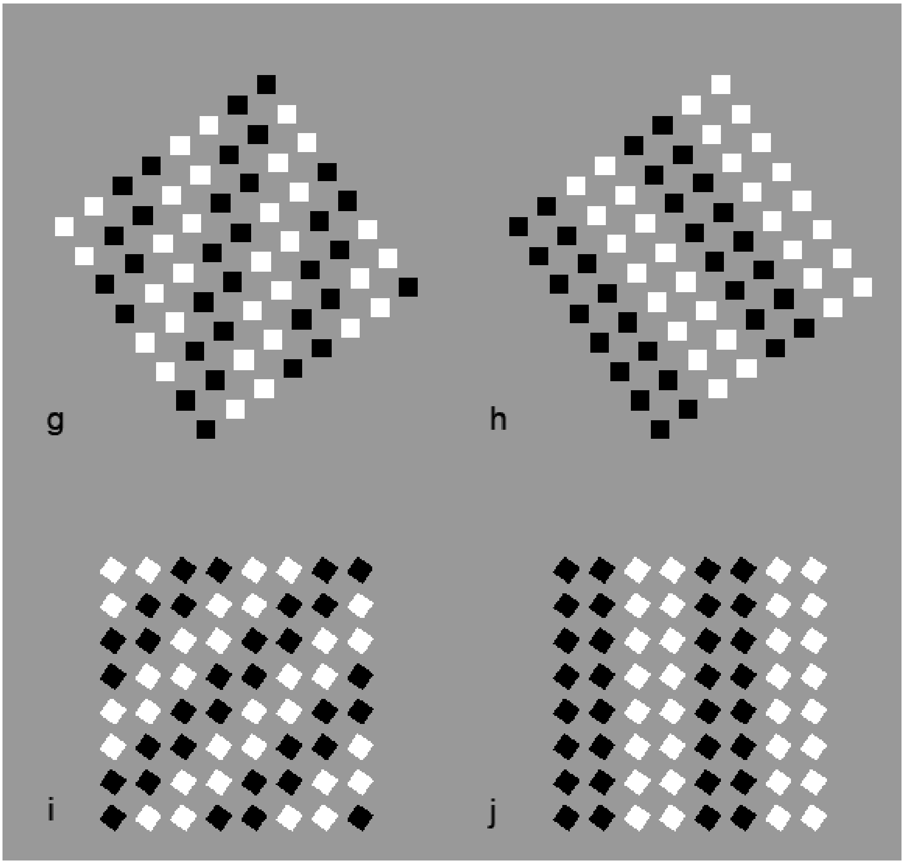


Fig. 4. *The Grouping Diamond Illusion*: The inner and the whole figures appear like having a diamond (a-d-h-j) or a square shape (c-f-g-i). Controls (b-e).

In Fig. 4c, the same components of Fig. 4a-b are now perceived like «small squares organized in tilted columns and creating a rotated large square. Both kind of squares (small and large) appear elongated in the same direction as the columns (87)». This result demonstrates the strength of the grouping due to similarity in forming the shape on the basis of the directional symmetry independently from and against the square-diamond illusion. It is worthwhile noticing that by comparing Figs. 4a and 4c, the rotation of both small and large squares with respect to the vertical-horizontal axis appears different: the elements and the whole square are perceived rotated and oriented in the same direction as the grouping, therefore in Fig. 4a they appears more vertical than those of Fig. 4b (89). These results entail that the directional symmetry influences also the orientation that is a perceptual component not only of the grouping but also of the shape as it will be shown in Fig. 5. There is another interesting effect that likely depends on the directional symmetry: the inner structure of Fig. 4a, due to the alternation of black and white columns, appears «waved like a sinusoid compared to the one perceived in Fig. 4c where the waved alternation appears as having a square shape (87)».

In Fig. 4d, the grouping forms the shapes of the local and global components similarly to Fig. 4a: the small and the large squares are «perceived as having diamond shapes (85)». These results emerge more clearly through the comparison with the control illustrated in Fig. 4e. In Fig. 4f, the results show «squares forming a large square, both appearing elongated (86)». The similarity principle induces a directional symmetry that determines, like in Fig. 1, the shape of the small and the whole components, i.e. the rectangle illusion, where the inner organization in column «orients and elongates the shape of both the small and the large squares in the same direction as the one of the perceptual grouping (83)». Furthermore, by comparing Figs. 4d and 4f the sinusoid vs. square wave effect is even stronger than the one emerging from Figs. 4a and 4c (85).

In Figs. 4g-j, controls for the previous conditions reporting the opposite results are illustrated: where squares were previously perceived, now diamonds are seen and *vice versa* (90). Similar reverse results involve also the perceived tilt of the small and large squares. While in Figs. 4a-f small and large squares are rotated in the same way, i.e. 35° or 0°, in Figs. 4g-j, small and large square are differently rotated within the same figure, i.e. 35° and 0°.

In Figs. 4a and 4d, differently from Fig. 1, the similarity principle operates either against the main orientation of the small squares or against the one of the whole square. This means that there are at least two grouping principles working at the same time: similarity and main orientation. As a consequence, the similarity of the achromatic color is pitted against the similarity of the local or global orientations. By comparing Figs. 4a and 4d, the role of the similarity of the main local and global orientations is clearer and stronger in Fig. 4d. Under these conditions, all else being equal, one principle (similarity of achromatic color) wins over the other. More precisely, one principle defines what determines the emerging whole when all else is equal. Therefore, the strength of what emerges by virtue of the winner principle is weakened by (subtracted of) the strength of the alternative grouping resulting from the loser principle.

This is an important point useful to understand the role of the directional symmetry due to the grouping by similarity. While the previous two similarities (achromatic and local/global orientation) are placed at the same phenomenal plane competing each other, under our conditions, similarity and directional symmetry are placed in different consequential planes or perceptual levels. In fact, they do not compete and do not cooperate but create different kinds of perceptual outcomes placed at different levels. They are also perceived phenomenally as different forms that can be considered as the result of different kinds of perceptual organization: form of grouping and form of shape. As regards Fig.1, this distinction can be expressed as follows: the achromatic similarity groups elements in rows and columns that in turn form the whole shape on the basis of directional symmetry. The latter principle is some kind of meta-principle that operates at another organization level after (or maybe at the same time as) the result due to the former. More precisely, the similarity is a part-whole grouping principle that puts together elements (the small squares) that are perceived as parts of a whole grouping (the rows). On the other hand, the directional symmetry is like a part-whole shape principle, where the elements (the rows) are perceived as parts (small rectangular shapes) of a whole shape (a large square) that appears similar to a horizontal rectangle. This distinction between principles and meta-principles or between grouping principles and shape principles is not merely linguistic but mostly phenomenological. It can be further perceived in the following figures, where the role of the form of shape emerges more clearly as an organization process independent from the form of grouping.

3.6. The Illusion of the Scalene Triangle

The role of grouping in the perception of shape is more clearly demonstrated by using small triangles that create a large triangle. In Fig. 5a, small isosceles triangles create «a large isosceles triangle pointing toward the top left-hand corner (93)» . This is the control for the next condition, illustrated in Fig. 5b, where the grouping of the triangles on the basis of similarity of lightness, synergistic with or parallel to the smallest side of each small triangle, makes «the large elongated isosceles shape to appear more pronounced than the one of Fig. 5a and more strongly determining the pointing of both large and small rectangles toward the top right-hand corner (99)». In Fig. 5c, the grouping of isosceles triangles is now parallel to one of the two equal sides of each small triangle, therefore creating both locally and globally what we call "the illusion of the scalene triangle": «the three sides of both the small and large triangles appear unequal, i.e. scalene, pointing preferentially toward the bottom right-hand corner (91)».

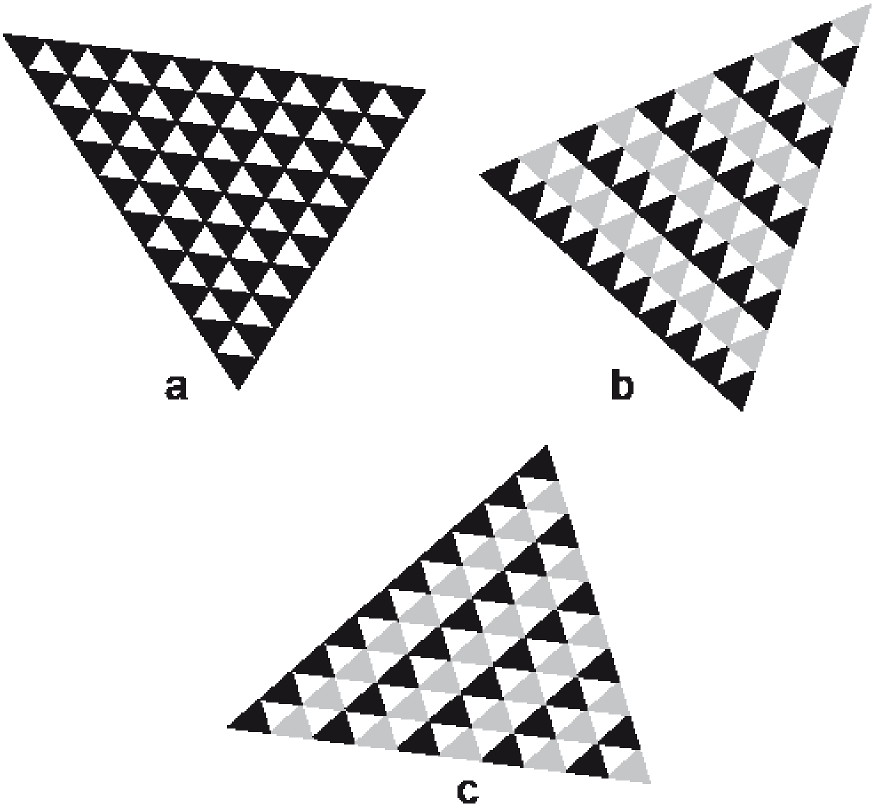


Fig. 5. *The Illusion of the Scalene Triangle*: (a) Small isosceles triangles create a large isosceles triangle pointing toward the top left-hand corner. (b) The grouping of the triangles on the basis of similarity of lightness makes the large elongated isosceles shape to appear more pronounced than the one of (a) and more strongly determining the pointing of both large and small rectangles toward the top right-hand corner. (c) When the grouping of isosceles triangles is parallel to one of the two equal sides of each small triangle, the three sides of both the small and large triangles appear unequal, i.e. scalene, pointing preferentially toward the bottom left-hand corner.

In Fig. 5, the patterns are differently oriented to avoid contaminations among the perceptual results and to annul the effect due to the vertical-horizontal geometrical orientation that, on the basis of its default domination, can influence the perceived organization of both shape and pointing of the triangles. During the experiments the orientation of the large triangle was randomly varied from one subject to another.

The phenomenon of pointing and the illusion of the scalene triangle can be related to the configural orientation effects studied by Attneave (1968), Palmer (1980,

1989) and Palmer & Bucher (1981). They studied the pointing of equilateral triangles aligned along their axis of symmetry or along one of their sides (see Fig. 14a) and demonstrated that the perception of local spatial orientation (the pointing of the small triangles) is influenced by the global spatial orientational structure. However, our conditions present several clear differences, suggesting that this is a different phenomenon. In fact, the spatial orientational structure among the elements is kept constant among the previous three figures, but only their grouping is varied. Furthermore, the effects perceived in our stimuli not only involve the local spatial orientation (the pointing) but also the shape perception (scalene vs. isosceles) of both the whole object (large triangle) and each single component (the small triangles).

The shape distortions depend on the similarity principle that induces new symmetric organizations (directional symmetry) in the entire set of triangles (see Fig. 5c) that wins over the symmetric organization of the global virtual boundaries (Fig. 5a). Fig. 5b shows that the two kinds of symmetries can operate synergistically and not only competitively.

The shape deformations induced by the directional symmetry is the opposite of what is expected by the *prägnanz* principle (Wertheimer, 1923), on whose basis under our conditions scalene triangles are more unlikely to be perceived than isosceles ones. In spite of these predictions, the perceived deformations "simplify" the single and whole shapes similarly to what is suggested by a general principle of *prägnanz*. In fact, the grouping principles induce a new direction of symmetry that defines the base of the triangle and, as a consequence, the global shape formation. In other words, they determine not only the pointing of the whole triangle but also the kind of triangle, and, at the same time, they reorient and determine the shape of each small triangle.

The directional symmetry and the grouping by similarity can be considered as the result of two different kinds of perceptual organization: form of grouping and form of shape. The similarity is a part-whole grouping principle that puts together elements (the small triangles) that are perceived as parts of a whole grouping (the whole triangle). Also, the directional symmetry is like a part-whole shape principle, where the elements are perceived as parts of a whole shape (the large triangle) that appears similar to a scalene triangle. These examples make it also clear that the part-whole organization due to the two principles operates at two different perceptual levels and meta-levels: the similarity groups elements that in their turn form the whole shape on the basis of the directional symmetry.

3.7. The Beveling Effect

According to Rubin (1915, 1921) the background has not a boundary but it belongs unilaterally to the figure. Therefore the background rather appears as an empty space without a shape. Less sharp and dichotomous is the case of the perception of gaps, missing components or beveling like the one illustrated in Fig. 6a. The beveling appears in fact as something in between a figure and a background. Unlike a background, it is not "nothing" but "something" (see also Metzger, 1963, 1975a); it appears segregated as an object, it has a shape and like an object it is active in the grouping and shape organization with the other contiguous objects. As such, its shape depends on grouping and figure-ground principles (see Pinna & Reeves, 2009) and interacts with the other elements becoming part of a whole shape. However, like a background, it appears as an empty space and manifests the properties of the background. It is a figure and a background at the same time. (In Section 4 we will show that the beveling is an emergent object that cannot be explained by uniquely invoking the forms of grouping and shape, but it necessarily requires one to hypothesize a new kind of perceptual organization that is the form of meaning.)

If this is true, a missing or beveled region can manifest figural properties due to related figure-ground principles like symmetry that influence the whole shape. The results of Fig. 6a showed that the beveling of the vertex of the large isosceles triangles of Fig. 5, made up of small isosceles triangles, created by the convergence of two sides of different length, changes both the shape of the triangles into scalene and their pointing in the direction of the beveling. This is obtained in the three conditions illustrated in Fig. 6 and related to those of Fig. 5: (i) when the triangles are all black, (ii) when they are not grouped synergistically with the geometrical isosceles pointing of both the large and the small triangles, and (iii) when they are synergistic with the pointing. «The large triangles and the small ones are scalene and point toward the beveling (95)». The scalene illusion and the pointing is stronger when the triangles are all black and even more when the grouping is synergistic with the pointing of the scalene triangle (see Figs. 6a and 6b).

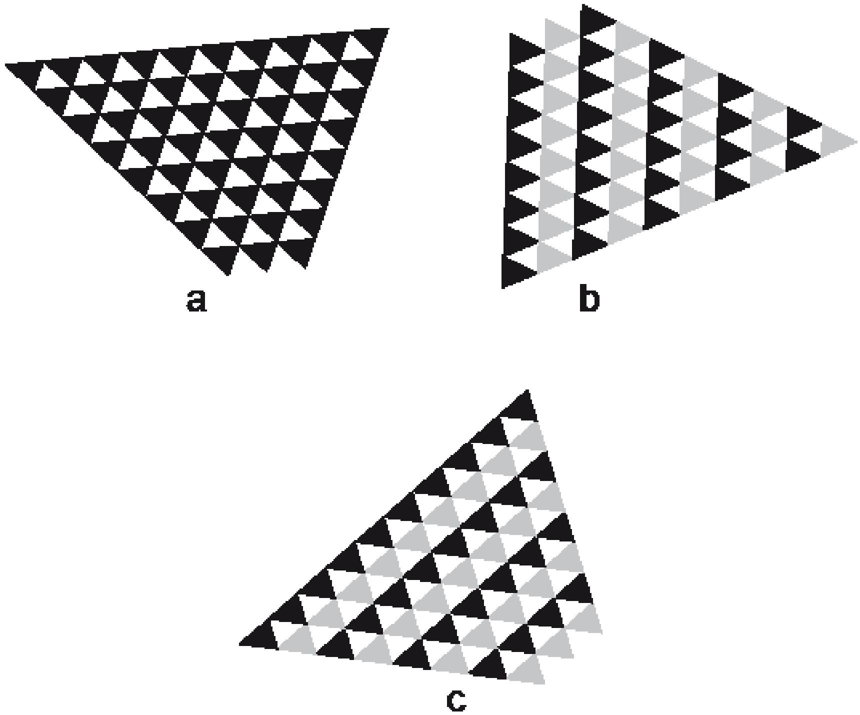


Fig. 6. *The Beveling Effect*: The beveling of the large triangles in one of the two vertexes obtained by the convergence of the two unequal sides changes both their shape into scalene triangle and their pointing in the direction of the beveling.

Under these conditions, there are three organization tendencies operating in opposite directions and inhibiting each other: similarity, isosceles shape and beveling. The strongest is the beveling that changes the directionality and the shape of the large and small triangles. This is due to the phenomenal properties of the beveling that appears as a basic component of the whole object and of its shape. In fact, the beveling induces a new direction of symmetry that defines the base of the whole triangle and the shape of each small triangle. If the effect of the beveling goes in the same direction as the one of the similarity, the change of the shape and of the pointing is stronger than the one illustrated in Figs. 6a-b (91, see Fig. 6c). These results are not expected from the configural orientation effects studied by Attneave (1968) and Palmer (1980).

Just as the grouping influenced the shape and the pointing perceived in the small and large triangles, as shown in the previous results, in the same way the shape variations due to the complete and beveled conditions change the strength of the perceived grouping by similarity. At the end of the previous experimental sessions, the task of the subjects was to scale the relative strength of the perceived grouping effect due to similarity, i.e. how easy, immediate and direct is it to perceive the grouping by similarity with respect to the perceived shape and pointing of the small and large triangles both complete or beveled. The range values were from 0 to 100. The upper value "100" was defined by the perceived strongest grouping among the six stimuli, i.e. by the one most easily and immediately perceived in relation to the shape and pointing, whereas the value "0" was defined as the minimum grouping perceived, i.e. the least easy, immediate and direct. The stimuli were present all at the same time to each observer in a random order.

The results showed that the beveling significantly weakens the grouping, the strength of which increases when grouping and shape are synergistic (93 - Fig. 5b, 86 - Fig. 5c, 45 - Fig. 6b, 60 - Fig. 6c). The low rating of the beveled figures demonstrates that they also influence the direction of the grouping by similarity, which can be clearly perceived only when the visual attention pursues the direction of the grouping by similarity.

In conclusion, the previous conditions explored the effect of grouping on shape perception and demonstrated that the grouping principles influence not only the way elements in the visual field "go together" to form an integrated, holistic (gestalt) percept, but also the local and the whole shape perception, i.e. the pointing and the shape of both the small and the large isosceles triangles. This creates the illusion of the scalene triangle: small and large isosceles triangles appear as scalenes. Conversely, the shape variation of the large triangle induced by the beveling influences the perceived strength and direction of the grouping of the inner small triangles. These results suggest that the forms of grouping and shape are two different but not independent processes. They are complemented and placed at different perceptual levels, namely the form of shape at second order.

Not only does the inner organization of many elements affect and contribute to the formation of the whole shape but also single elements and their phenomenal properties can strongly contribute to the whole shape formation as is demonstrated in the next sections. This idea is based on one of the basic concepts of the notions of Gestalt, according to which each element can affect and be affected by any other element of the visual field. This implies a systemic organization theory (Metzger, 1963, 1975a) that takes the idea of organization into perceptual objects a step forward suggesting that the understanding of the different kinds of organization can explain the complexity of the visual world. The aim of the next sections is to understand what shape formation is, how it differs from the form of grouping and its limits that indicate the necessity for a further and more complex kind of perceptual organization.

3.8. The Concave/Convex Illusion

In the Rod and Frame illusion the surrounding of a vertical rod with a tilted frame causes observers to misperceive the orientation of the rod in the direction of the frame (Ehrenstein, 1925; Kopfermann, 1930). We here present the opposite effect, where the orientation of inset elements affects the orientation of the surrounding frame in the opposite direction. This result reverses the well known effect of frames of reference, whose notion suggests a unidirectional influence of the surrounding including frame on the included elements.

The reversal effect is clearly demonstrated in Fig. 7, where the white bars, inset within the squares, tilt each square in a direction opposite to the smaller angle created by the rectangle and the square, thus apparently increasing the acute angle. This is shown through the whole effect resulting from the organization of the local tilts, according to which «a large square with concave vertical and convex horizontal sides in Fig. 7a and, conversely, a large square with convex vertical and concave horizontal sides in Fig. 7b (93)» are perceived. These results imply that the including/included organization can influence the whole shape creating "the concave/convex illusion".

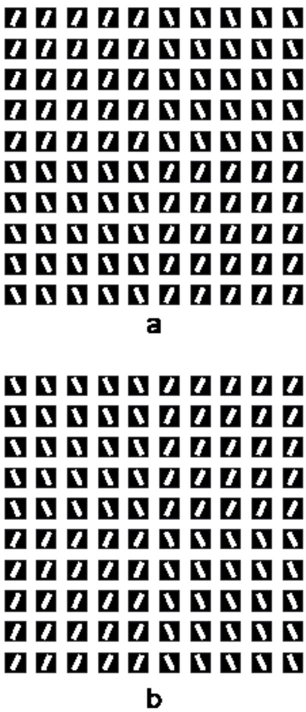


Fig. 7. *The Concave/Convex illusion*: A large square with concave vertical and convex horizontal sides (a) and, conversely, a large square with convex vertical and concave horizontal sides (b).

By rotating the squares of Fig. 7a, as illustrated in Fig. 8, the concave/convex effect is «enhanced when the inset rectangles follow the diagonal of each square (90 - Fig. 8a) and weakened or annulled when they are parallel to the vertical orientation of the square sides (92 - Fig. 8b)». Furthermore the perceived result is switched from diamonds to squares, when, going from Fig. 8a to Fig. 8b, the directional symmetry of the inset rectangles is synergistic with those of the shapes that now appear as tilted squares. Finally, even if the size of the squares of Figs. 8a-b are the same they appear different according to the deformation of the shape induced by the directional symmetry.

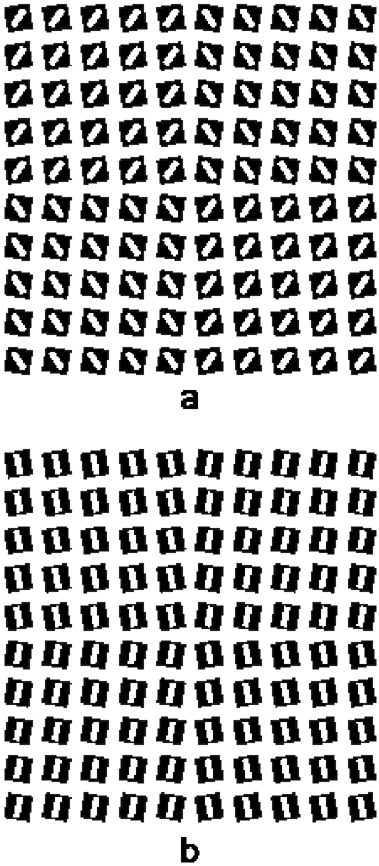


Fig. 8. The Concave/Convex effect is enhanced when the inset rectangles follow the diagonal of each square and weakened or annulled when they are parallel to the side orientation.

In Fig. 9a-b, some effects similar to Figs. 7 and 8 but elicited by simpler inducers are illustrated. Under these conditions the position of the small white squares – along the diagonal or parallel to one side of the squares – polarizes the directional symmetry of each shape like a diamond (Fig. 9a-b) or a square (Fig. 9c) but less strongly than in Figs. 7 and 8. The results of Figs. 9a-b are «whole deformed squares respectively with concave and convex sides (85)», while in Fig. 9c (control), the position of the small inset squares placed parallel to the sides «annuls the concave/convex effect (87)».

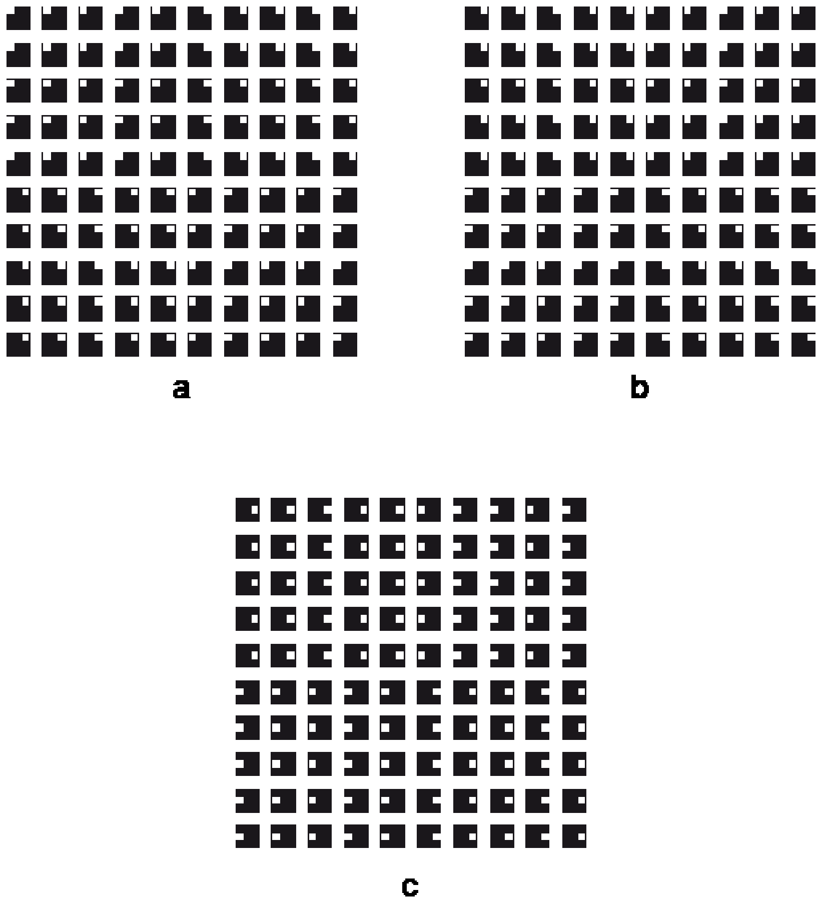


Fig. 9. The Concave/Convex illusion is similar to Figs. 7 and 8 but elicited by simpler inducers.

The previous results demonstrate the role played by the concave/convex illusion that, under our conditions, is the inverse of the Rod and Frame illusion (see Section 3.11) and is also related to the Zöllner, Wundt-Hering, Orbison and the Tilt illusions (Zöllner, 1860; Hering, 1861; Wundt, 1898; Ehrenstein, 1925; Schilder & Wechsler, 1936; Orbison, 1939) as it is illustrated in Fig. 10. Similarly to Fig. 7, the straight sides of the large inset squares of Fig. 10 are illusory deformed: in Fig. 10a «the vertical sides appear convex, while the horizontal ones concave (96)», in Fig. 10b «the opposite of Fig. 10a (94)» is perceived. Even if this effect is reminiscent of the Zöllner, Wundt-Hering, Orbison and the Tilt illusions, it differs from them because it does not contain intersecting lines.

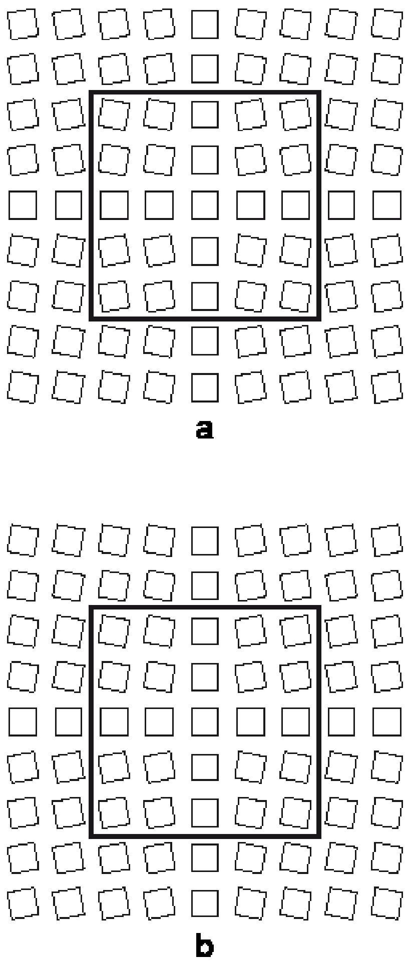


Fig. 10. The Concave/Convex effect: the sides of the large square appear convex and concave.

3.9. The Trapezoidal Illusion

Our conditions are more complex than those predicted by known illusions. In fact, they include also other kinds of effects that we called "the trapezoidal illusion" illustrated in Fig. 11 (Pinna, 1990).

In Fig. 11, the rotation of columns of squares in opposite directions induces: «a shape deformation of the vertically/horizontally oriented squares, placed in between the two columns, that both locally and globally appear as having a trapezoidal shape (91 - Fig. 11a, b, d, e)»; «a whole anti-clockwise tilt of the large square which contains the empty tilted small squares (88 - Fig. 11c)» and «a convex/concave deformation of the large square where the empty small squares are included (85 - Fig. 11f)». The shape deformation can involve the whole perimeter surrounded by the tilted squares (Fig. 11e) or the perimeter surrounding them (Fig. 11c, d, f). This trapezoidal effect clearly demonstrates the role of the directional symmetry and the role of the form of shape as a level of organization different from the form of grouping.

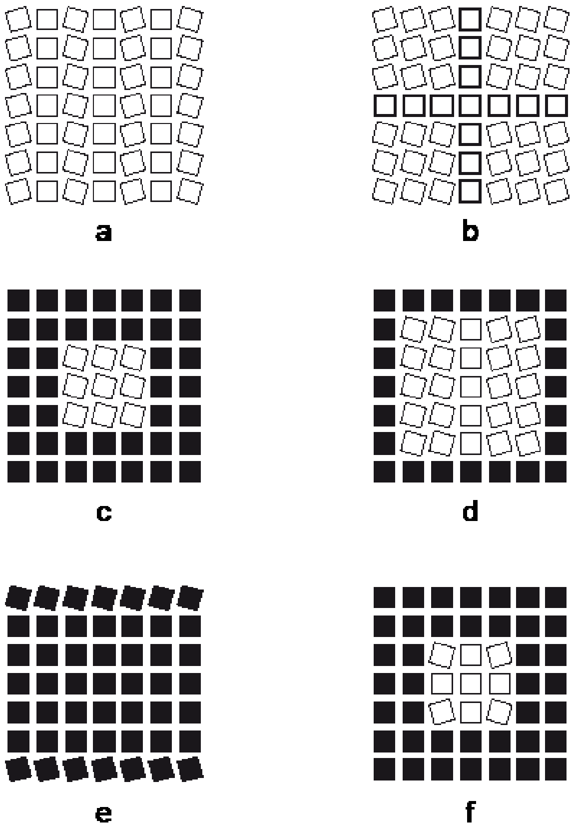


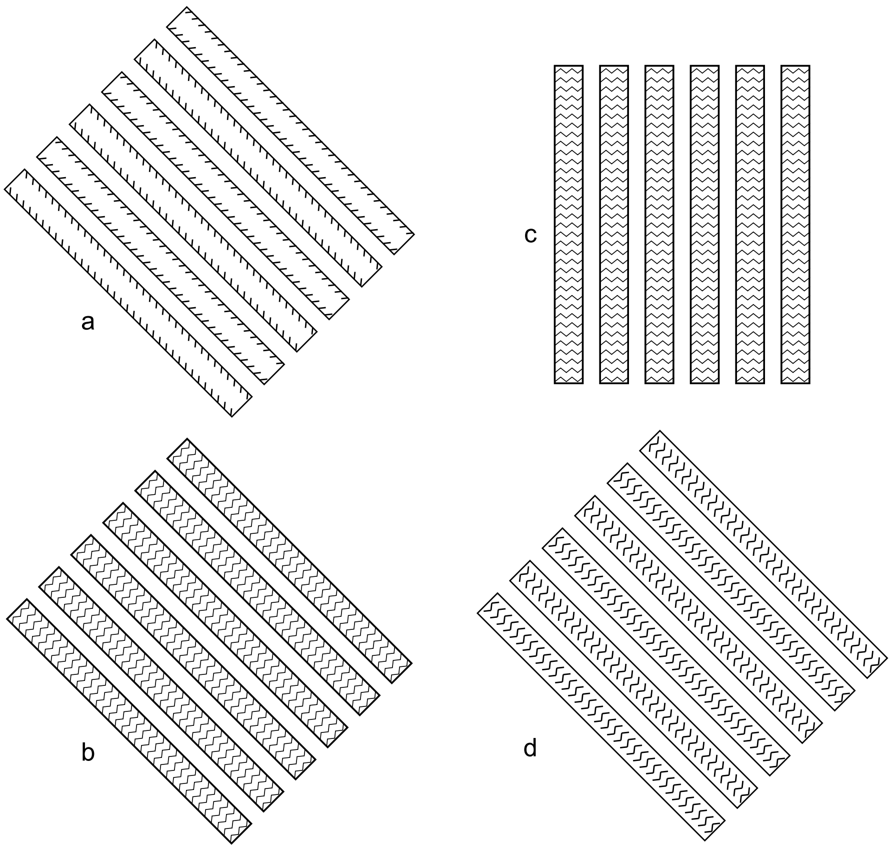
Fig. 11. *The Trapezoidal Illusion*: trapezoid deformations.

3.10. Undulation and Twist Illusions

The complexity of the interaction between the form of grouping and the form of shape is shown in the next figures, where the shape of the inner texture influences the whole shape differently from what is expected from the Zöllner illusion.

In the Zöllner illusion parallel lines are perceived as being tilted in a direction perpendicular to the intersecting oblique segments (see Figs. 12a): «the geometrically parallel rectangles are perceived converging and diverging (88)» as expected from the Zöllner illusion. The most invoked explanation of this illusion is based on the principle of perceptual enlargement of acute angles.

By continuing the oblique segments of Fig. 12a, so that each of them becomes the external component of a zigzag path, an array of parallel horizontal zigzags is created within the rectangles. Under these conditions the local geometrical properties of the stimulus are the same as the ones of Fig. 12a. If the principle of perceptual enlargement of acute angles is valid, under these conditions Zöllner's tilt should be expected. However, this is not the case. In fact, the shape of the



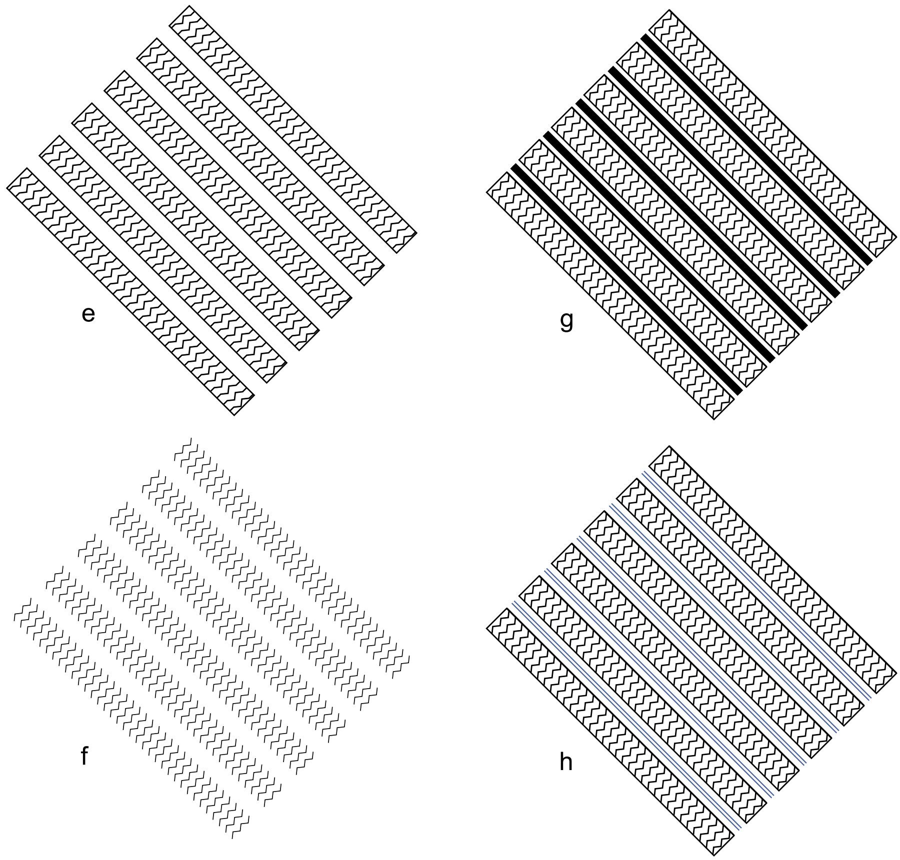


Fig. 12. *The Undulation and Twist Illusions*: (a) Zöllner illusion. (b) The longer sides of the rectangle appear clearly undulated. (c) The undulation effect is clearly perceived when the rectangles are orientated vertically/horizontally. (d) The undulation is perceived without intersecting the sides of the rectangles and (e) when the intersecting segments are perpendicular to the sides of the rectangles. (f) By removing the target parallel lines, the illusory undulation is perceived in the alignment of the zigzag terminators. (g-h) The straight edges in between the rectangles appear twisted.

rectangles is influenced by the shape of the parallel zigzags and by their grouping in a homogeneous texture: «the longer sides of the rectangle appear clearly undulated (93 - Fig. 12b, see also Pinna, 1990)». This is what we called "the undulation illusion".

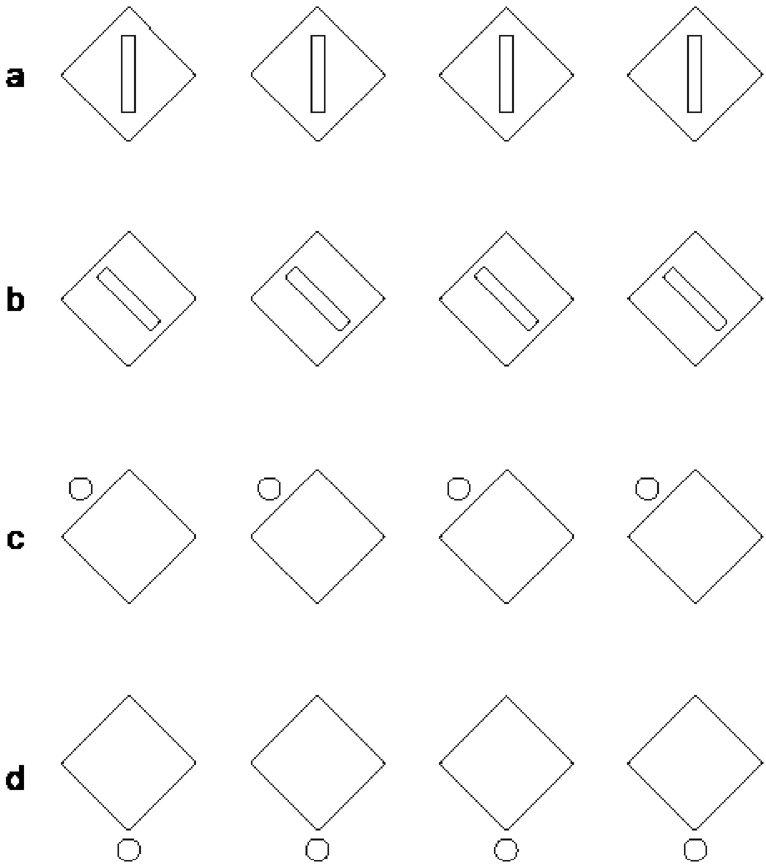
The main phenomenal properties of the illusion are the following. (i) Like Zöllner's tilt, the undulation illusion is enhanced by rotating the stimulus by 45° but it is clearly perceived when the rectangles are orientated vertically/horizontally (86 - compare Figs. 12b-c). (ii) The zigzags induce undulation at a long distance without intersecting the sides of the rectangle (88 - see Fig. 12d). (iii) The perceived undulations of the two longer sides of the rectangles do not appear parallel but opposite curved with concave and convex alternations (81). (iv) By increasing the width of the rectangles the strength of the undulation increases accordingly (83 - not illustrated). (v) The undulation is also induced when the intersecting segments are perpendicular to the target parallel lines (88 - see Fig. 12e). Under this condition no Zöllner's tilt is expected, as a consequence the undulation illusion is a different new illusion. (vi) By increasing the width and the spatial frequency of the zigzags, the strength of the undulation decreases (81 - not illustrated). (vii) By removing the target parallel lines, the illusory undulation is perceived either in the alignment of the zigzag terminators or, if the conditions are favorable, in the resulting line-induced illusory contours (89 - see Fig. 12f, Ehrenstein, 1941). (ix) The undulation persists even without the interruptions of the zigzags in the spaces among the rectangles (86 - not illustrated) and by replacing the zigzags with wavy lines (85 - not illustrated).

When a black bar is inserted in between each couple of adjacent rectangles another effect emerges: «the straight bars appear twisted (91 - Fig. 12g)». If two parallel stripes are now inserted, «each of them appears twisted and both intertwine (89 - Fig. 12h)». We called this phenomenon "the twist illusion". The phenomenology of the twist illusions is analogous to the one of the undulation illusion. These results suggest an explanation in terms of long range induction of undulation and twist due to nearby zigzagged perpendicular orientations. The undulation induction may derive from a stage of push-pull competition between overall like-orientation at nearby positions followed by a push-pull competition of perpendicular orientations at the same position (Grossberg & Mingolla, 1985). The same idea can also be expressed in terms of grouping of the inner pattern and the surrounding boundary contours, whose shape is influenced by the grouping of zigzags that induce an undulated directional symmetry along the boundaries. The grouping-shape dynamics are similar to those illustrated in the next Section.

3.11. The Inverted Rod and Frame Illusion

The role of the directional symmetry in forming the shape of a square is clearly shown in Fig. 13a-d, where «the square shapes within the four rows appear as diamonds (86 - Fig. 13a and 13d) or tilted squares (87 - Fig. 13b and 13c)» respectively by virtue of the orientation of the inner rectangle (Fig. 13a-b) or of the position of the circle (Fig. 13c-d). We called these effects "the inverted rod and frame illusion". Just as the rectangles determine the directional symmetry of the square shapes in the inverted rod and frame illusion, in the same way the zigzags determine the undulated directional symmetry of the rectangles in the undulation illusion.

A more subtle observation of Fig. 13 reveals that «the square shapes appear slightly elongated like a rectangle in the same direction as the inner small rectangle and the circle (81)». By changing the directional symmetry not only does the shape change but also the apparent tilt of the shapes changes: «the shapes perceived as squares are perceived more clearly rotated anti-clockwise than the diamond shapes (80)». It is worthwhile noticing that in Figs. 13b-c there are two different orientations of the directional symmetry: the strongest and local one is due to the orientation of the rectangles and to the position of the circles; the weakest and global one is due to the alignment of the square shapes that is in favor of the vertical orientation and hence in favor of the diamond shape. This implies that in Figs. 13b-c, the two directional symmetries are not synergistic like in the other two figures but pitted one against the other. The grouping principles cannot explain the form of shapes in any of these cases and especially the one of Fig. 13c-d without invoking the meta-principle of directional symmetry. Under these conditions, the notion of directional symmetry cannot be assimilated or considered like a grouping principle. In fact, it does not form the grouping but the shape.



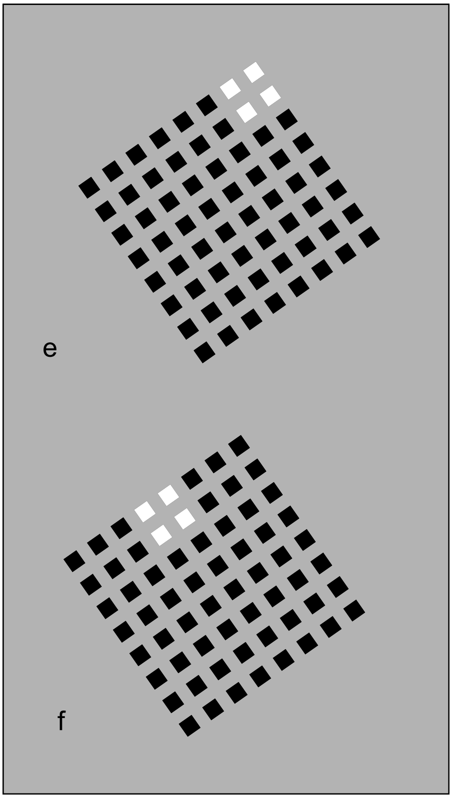


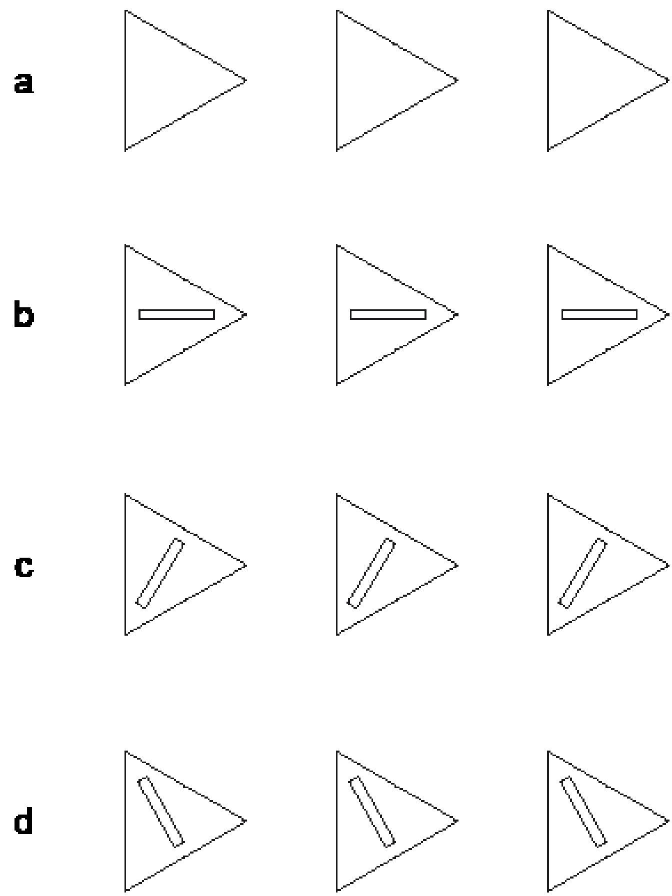
Fig. 13. *The Inverted Rod and Frame Illusion*: The shapes within the four rows appear as diamonds (a-d) or tilted squares (b-c) respectively by virtue of the orientation of the inner rectangle (a-b) or of the position of the circle (c-d). The grouping and the position of the white components define the shape: diamonds (e) and squares (f).

A further demonstration of the necessity of this distinction is illustrated in Fig. 13e-f, where the grouping and the position of the white components define the directional symmetry that forms the orientation and the shape of the small and the whole elements («diamonds - 83» in Fig. 13e and «squares - 86» in Fig. 13f). The inverted rod and frame effect can also influence the pointing of triangles as shown in the next Section.

3.12. The Pointing Illusion

The directional symmetry, due to the alignment of the equilateral triangles (see Fig. 14a), determines that they are «pointing toward right (84)», even if, as equilateral triangles, they can theoretically point in the direction of the other two vertexes. Under these conditions, the directional symmetry corresponds to the configural orientation effect studied by Attneave (1968), Palmer (1980, 1989) and Palmer & Bucher (1981). In stimuli like those illustrated in Fig. 14a, these authors investigated the pointing of equilateral triangles aligned along their axis of symmetry or along one of their sides. They demonstrated that the perception of local spatial orientation (the pointing of each triangle) is determined by the global spatial orientational structure.

In Fig. 14b, the orientations of the directional symmetries, the alignment of the triangles and rectangles and the orientation of the rectangles are synergistic. Under these conditions, «the triangles appear pointing more strongly than in Fig. 14a toward right (93)». This is not the case of Figs. 14c-d, where the two directional symmetries are oriented in different ways one against the other. «The rectangles appear oriented respectively toward the bottom-left hand and the top-left hand corners of the triangles (90)», while the triangles due to the configural orientation effect are oriented always toward the same right direction. Under these conditions the configural orientation effect is ineffective and the pointing of each triangle is due to the directional symmetry induced by the inset rectangles. We called this "the pointing illusion". The form of shape involves not only the pointing but also the shape of each equilateral rectangle that appear now like «isosceles triangles with the two longer sides converging in the direction of the apparent pointing (89)». As a consequence not only the pointing but also the tilt of each triangle in Fig. 14b is perceived different from those of the ones in Fig. 14c-d. «The perceived orientation appears tilted toward the direction of the pointing (90)».



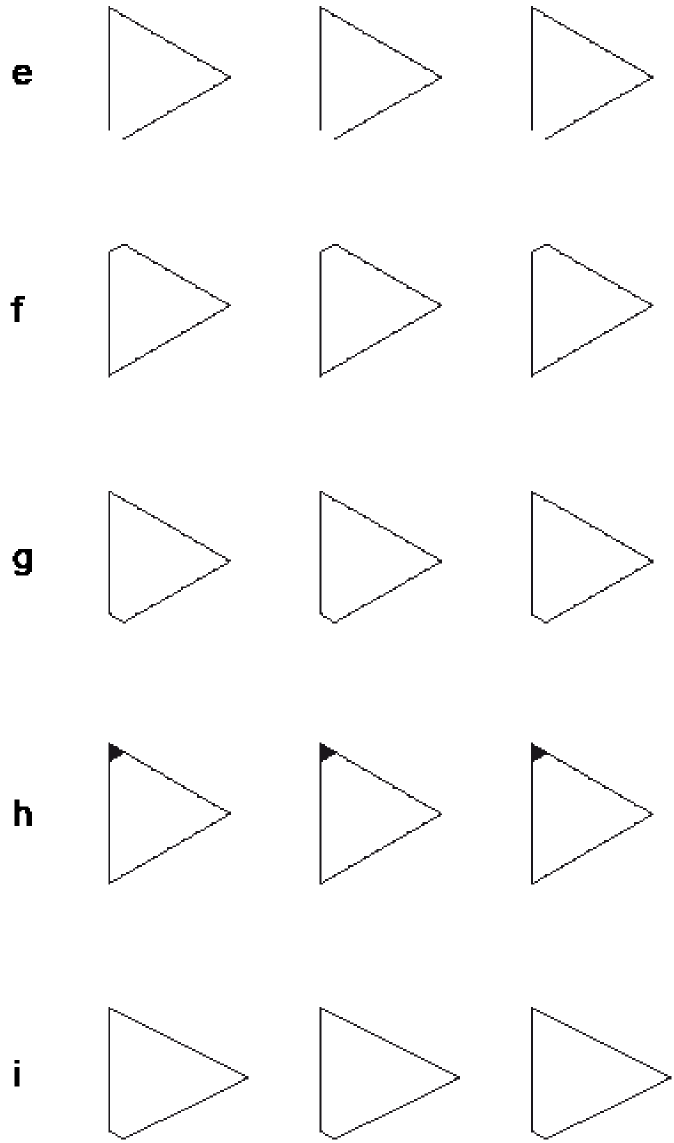


Fig. 14. *The Pointing Illusion*: The directional symmetry determines the pointing of rows of triangles in different directions.

There are other ways to create a strong directional symmetry that forms the shape and its components like the apparent tilt and the pointing (see Fig 14e-i). In Fig. 14e the beveled or cut vertexes of the triangles define the directional symmetry and as a consequence «their pointing (bottom-left hand - 92) and their shape (equilateral triangle that now appears slightly as isosceles - 93)». Similar effects are perceived in Figs. 14f-i, where beveled triangles (91) or triangles with one blackened vertex (90) are the phenomenal inducers of the directional symmetry. In Fig. 14i, isosceles triangles with the longest sides converging toward the right direction are beveled at the bottom-left hand vertex. The resulting effects are «three scalene triangles pointing toward the bottom-left hand corner (89)». The directional symmetry forms the shape (scalene triangles) and its attributes (pointing and orientation). Even if the form of grouping plays some role, its difference with the form of shape is unambiguous.

3.13. The Loss of Collinearity Effect

There is another shape attribute derived from the grouping principle of good continuation and determined by the directional symmetry: the perceived collinearity. In Fig. 15a, «circles and concentric dots appear collinear (96)» as they really are. Giovannelli (1966) discovered a deformation of the dot collinearity by changing the arrangement of the surrounding circles as illustrated in Fig. 15b. Under these conditions, «the dots do not appear collinear but slightly misaligned or lightly zigzagged (91)». This effect was attributed (see also Kanizsa, 1972) to the conflict, i.e. to the predominance of the relative position of the wider frame of reference (the circles) over the enclosed components (the dots).

Unlike Kanizsa, we suggest that the main factor responsible for the loss of collinearity of Fig. 15b, is the interaction between the two directional symmetries due to the circles and the dots and not to the effect induced by the wider frame of reference. In fact, in Fig. 15c, the apparent misalignment does not concern the dots but the circles and therefore the wide frame of reference that appears now misaligned by the included components thus creating the opposite of the Giovannelli illusion which we called "the loss of collinearity effect": «the circles surrounding the dots appear slightly misaligned and alternately shifted up and down following the direction and the position of the dots (86)». In Fig. 15d, the rotation of the lines within the circles induces their «slight misalignment and loss of collinearity (85)». (Compare this result with the control illustrated in Fig. 15e). A similar effect (83) induced by the position of the missing part within each circle can be perceived in Fig. 15f. The change of the distance among the dots can apparently change not only the collinearity among the circles but also their distance as shown in Fig. 15g, where «the circles are not perceived as equidistant (86)». Even if the form of grouping plays some role in eliciting these effects, it cannot fully explain them without invoking the directional symmetry and another kind of perceptual organization like the form of shape.

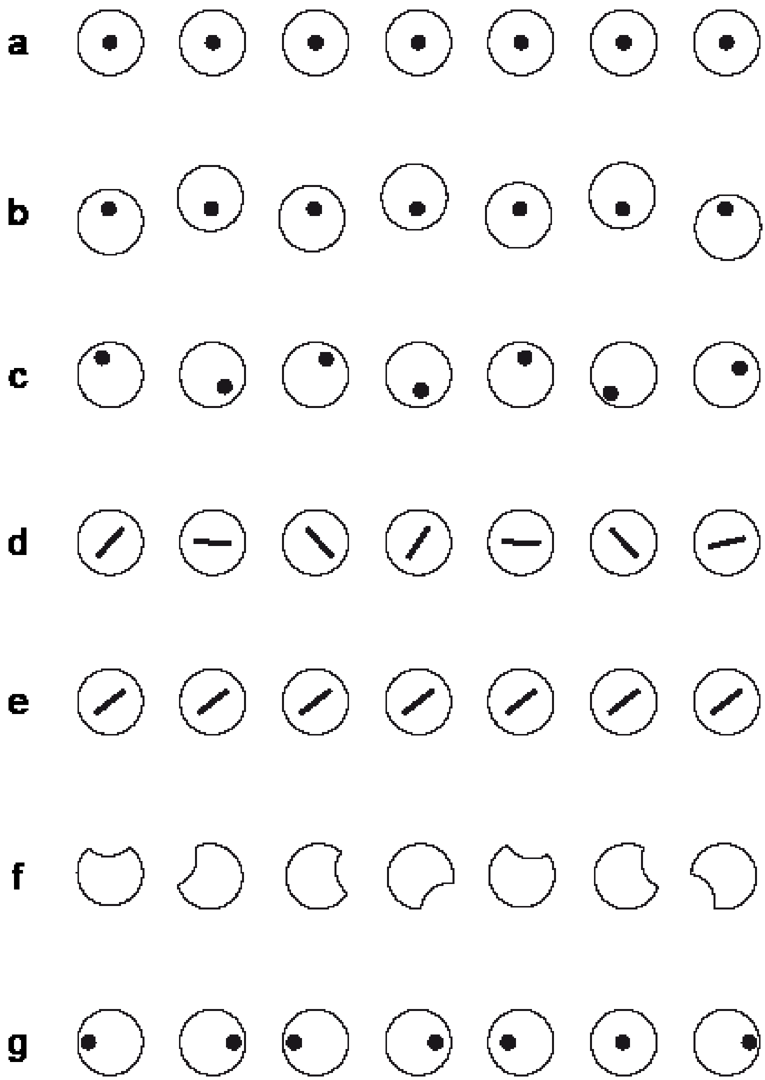


Fig. 15. *The Loss of Collinearity Illusion*: The opposite of the Giovannelli illusion.

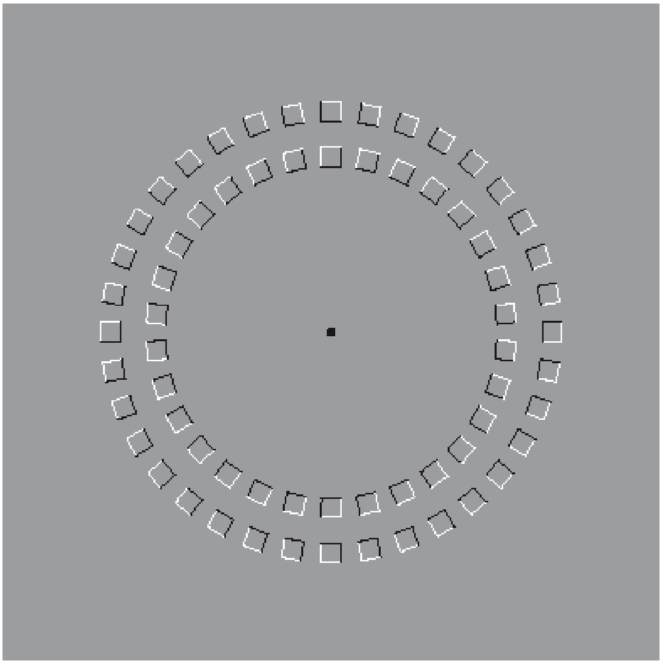
3.14. The Shape of Motion Due to Grouping

Two types of orientation cues can instill "polarity" to a basic square element: (i) cues of the explicitly oriented form (explicit orientation polarity), i.e. the orientation and tilt of the square itself, and (ii) cues rendered by the internal organization of luminance – such as the diagonal organization of the narrow black and white edges in the square (implicit orientation polarity) illustrated in Fig. 16a, i.e. the dominant orientation along its internal diagonals of asymmetry.

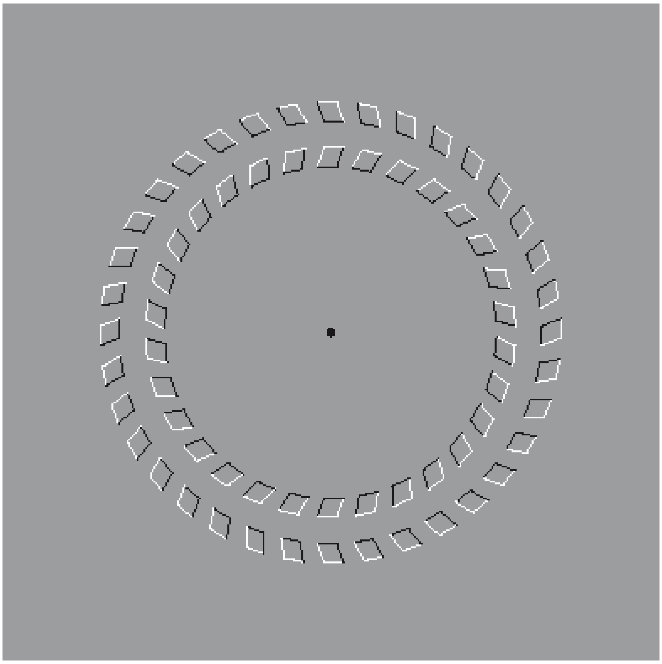
The role of implicit orientation polarity is basic to elicit motion starting from the grouping of elements (Pinna, 1990, 2009; Pinna & Brelstaff, 2000; Pinna & Gregory, 2009). In Fig. 16a, the squares, grouped by proximity in two concentric rings with opposite implicit orientation polarity, elicit an illusory «counter rotation of the two rings (97)» while the head is moved towards the figure or away from it, and the gaze is fixed on the central dot (Pinna & Brelstaff, 2000). Direction-selective neurons at early stages of visual processing, signalling the speed of the diagonal orientation polarity of its preferred orientation through the receptive field, may be responsible for the local motion vectors perpendicular to the orientation polarity (aperture problem; Mather, 2000; Pinna & Brelstaff, 2000; Bayerl & Neumann, 2002; Gurnsey et al., 2002; Morgan, 2002; Fermüler & Malm, 2004; Pinna & Spillmann, 2005). The local motion signals within single squares group into a whole circular flow according to the proximity factor (Pinna & Gregory, 2009).

In Fig. 16b, the square elements are grouped circularly by proximity and similarity of shape, i.e. the opposite rhombic skew of the square elements in between the two concentric rings. Within these conditions «the counter rotating effect is enhanced (98)» due to the synergistic orientation of both the implicit and explicit orientation polarities. When the implicit diagonal orientation polarities and the explicit orientation of the skewed squares are antagonistic, the strength of «the illusory counter rotation effect is strongly reduced (97 - Fig. 16c)».

«The apparent rotation is annulled (92)» when the implicit orientation polarities and squares do not change their relative orientation in their circular arrangement (Fig. 16d). Under these conditions the organization of the implicit orientations induce «a sliding motion in a direction roughly perpendicular to the true motion (95)». The effect can be also obtained when the eye follows the tip of a pen moved horizontally or vertically across the pattern.



a



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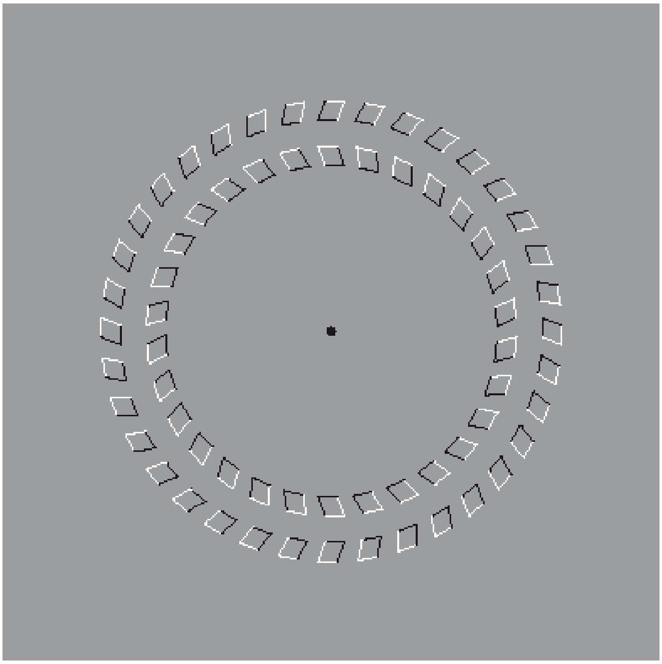

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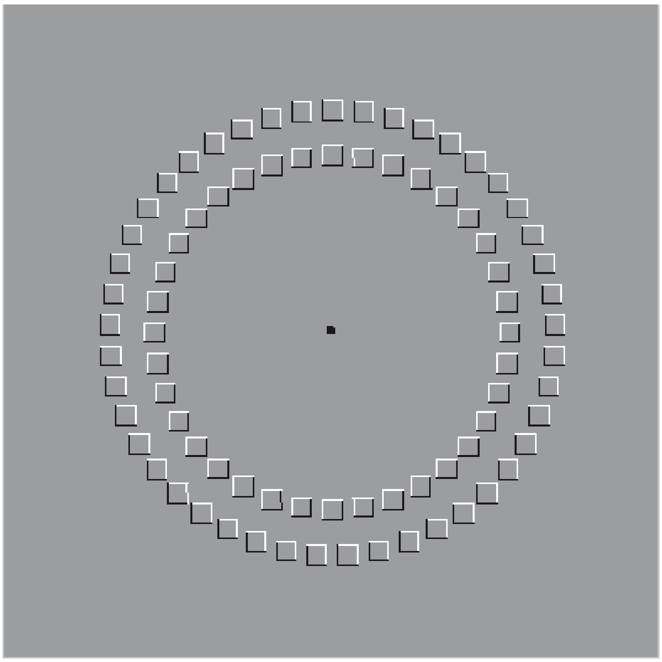

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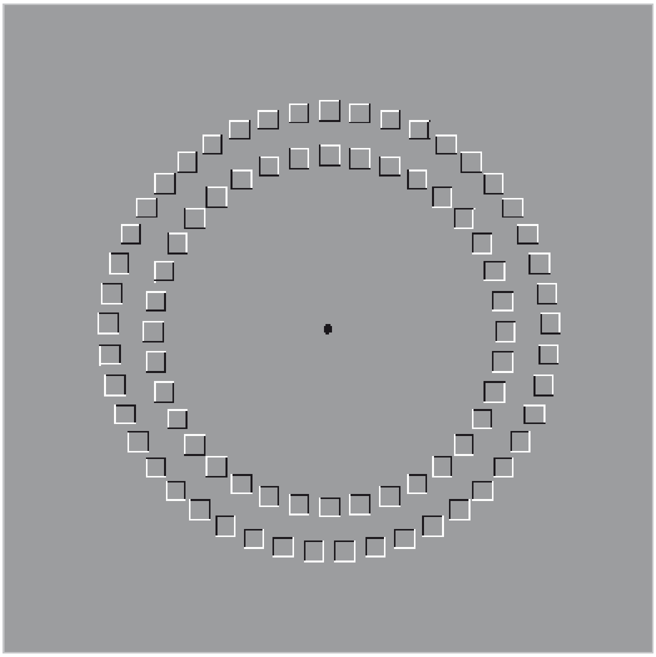

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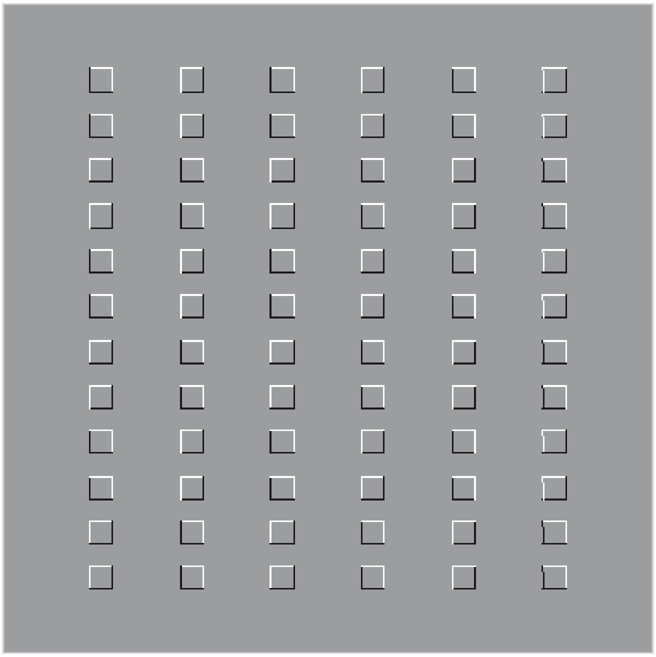


f

Fig. 16. *The Counter Rotation Illusion*: (a) The squares elicit an illusory counter rotation of the two rings while the head is moved towards the figure or away from it, and the gaze is fixed on the central dot. The counter rotating effect can be (b) enhanced, (c) reduced, (d) annulled, and (e) restored. (f) A waving and twisting apparent motion is perceived when the gaze follow the tip of a pen moved vertically across the pattern.

«The apparent rotation is restored (93)» if groups of at least four squares equally oriented (see Fig. 16d) show different implicit orientation polarities (Fig. 16e). «The apparent rotation is now weaker than the one of Fig. 16d (92)» because within each group the squares have the same orientation polarity, i.e. they do not change radially. Finally, the alternation of implicit diagonals, organized in columns, as illustrated in Fig. 16f, produces «a waving and twisting apparent motion (86)» when the gaze follows the tip of a pen moved vertically across the pattern. The motion vectors are integrated according to the organization in columns induced by the gestalt principle of proximity.

These results clearly demonstrate the role of the Gestalt principle of proximity, similarity and common fate in forming the shape of the perceived motion. However, the Gestalt principles cannot explain this motion illusion but only the directions of the neural integration processes occurring among local motion vectors. This integration process is equivalent to the direction symmetry demonstrated in the previous sections.

3.15. The Watercolor Illusion and the Illusion of Shape

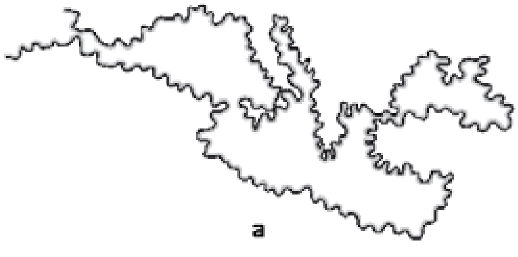
In Fig. 17a-b the watercolor illusion is demonstrated (Pinna, 1987; Broerse & O'Shea, 1995; Broerse, Vladusich & O'Shea, 1999; Pinna, Brelstaff & Spillmann, 2001; Pinna, Werner & Spillmann, 2003; Pinna & Grossberg, 2005; Pinna, 2005b, 2008b, 2008c; Werner, Pinna & Spillmann, 2007; Pinna & Tanca, 2008; Tanca & Pinna, 2008): purple undulated contours flanked by orange edges are perceived as «two undefined shapes evenly colored by an opaque light veil of orange tint, with a clear surface color property (*Erscheinungweise der Farbe*, Katz, 1911, 1930) spreading from the orange edges (94)». «The two undefined shapes manifest a strong figure-ground organization and a solid figural appearance comparable to a bas-relief illuminated from the top. The complementary regions appear as holes or empty spaces (91)».

In Fig. 17c-d «the Mediterranean Sea and parts of Great Britain and Ireland (94)» immediately and clearly emerge as figures and appear illusorily colored with the same orange tint as in Figure 17a. These effects are obtained by reversing the orange and the purple lines.

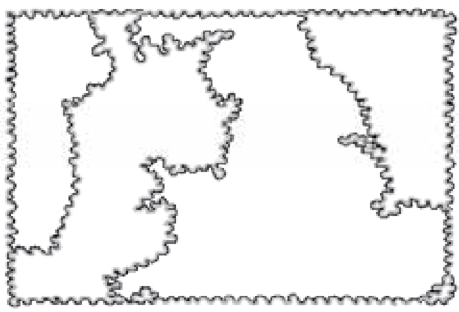
The watercolor illusion demonstrates that, all else being equal, given an asymmetric luminance contrast on both sides of a boundary, the region, whose luminance gradient is less abrupt, is perceived as a figure relative to the complementary more abrupt region perceived as a background. This principle was called "asymmetric luminance contrast principle" of figure-ground segregation and it is contained within the figural effect of the watercolor illusion (Pinna, 2005b).

The asymmetric luminance contrast principle can influence not only the form of figure-ground segregation but also the form of shape, as it can be demonstrated by using the Wundt-Jastrow illusion (Jastrow, 1891; Müller-Lyre, 1898; Wundt, 1898). In this illusion two identical tapering annular or ring segments or trapeze placed one above the other appear clearly unequal in size. The figure that appears larger is the one with the longer side in contrast with the shorter side of the other figure. The effect can also be obtained by using triangles.

In Fig. 17e-f, the watercolor illusion can reverse the effect of the different size of the Wundt-Jastrow illusion by switching the figure-ground organization of the triangles and then their pointing in one (top) or in the opposite (bottom) direction. Under these conditions, «the two sets of triangles appear diverging respectively towards the top (Fig. 17e) or the bottom (Fig. 17f) according to the figure-ground segregation (88)». In other words, «when the triangles are perceived with the head up the global organization and alignment of the triangles diverge (88) and *vice versa* (86)». It is worthwhile noticing that in both figures the contour conditions are the same, only the purple-orange spatial position is reversed. This reversion is similar to the "duck-rabbit" effect (Ehrenstein, 1930, 1954). The figure-ground segregation, induced by the asymmetric luminance contrast principle, influences but does not fully explain the shape formation of the Wundt-Jastrow illusion that is strongly related to the directional symmetry.



a



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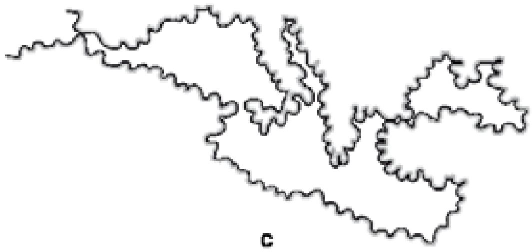

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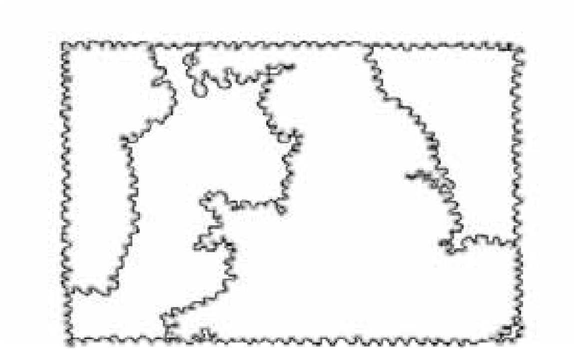

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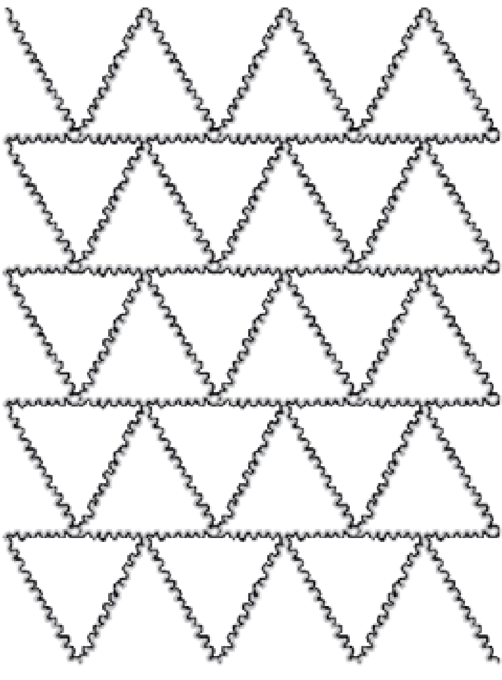

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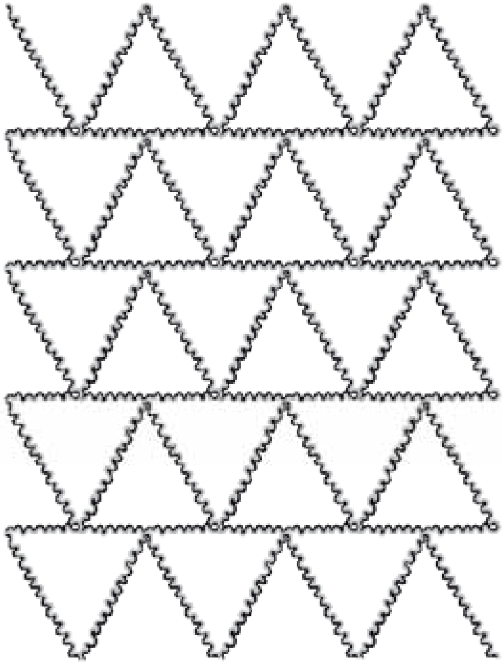


f

Fig. 17. *The Watercolor Illusion*: (a-b) Purple undulated contours flanked by orange edges are perceived as two undefined shapes evenly colored by an opaque light veil of orange tint, with a clear surface color property spreading from the orange edges. (c-d) The Mediterranean Sea and parts of Great Britain and Ireland watercolored. (e-f) The watercolor illusion can reverse the effect of the different size of the Wundt-Jastrow illusion by switching the figure-ground organization of the triangles.

3.16. Limits of the Forms of Grouping and Shape: The Perception of Absence

So far, these results can be explained within the more general problem of formation of shape, where the directional symmetry can be considered as the basic principle creating both the local and the whole shapes and their attributes. In addition, these phenomena concerned interactions as well as distinctions between the form of grouping and figure-ground segregation, as described by the Gestalt principles, and the form of shape that complements the form of grouping in a more holistic way. The form of grouping puts together the elements and the form of shape draws the perceptual structure and the spatial attributes of the figure both locally and globally. The form of grouping cannot explain the form of shape and *vice versa*, but both forms are reciprocally related.

There is another kind of form that cannot be explained by the forms of grouping and shape. This new form is introduced by a variation of Fig. 13e-f illustrated in Fig. 18.

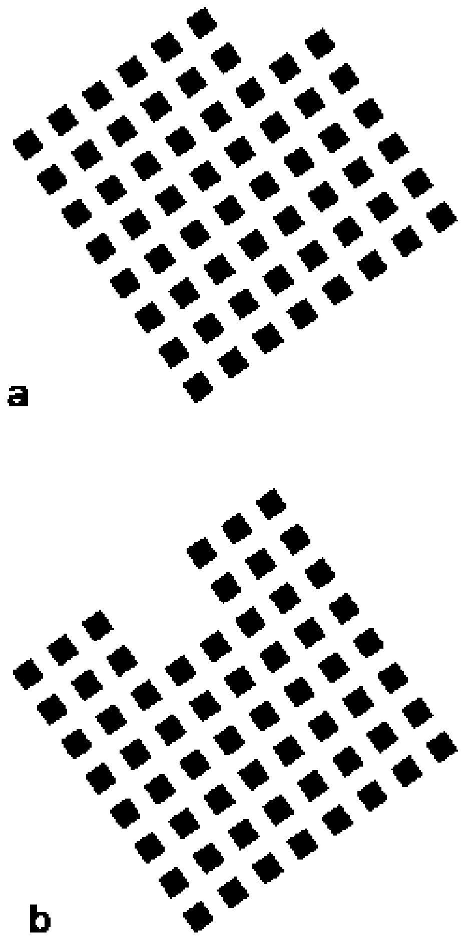


Fig. 18. Given the empty space in the top hand corner (a) or on the top-left hand side (b) of the whole figures, the directional asymmetry creates respectively diamonds and squares both locally (in each element) and globally.

In Fig. 18, the form of grouping puts the black elements together, parallel to the sides of the whole figures on the basis of the proximity principle. Given the empty space in the top hand corner (Fig. 18a) or on the top-left hand side (Fig. 18b) of the whole figures, the directional asymmetry creates «diamonds (88)» in Fig. 18a and «squares (87)» in Fig. 18b «both locally (in each element) and globally (in the whole figure) - 87». It is worthwhile noticing that the directional symmetry is different under these conditions from the gestalt principle of symmetry that defines uniquely the grouping arrangement of the elements but not the shape of the elements and of the whole figure. In other words, the gestalt grouping by symmetry does not instill polarity to the shape. Therefore, the results of the form of shape are different from the results of the form of grouping.

The results of Fig. 18 are not only diamonds and squares, but, more precisely, «a diamond with the top corner missing or cut with the absence having a diamond shape (89)» and «a square with a missing or cut piece in the region of the top-left hand side with the absence having a square shape (88)». The complexity of these forms is far beyond the forms of grouping and shape. It contains more "things" or couples of interrelated things – diamond/square and missing/cut pieces – that do not exist in themselves and that cannot be explained without invoking a new form of perceptual organization. In fact, on the basis of the principles of proximity, similarity, good continuation and *prägnanz*, there is not a large diamond or a square but respectively an irregular shape with six sides having the same size in pairs (Fig. 18a) and an irregular shape with eight sides, five and three of which have the same size (Fig. 18b). These are the results of the forms of grouping. The form of shape, through the directional symmetry, can only draw the shape of the whole irregular shapes but it cannot say anything about the complex phenomenal description previously reported. Missing parts, cut or absences are not "words" of the vocabulary of the two forms of grouping and shape. Furthermore, because diamonds and squares can be formed as such only by virtue of the missing parts, cuts or absences, they emerge with these meanings only beyond the forms of grouping and shape. This is all the more true on the basis of the antinomic properties of the absences that are "something" and "nothing" at the same time. They are not like the background, but manifest figural properties. Conversely, they are not figures but like the background they are nothing. Even if under the form of grouping and figure-ground segregation the emptiness is opposite to the figureness that is a solid filled object property (Rubin, 1921), in the case of the absences, the dichotomous complementation is much more complex and can be understood only in the light of a new form of organization. This is the form of meaning.

4. From the Illusion of Shape to the Illusion of Meaning

More complex results in terms of form of meaning than those of Fig. 18 are illustrated in Fig. 19. In Fig. 19a, good continuation, *prägnanz* and closure principles group all the sides of the figure to form «a pentagon (2)». The same result is expected in terms of form of shape. Nevertheless, the phenomenal result is «a beveled square (98)». Within the forms of grouping and shape there is neither a "square", nor a "beveling" or an "a". "A beveled square" is the result of the form of meaning, through which a complex set of meanings reciprocally related emerges.

The way the meanings are related is similar to a language, with a subject, a verb and a complement that is here implicit (a square beveled by something). This organization does not change by changing the specific meanings as illustrated in the following examples. The invariant structure is the foundation of the form of meaning.

In Fig. 19b, neither the gestalt principles nor the form of shape can explain: «a square perimeter whose top right corner is absent, missing, deleted or cut (89)». In Fig. 19c, «the glass square is broken in a corner (90)». The square appears «made of glass» (95). In Fig. 19d, «a gnawed or nibbled square (90)» is perceived. The emergence of new meanings involves also the matter of the square that changes by changing the happenings (compare Figs. 19c-d). In Fig. 19e, «a square made up of a soft material like plastic appears deliquescing (91)». None of these meanings are expected and can be fully explained by the forms of grouping and shape. Furthermore, the happenings are like meanings of some kind of perceptual sentence or predicates of the main subject which is the square. They show the action performed (a happening) and the state attributed to the subject. The form of meaning of these figures includes not only a happening (the verb) but also other objects/meanings governed by the verb and modifying it. These secondary meanings are complements that complete the subject and specify the verb. Phenomenally, the implicit or explicit complements are the how, the what and the why the cut, the bevel, the shatter and the gnaw are determined. The complements can be easily perceived in Fig. 19f where «the square is deformed by a scorch (87)». "Deformation and scorch" are meanings of the happening that qualify the square and its matter, but also the happening itself, suggesting how the square was deformed, or scorched.

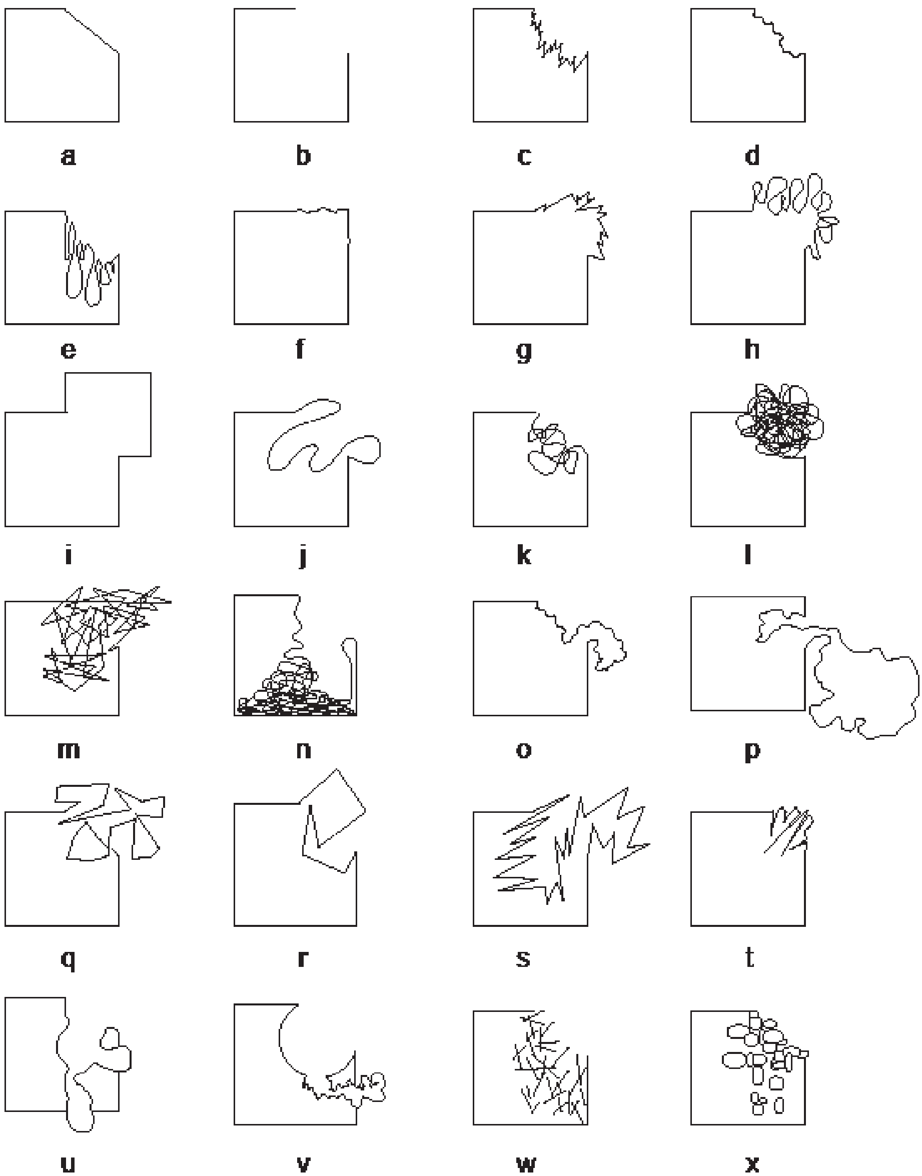


Fig. 19. *The Illusion of Meaning*: A square showing different kind of happenings – something different happens to each square (see text).

In Fig. 19g the happening appears like «a crystalline growth (89)». The square of Fig. 19h appears «spreading some very dense liquid matter (88)». In Fig. 19i «the square splits into two (91)». The square of Fig. 19j «is deformed like rubber

(87)». In Fig. 19k, «the square is like a cable tangled up in a corner (86)». In Fig. 19l «the corner of the square is tangled up or twisted like a ball (88)». The corner of the square of Fig. 19m «is like a steel cable fragmented and mixed (86)». In Fig. 19n «the square is undoing its perimeter at its corner in a strange too long length (87)». The happening of Fig. 19o is like «a strange flimsy tear that does not coincide with the matter missing to the square (85)». The "strangeness" of the previous two figures is a new emerging meaning that is stronger in Fig. 19p, where «a strange huge tear like a giant eructation of quasi-solid matter (83)» is perceived. Also Fig. 19q is perceived as strange and unexplainable: «The growth of the square appears strange and nonlogical (84)». Although the happening is clearly perceived, no univocal words can describe it being nameless and difficult to put into words. This argument leads us to hypothesize that the visual language precedes the spoken language and can be richer than it, i.e. the perceptual language sees something that the spoken language cannot describe. Other happenings without words or which are nameless are illustrated in Figs. 19r-t, «the squares are broken or damaged in a nonlogical and strange way due to some unknown tool or to some reason impossible to define (89)». These happenings require some kind of explanation or deeper observation.

More amazing than these last figures is the square illustrated in Fig. 19u «with a paradoxical happening that is something and a void at the same time: it is something similar to a matter melting, dripping, filling and occluding the base of the square and at the same time similar to a void that appears as an empty or missing space (83)». This kind of part-whole organization does not obey a cognitive logic. In the perceptual language the meanings can be antinomic and paradoxes are allowed. In Fig. 19v, a "happening" occurs to a "happening" and both create a paradox similar to the previous one: «a square with a missing corner having a circular shape with an irregular further missing region that paradoxically occludes the square (87)». The square of Fig. 19w is «a strange square crashing and splintering its corner in a huge and impossible number of pieces (88)». Finally, in Fig. 19x «the square appears transforming itself in a strange kind of crumbling small elliptical pieces (87)».

What is perceived in Figs. 19 are meanings of shapes whose components are grouped according to the gestalt principles. Without the perception of meanings we would have perceived only signs or elements grouped and ungrouped in a shape that includes these elements. This is not comparable with the richness of the meanings and with their complex net of relations similar to a language much richer than the spoken language. Nevertheless, even if the gestalt grouping principles are insufficient to explain the formation of perceptual meanings, they play a basic role, useful to understand the form of shape that is useful to understand the form of meaning. On the basis of the gestalt principles the elements of the previous figures are grouped and ungrouped creating homogeneous wholes. For example, in the case of Fig. 19c, these principles segregate the two horizontal and the two vertical sides from the oblique-zigzagged contour on the basis of similarity. At a very first level, the horizontal lines are segregated from the vertical ones because they have opposite orientations. But at a second grouping stage they are grouped with respect to the oblique-zigzagged contour, because they are more similar than this one: straight vs. zigzagged. All of them are subsequently grouped together on the basis of closure and good continuation. The final result should be an irregular shape. Unfortunately, there is nothing within the gestalt principles referring to the perceptual meanings.

4.1. The Form of Meaning and its Levels of Perception

In Fig. 19, the antinomic properties of both the figures and the absences are isomorphic to two levels of perceptual organizations that can be phenomenally observed and that can be called "ideal" and "contingent" levels. The perception of the happenings (missing, cut, deformation, absence, etc.) is a contingent, specific and direct result of an action which happened to the figure, making it appear incomplete and irregular. Without the happening, however, at an ideal perceptual level, the figure would have been complete and perceived as a square that is the ideal, general and indirect result. This entails that the happening makes the figure appear incomplete and irregular and at the same time complete and regular. In other words, due to the happening the figure appears incomplete (contingent level) to appear complete (ideal level).

The two perceptual levels, specifically in relation to Fig. 19b, can be summarized as follows: the square and the filling-in or completeness of the absence represent the ideal level complemented by the irregular shape and the absence that are contingent perceptual levels. Both ideal and contingent levels can be perceived simultaneously and depend on each other, i.e. they are reciprocally determined. In other words, one level is related to the other, namely one is perceived only if the other is also perceived. Furthermore, they are directly and immediately perceived without any cognitive mediation but as a phenomenal result of an early part-whole organization eliciting perceptual meanings. This new kind of perceptual organization induces the emergence of new meanings including what we previously called "happening", a word used spontaneously by the subjects, and that in Fig. 19b appears specifically as a "missing, absence, deletion or cut". In addition to the happenings, the incompleteness vs. completeness and also the square are emerging meanings. None of these perceptual terms can be explained through grouping and shape formation. Within the form of meaning the phenomenal split into two levels is structurally invariant and independent from the specific emerging meanings.

4.2. The Amodal Wholeness

The ideal and contingent levels are not perceived in the same way: the former is perceived amodally, the latter modally. The complete *whole* (the square) is seen amodally (amodal completeness), while the incomplete *whole* (irregular shape) modally (modal incompleteness). Similarly, the complete *part* (the absence that at the ideal level is filled with what is missing) is perceived amodally, while the incomplete *part* (the absence as it is perceived) modally. Both ways coexist and reinforce each other. Briefly, the square appears as the amodal whole object and the absence as the modal part of it. The square is the result of the *amodal wholeness* completion of something perceived as its visible modal portion. Like the absence, the square is perceived and not perceived at the same time and its amodal whole completion occurs beyond (ideal perceptual level) the absence. It is the absence that makes the square appear as such and to complete amodally beyond it. In other words, the square cannot be perceived with this meaning if the absence is not perceived. Otherwise, the square would be perceived like an irregular shape, and *vice versa*, it is the perceptual meaning of the square that makes the empty space appear like an absence. None of these meanings can exist without the others.

There is a clear link between amodal wholeness and amodal completion (Michotte, 1951; Michotte, Thinès & Crabbé, 1964/1991). Amodal completion occurs when a portion of an object is hidden due to its occlusion behind another object. Under these conditions, the object perceived as occluded is seen as a unitary object, whose boundary contours amodally complete behind the overlapped modal object. The term 'amodal' refers to the fact that even though some object contours are not actually seen, the resulting object appears with a vivid sense of completeness and object unity. By perceiving "a large square partially occluded by a small one", we perceive meanings similar to and with the same phenomenological structure than those illustrated in Fig. 19. The "overlapping" is the happening that induces the amodal wholeness of the occluded object which can now appear unitary at an ideal and amodal level. This implies that the amodal completion can be considered as a subset or as an instance of the more general problem of amodal wholeness.

4.3. Towards a Perceptual Language

The kind of organization of Fig. 19 can be considered as a process of meaning assignment that reveals some kind of primitive perceptual language. One emergent object/meaning is the square that can be phenomenally considered like the subject of the description/proposition, i.e. like the "noun" that refers to a thing and denotes what is described by the "predicate" or like the term of the perceptual "sentence" about which something is affirmed or denied. The square appears to complete itself 'beyond' the absence that "occludes" its wholeness thus eliciting its amodal completion. The absence is like a doing word or a "happening", i.e. something that occurs to the square so that without it the square would have been complete. It follows that the happening is like a visual "predicate" or like a perceptual "verb" of the sentence expressing properties, existence, action or occurrence of the subject.

These phenomenal properties belong not only to the meaningful figures like Fig. 18 and 19 but also to Fig. 13e-f that can be described like «a black diamond/square shape, made up of black small diamond/square shapes, with four white components (88)». Under these conditions, the amodal wholeness creates complete diamond/square shapes and the happenings are represented by the components that are white instead of black as they should be. Also Fig. 1, considered as the closest to the forms of grouping and shape, can be seen in terms of perceptual meanings: «Two large squares/rectangles made up of alternated black and white columns and rows (93)». The term "made up" reveals the happening occurred to the perceptual subject, i.e. the square/rectangle that amodally is perceived homogeneous without the grouping in rows and columns. Furthermore, the following description "small and large squares appear elongated in the same direction as the perceptual organization" shows the following emerging meanings: "squares" that appear or "become" "elongated". The elongation represents the happening of the visual language. The square is the subject and the elongated rectangular shape is the complement. These remarks suggest that every perceptual condition shows the three forms of organization at the same time.

The limiting case can be a square that is the result of a grouping principle like closure that puts together the four sides, but the square is also the result of the form of shape where the square is a figure with a precise orientation, with four vertexes and with a stable inner equilibrium. In terms of form of shape the square is perceptually compared with other shapes like diamond, trapezium, triangle, circle, etc. Furthermore, the square is also the result of the form of meaning. As such it can assume different meanings that go from the square we have previously shown in Fig. 19 to complex emerging meanings shown in art and particularly in Malevich's square. In Suprematism, art is reduced to nothing more than a black square on a white background. The complexity of the nested meanings within Malevich's square reveals the following perceptual paradoxes (see Pinna, 2008a). Malevich's square, having the shape of a square, may be considered a trivial square but it is not a mere square being an artistic abstraction. However, for this same reason, it is a square because, in Suprematism, art is reduced to a square. Therefore if art can be reduced to a square, all the squares can be art, yet all the squares are not Malevich's squares, hence they cannot be art but if they cannot be art, art cannot be reduced to a square and, as a consequence, Malevich's square is just a square but as such it can be art because art, in Suprematism, was reduced to a square. Every square is and, at the same time, is not a Malevich's square: everybody can create a black square on a white background similar to Malevich's square but this new square is not a square in the sense of Malevich's square. There is only one Malevich's square. All the others are only squares and not Malevich's squares. However, all the squares can be art in the sense of Malevich's square. For a complete explanation of these paradoxes see Pinna (2008a).

The crossroads of different forms of perceptual organization and their complementation represent a turning point in the evolution of human vision. In fact, the increasing of complexity and abstraction, going from the form of grouping to the form of meaning, can be considered as the evolutionist demonstration of a new and "intelligent seeing", peculiar to the human species, from which a holistic visual communication among objects and a "visual language" emerge.

4.4. The Illusion of Meaning

The three forms of organization – grouping, shape and meaning – are present all at the same time in every perceptual pattern. There is no perception without the co-presence of the three forms. Nevertheless, there are several conditions where one of these forms can be seen more easily than the others and where the limits of one of these forms is more clear if compared with the other forms. This is the case of the following figures where the form of meaning is dominant over the others. In Fig. 20a, alternated filled (black) and empty (white) squares are perceived as «a checkerboard (100)». This result is not a shape in the sense of the form of shape organization. It is due to grouping, although it is beyond grouping. The alternation creates some kind of homogeneous structure with a precise meaning. This meaning is not due to its being a checkerboard because we know and use it as a checkerboard, but we know and use it as a checkerboard since it has that meaning. In Fig. 20b, «a large piece of checkerboard appears removed from the top-right hand corner (93)».

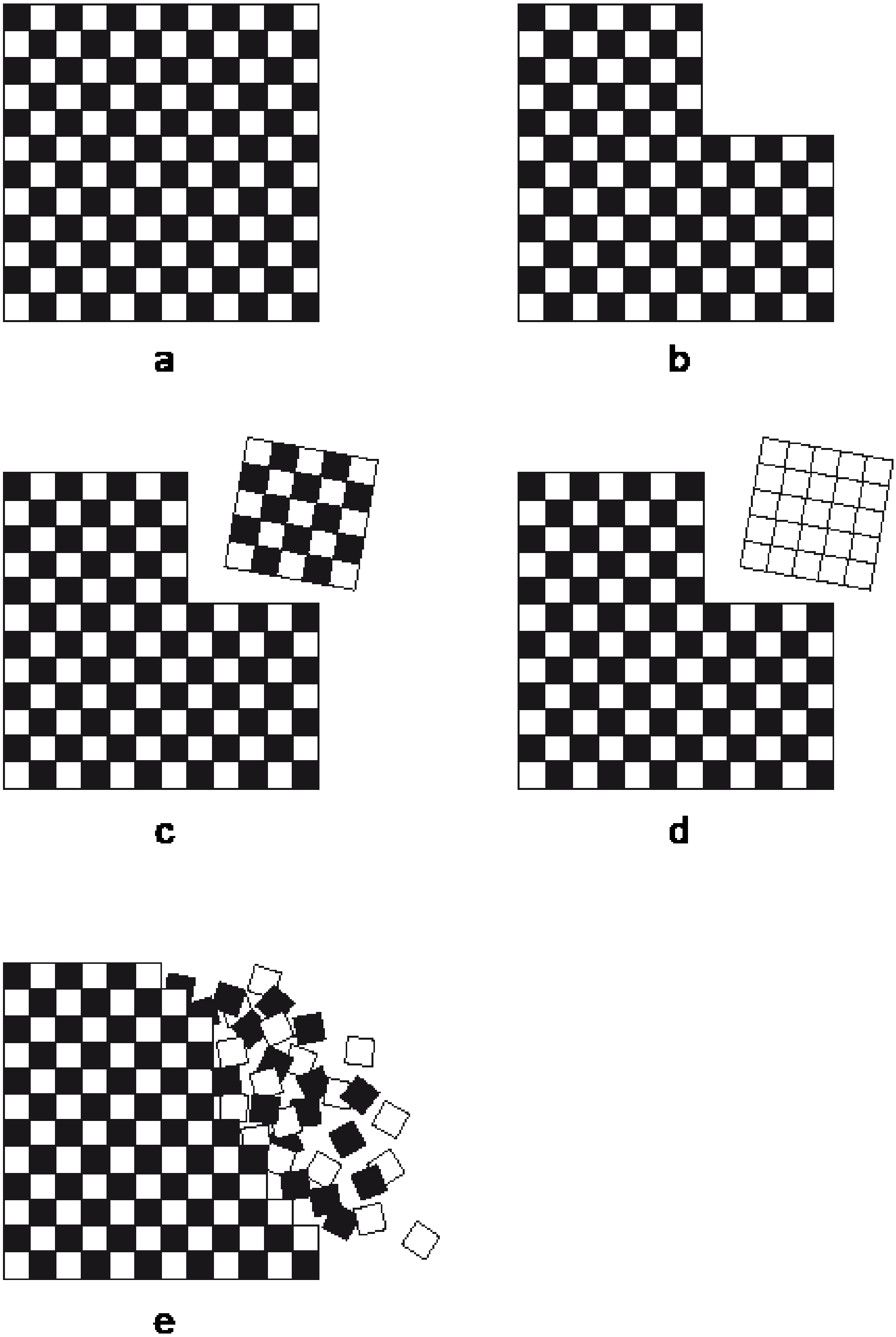


Fig. 20. The Illusion of Meaning: A checkerboard showing different kind of happenings.

The relevance of this description not only lies both in its complexity and simplicity but also in several emerging "things". The complexity is revealed by the emergence of terms/meanings apparently beyond what is represented and beyond its constituent parts. These terms are: mutilation, remotion, and missing piece of checkerboard. Also the missing checkerboard has the form of a checkerboard. This apparent tautology suggests a general rule of the form of meanings: every missing component has the shape of the whole object to which that component belongs. In Fig. 20c, «a piece of checkerboard comes away from the main checkerboard and tumbles down (89)». By comparing Figs. 20b and c, it seems that the piece illustrated in Fig. 20c is the one missing in Fig. 20b. However, this result emerges only through the comparison between the two figures, in fact the amodal wholeness of Fig. 20b, when it is shown alone without any comparison, is the complete checkerboard illustrated in Fig. 20a and not the one of Fig. 20c. If the properties of the piece of checkerboard are changed, as illustrated in Fig. 20d, the result is «a piece of checkerboard transformed or discolored that comes away from the main checkerboard and tumbles down (91)». In Fig. 20e, the checkerboard form of meaning is «weakened while it crashes and its components made up of filled and empty squares come down rolling one over the other (91)». The checkerboard is not a checkerboard anymore but a set of alternated filled and empty squares. It is worthwhile noticing that the grouping principles predict the segregation of the two regions: the checkerboard and the coming down checks. What is segregated by the grouping principles is put together into a new meaningful way by the form of meaning, whose integration properties are much stronger than in the other forms of organization.

We have previously seen that in the amodal completion the object perceived as occluded is perceived as a unitary object with boundary contours that amodally complete behind the overlapped modal object. The happenings do not necessarily complete amodally something that is modally perceived as a piece or a portion of an entire or unitary object, but can also complete attributes of something that is already a unitary object. This is the case of Fig. 21, where the checkerboards are perceived deformed: folded, stretched, pulled, pushed, extended, etc.

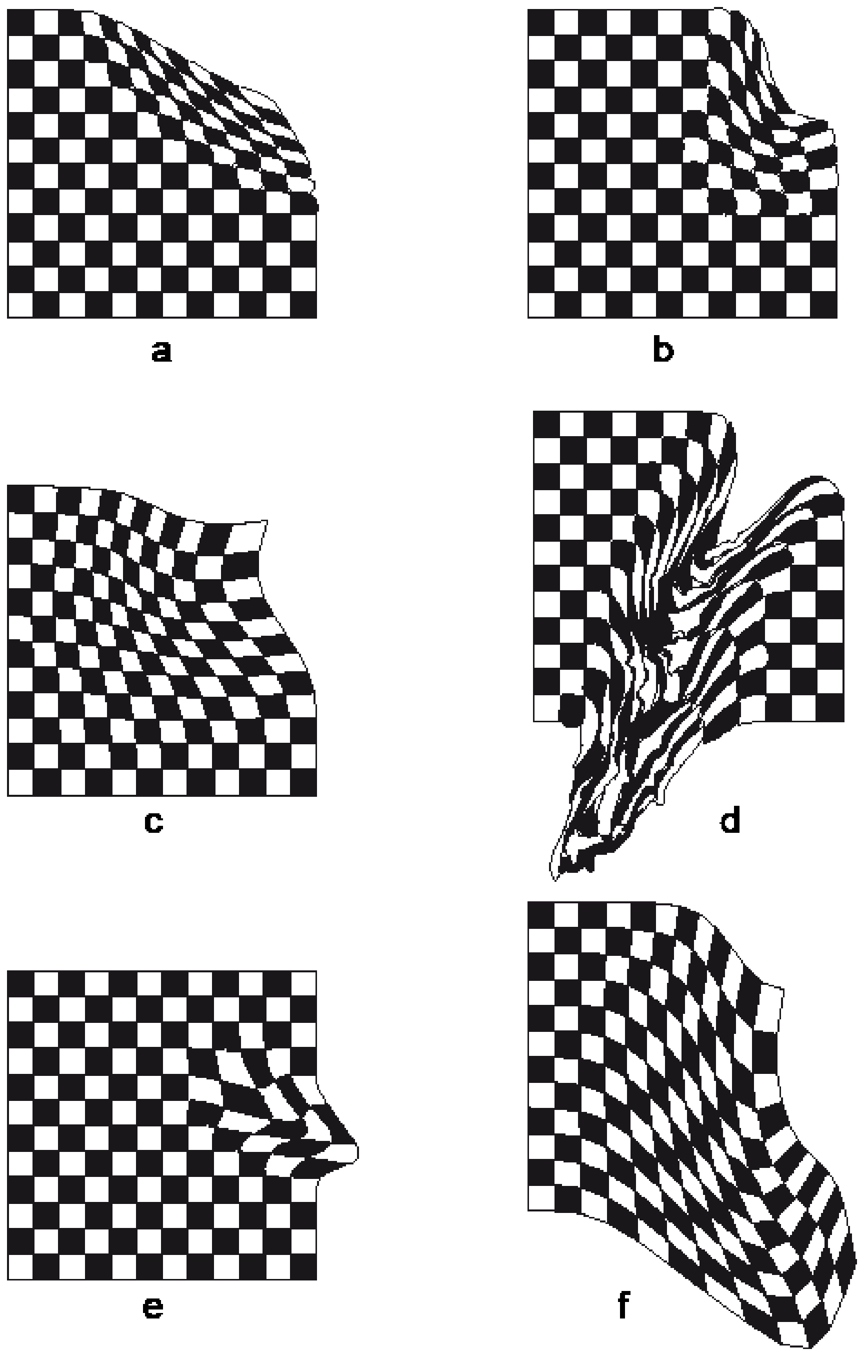


Fig. 21. The Illusion of Meaning: The checkerboards are perceived deformed: folded, stretched, pulled, pushed, extended, etc.

All these happenings behave similarly to the amodal completion of partially occluded objects. They amodally complete and homogenize its subject, i.e. the checkerboard. However, while in the case of occlusion the cause of the modal incompletion is modally perceived, i.e. the overlapped object, in Fig. 21 the happenings are modally perceived as "occluding" the unity, integrity and homogeneity of the checkerboard, but the cause is invisible although amodally perceivable. The cause of the deformations is the complement of the perceptual sentence, which can be amodally completed on the basis of the specific meaning of the happening. Each happening in describing a specific action performed on the subject also describes the shape and the properties of the complement that causes that happening. It can be an object, moving in a certain direction and at a certain speed, that hits the checkerboard thus causing the deformation. These examples suggest that the form of meaning is not only a process of meaning assignment but also a process of meaning creation. Meanings create other meanings that in their turn create other meanings and so on (principle of meanings multiplication).

The meanings do not necessarily have a name and are not necessarily identifiable. In Fig. 22, the happenings and the checkerboards are clearly perceived but it is extremely difficult to perceive and say what is "happening" and what is causing that "happening".

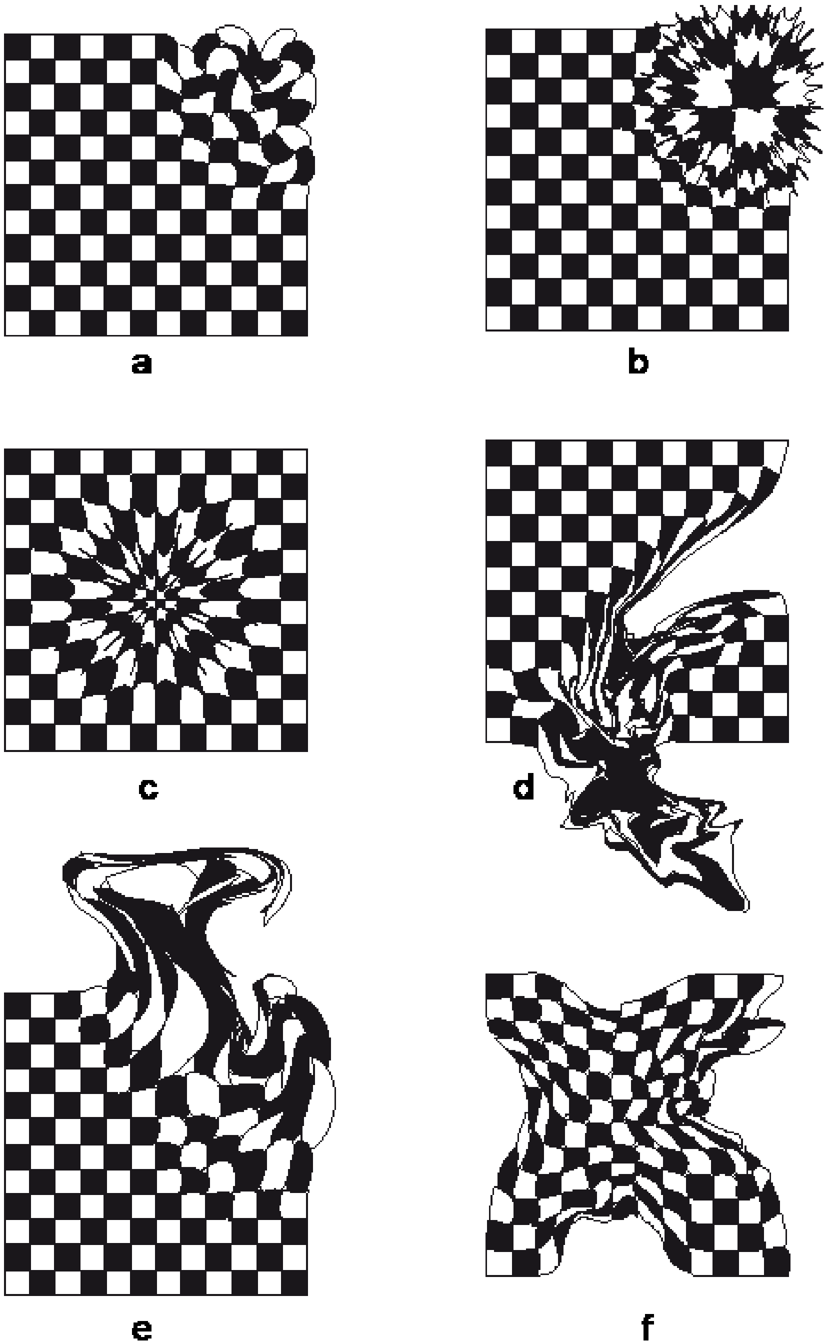


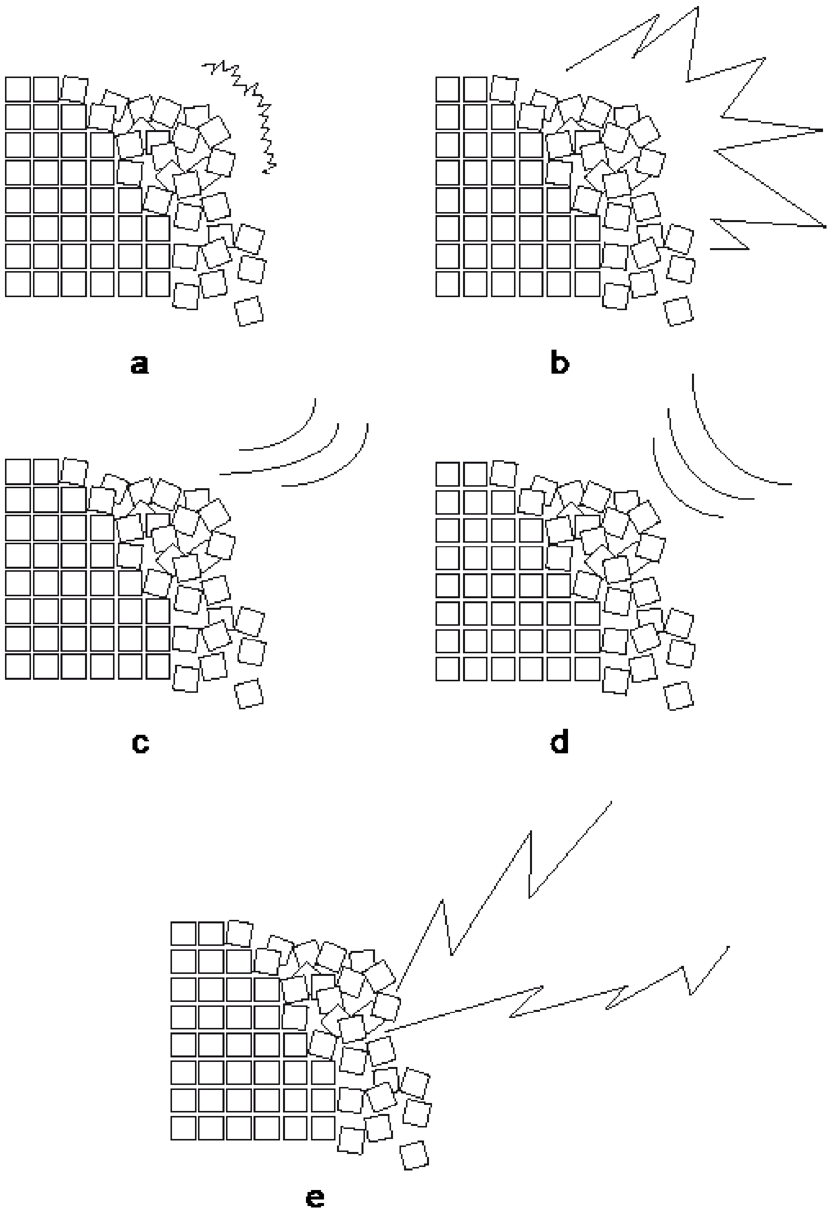
Fig. 22. Other deformations of a checkerboard: Happenings and checkerboards are clearly perceived but it is extremely difficult to perceive and say what is "happening" and what is causing that "happening".

From the previous figures, it follows that the form of meaning and its processes of meaning assignment obey apparent antinomic rules. On the one hand they put together everything, so that everything can stay with everything else in a meaningful way. This imparts unity, integrity and homogeneity among all the components. On the other hand, they divide, segregate or break the homogeneity, thus appearing as the opposite of unity, integrity and homogeneity. These two antinomic dynamics are not equivalent to the grouping/segregation formed by the gestalt principle of similarity placed at another perceptual level. In the form of meaning the two dynamics do not annul or weaken but strengthen each other by creating the two perceptual levels (ideal and contingent) we previously mentioned. Therefore, what is segregated becomes the happening, i.e. something different from the main meaning (subject). The happening is discounted but at the same time it becomes part of the subject by qualifying it and explaining in terms of action the reason for the loss of homogeneity, integrity and unity of the subject. In this way the subject can assume, establish or restore its homogeneity that is like a basic assumption within the process of meaning formation. In other words, differences, variations and lack of homogeneity become the special emerging meanings that we called "happenings", whose aim is to create homogeneity and, hence, unity. The paradox of meaning is avoided by creating and organizing the resulting meanings in the two perceptual levels already mentioned: amodal/ideal and modal/contingent.

4.5. Everything has a Meaning

Everything assumes a meaning within a context of other meanings. Everything is perceptually put together into a meaningful way. This is a basic general principle of the form of meaning. The questions are: How does the presence of a new element influence the part-whole meaning organization? Under these conditions, does the part-whole organization change its structure?

In Fig. 23a the zigzagged contour appears as a property of the happening: «a trembling of the squares during the breakdown (85)». It is like an onomatopoetic noise and movement. The wider zigzagged contour of Fig. 23b appears again as a property of the happening but different from before. It has the meaning of «an explosion causing the breakdown of the squares (91)». The curves of Fig. 23c describe another cause of the happening: «some kind of breeze or strong wind moving the squares in the same perceived direction of the wind (87)». Therefore, «they appear first floating and then breaking down (85)». «The waves», perceived in Fig. 23d, «squash and crunch the large square inducing the breaking down of the small squares (84)». The lines of Fig. 23e become «a lighting trucking the large square (87)». The waves perceived in Fig. 23f do not induce a squash as in Fig. 23d but «a spreading of squares during their breaking down (89)». The expressive sinusoid lines of Fig. 23g are more difficult to describe, although it is clear that they represent a quality of a happening. «They appear like a wavy energy that destroys the alignment of the squares causing them to break down (76)». Also «the scribble (84)» of Fig. 23h assumes a meaning within the whole object, even though not easy to define. It is likely «a dense smoke that creates instability in the small squares that are in a delicate equilibrium (86)».



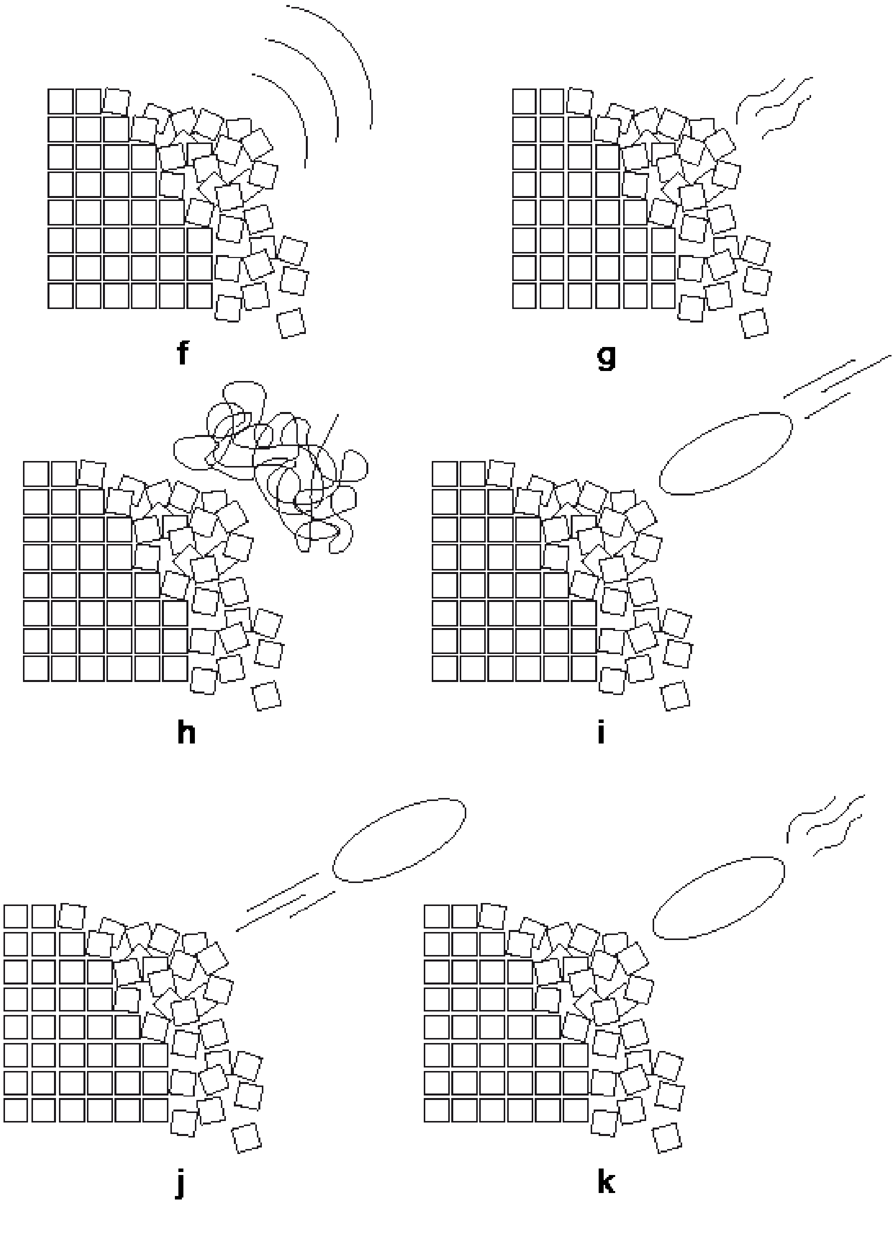


Fig. 23. The Illusion of Meaning: Everything assumes a meaning within a context of other meanings. Everything is perceptually put together into a meaningful way.

By adding one more element, the whole object continues to assume new meanings with a part-whole structure similar to the one previously described. The expressive lines of Fig. 23i appear now as properties of the new object: «the ellipse jumps rapidly over the large square destroying its shape (83)». In Fig. 23j «the ellipse smashes the large square while flying rapidly toward the sky (82)». «The ellipse of Fig. 23k falls slowly over the square destroying its shape (84)».

It is worthwhile noticing that the basic pattern of squares is always the same in all the conditions illustrated in Fig. 23. Nevertheless, none of the subjects reported it during the description of the different conditions. Furthermore, when they were asked to complete by adding (drawing it) the basic pattern of squares to the other elements (zigzagged contours, waves and ellipses) shown alone on a sheet of paper, the subjects drew patterns of squares changing according to the different conditions. These results are in agreement with the form of meaning organization and the inner dynamics that will be described in the next sections.

5. On the Three Forms of Perceptual Organization

5.1. General Propositions and Definitions

On the basis of the phenomenal observations described in this work we suggest the following general propositions (*P1* to *P5*) and definitions (*D1* to *D3*); see also Pinna & Albertazzi (in press) and Pinna & Reeves (2009).

P1: There is no perception without the three forms of organization: grouping, shape and meaning. To perceive is not just to perceive groups and shapes, but also to perceive meanings. What we perceive has always a meaning. Vision is also perceiving meanings.

P2: The form of shape goes beyond the form of grouping and the form of meaning goes beyond the form of shape. The three kinds of forms are not rivals but complement and reinforce one another organizing the visual field at different perceptual levels.

P3: In the form of meaning, anything can stay with anything else becoming meaningful and creating sentences of a visual language.

D1: We call "perceptual meaning" what is expressed, indicated or conveyed by a grouping and a shape through the "amodal wholeness" and the "modal partialness" (see the next definitions).

D2: We call "amodal wholeness" the vivid percept of object unity and wholeness even though the observer does not actually see a contour in regions where the completion of the whole object occurs at a level after the 'happening'.

D3: We call "modal partialness" the clear modal emerging of a specific happening that occludes the completion of one part of the complementary region, such as a square, that appears as the whole.

P4: Amodal wholeness and modal partialness are mutually related: variations in the meaning of one component imply variations of the other. Each happening, partially 'hiding' or 'occluding' the whole, determines the amodal wholeness. Conversely and at the same time, each whole makes the discontinuities appear as they are and as its happenings or actions with that specific meaning.

P5: Stimulus variations split phenomenally into at least two independent and opposite phenomenal components: one component ("homogenous and invariant") is perceived not directly but amodally, while the other ("heterogeneous and variant") is perceived directly and modally. One component acts to discount or annul the variations creating an amodal wholeness, while the other subsumes all the variations attributing them to a different "thing or happening" of the whole becoming the modal partialness. The two components reinforce their role reciprocally so that a certain variation of one component is counterbalanced by the contrary variation of the other component.

Pinna and Reeves (2006) used *P5* to explain the form of figurality, i.e. the phenomenal apparent organization of what is perceived as a figure within the three dimensional space and under a perceived illumination.

Unfortunately, there is nothing within the Gestalt grouping principles and the form of shape about the components that are grouped at one level and ungrouped at a different level. Even if these levels were never introduced or suggested by gestalt psychologists, it is necessary to keep track of them at least because they are visual results. The form of meaning not only keeps track of them, but also puts together phenomenal similarities and dissimilarities, homogeneities and heterogeneities, continuity and discontinuity in a meaningful sense: they do not annul or weaken each other but synergistically complement and contribute to create a whole meaning as described in *P5*. By becoming meanings, the homogeneous vs. heterogeneous and continuous vs. discontinuous components are made simpler and more economical by shifting the level of complexity toward a higher one. A mutilated checkerboard is much more economical than the irregular shape made up of juxtaposed alternated black and white squares. This preludes to the following properties related to the complexity manifested by the perceptual meaning.

5.2. Complexity of the Form of Meaning

The emerging meanings manifest the following properties (see also Pinna & Albertazzi, in press).

(i) *Unpredictability*: Differently from the form of grouping and from the form of shape, the complex form of meaning can produce unexpected and unpredictable meanings. Furthermore, as it was previously shown, some perceptual meanings cannot be easily seen and described even if they are clearly perceived as happenings.

(ii) *High connectedness*: The form of meaning can involve a large number of components with many feedback loops that enable the system to restructure promptly. By comparing one figure with another, the emerging form of meaning can change depending on whether it is perceived alone or compared with a new figure. This is because the new figure becomes a new component and therefore part of the whole meaning.

(iii) *Emergence*: The perceived meanings are not present in any of the individual subcomponents taken alone, but emerge from component interactions, e.g. the checkerboard form of the cut-out piece.

(iv) *Non-decomposability*: The emerging meanings are irreducible. The complex form of meaning cannot be resolved into isolated subcomponents without suffering an irretrievable loss of the meaning. Neglecting any part of the process of meaning assignment or severing any of its connections usually destroys essential aspects of the structure of meanings.

(v) *Hierarchical organization and centralized control*: The complex form of meaning manifests a hierarchical control with a structure similar to a perceptual language, but the power is spread over a decentralized structure that involves all the components. A number of units combine to generate the actual system of meanings, so that the meaning of one component depends on the meanings of the others.

(vi) *Invariability*: The form of meaning manifests a strong resistance and adaptability to changes. By introducing variations, changes and happenings the whole meaning tends to be modally invariant. This creates a great stability even to huge disturbances.

(vii) *Variability*: The happenings manifest chaotic behaviors, in the sense that very tiny variations in the happenings can induce a huge variation in their meanings. This implies a great instability that is the source of mutations and creativity of the meanings. This is the basis of the creativity of vision.

These properties suggest that the perception of a meaning is not equivalent to the perception of a shape or of a grouping, as demonstrated in the previous sections. In general, a shape is the starting point of a meaning and a meaning is the meaning of a shape. But, the same shape can have different meanings. We assume a continuum between shape and meaning perception: phenomenally a meaning represents what is expressed, indicated or conveyed by a shape. The "checkerboard with a cut-out piece" is a shape expressing or indicating a whole meaning made up of meaning components like the checkerboard and the cut-out piece organized so that one meaning component appears as such within the contest of the other meaning (part-whole organization). In this sense the meaning is more than a shape and can be used to convey, represent and denote something beyond its shape.

5.3. What are the Main Properties of Perceptual Meanings?

The following list of properties (*Pr1* to *Pr8*; see also Pinna & Reeves, 2009) should allow us to summarize and to define the properties subsumed above, especially to substantiate the term of perceptual meaning.

Pr1. Many become few.
Through the form of meaning many elements are reduced to few integrated meanings. All the shapes illustrated in Figs. 19-23 are reduced to a square or a checkerboard with a specific happening. Without these kinds of organization they would have been perceived like different irregular shapes.

Pr2. What is segregated is integrated.
Elements segregated by grouping principles or even disparate objects are integrated through the form of meaning.

Pr3. Multiplicity and divergence become homogeneity and unity.
Within a whole meaning discontinuities, divergences, contrasts and paradoxes are solved and "explained". The components are restructured in a meaningful way: the discontinuity becomes the predicate (happening) of the subject (amodal meaning).

Pr4. Homogeneous and heterogeneous, continuous and discontinuous conditions, similarities and dissimilarities among elements within the form of meaning do not weaken or annul but strengthen one another.

Pr5. The form of meaning creates different perceptual levels of complexity (ideal and contingent).

Pr6. From one meaning to another.
The form of meaning not only reduces the number of perceived elements that becomes meanings, but also creates other meanings placed at higher perceptual levels connected in some kind of 'perceptual net'.

Pr7. From the grouped elements to the meaning formation, to the perceptual language.
The meanings organize themselves like the components of a language. The main components are the subject, the predicate (happening) and the complements.

Pr8. Every perceptual element communicates a meaning within a context of other meanings.
Even the most senseless pattern creates and communicates a meaning.

6. Conclusions

The theory of parallel and complementary organizations here suggested concerns a three-level hierarchy: forms of grouping, shape and meaning. The organization progresses to more and more complex stages.

Why should we introduce these multiple organizations rather than rely just on a single one? The answer to this question is based on the previous phenomenal results demonstrating that these levels are all present at the same time in a figure, although they are often latent and only some become manifest to determine the final perceptual outcome. Furthermore, the results of one level may not influence the results of the others, even if each one is needed to trigger the other. This is the case of the similarity that triggers the directional symmetry.

What is the advantage of introducing a three-level organization hierarchy? One might first expect that it presupposes unnecessary complexity. However, the opposite is true. The final result emerging from each level is in fact much simpler than the number of its members. The algorithmic information content (Kolmogorov complexity) derived from each form is much reduced and simpler. The increasing of complexity from one level to another is accompanied by a strong reduction of the number of contents and by the increasing of simplicity. Furthermore, going from one level to another eliminates the need to specify the initial condition of the previous level. The basic components (primitives or atoms) of one level are different from those of the other levels. We can say that the results of one level are the grounding components of the next level. In fact the outcome of each level is an emergent form quality, i.e. the grouping of figural elements, of shape and finally the meaning of shapes.

These hypotheses are consistent with the key feature of a knowledge-acquiring system like the human brain that has in fact the capacity to abstract from the experience of many particulars or to minimize the number of elements. However, this capacity is accompanied by its complement, i.e. the capacity to maximize the information and then to create new meanings in a highly creative process.

The cons of introducing the notion of *perceptual meanings* are that they can depend also on cognitive processes placed at a higher level and involving past experience. Therefore, the separation of perceptual meanings from cognitive meanings might become impossible. Nevertheless, we suggest that the *perceptual* meanings, by their immediate presence, can be considered as the foundation of more refined and elaborated *cognitive* meanings, not necessarily in contrast with them, even if a distinction between seeing and thinking is surely necessary (Kanizsa, 1985, 1991). We propose that the cognitive meanings can be linked to the perceptual ones. The latter can be considered like the prime components of some kind of non-verbal primitive language which is still devoid of cognitive meanings. They may provide the raw materials for cognitive processes. The advantage of introducing perceptual meanings may be summarized as follows: (i) they are part of perceptual processes primary with respect to the cognitive ones; (ii) the form of meaning and the underlying phenomenal processes here suggested are reduced to the problem of perceptual organization; (iii) the form of meaning is strongly linked to the form of shape and grouping; (iv) the perceptual meanings have a strong phenomenal status; (v) their inner structure can be observed and by this provide valuable heuristics for the problem of how the brain creates meanings; (vi) compared to other more complex explanations involving higher cognitive processes, they better fit *lex parsimoniae* of Occam's razor.

The notion of "happening" may be related to that of "affordance" studied by Gibson (1977, 1979). Briefly, the "affordances" can be defined as all action possibilities latent in the environment, measurable and independent from the individual ability to recognize them. Happenings and affordances do not coincide but do not exclude each other. The happening is something that happens to an object also beyond the ecological possibilities: strange, paradoxical, nonsense, unnatural meanings can happen beyond the affordances. In this sense the happenings provide a much larger frame that include the affordances as a special case.

Furthermore, *happenings* are just one class of perceptual meanings. The other meaning components are the subject and the complement of the perceptual language without which the happenings cannot be perceived as meanings. Subjects and complements are beyond affordances.

There is another important difference. The happenings are not necessarily affordances. They are also meanings that can assume the role of subjects. This means that depending on what we are perceptually looking for, the way we see, the way we organize the meanings and which visual "sentence" we "read", the happenings can change their meaning and become something else within the perceptual language, something that is not an affordance. The opposite of the previous argument is also true. The subject of the perceptual language is also a happening, but as such would hardly be ascribed as an affordance. A checkerboard is not only the subject of the form of meaning but also a happening in the sense that it is the resulting action of combining in a whole object its elementary components.

In conclusion, the form of meaning explained in terms of perceptual organization related to the form of grouping and shape can help to understand how the brain creates meanings. For a possible neural account see Pinna & Reeves, 2006.

Acknowledgments

Supported by: Fondo d'Ateneo (ex 60%), Fondazione Banco di Sardegna, and Alexander von Humboldt Foundation. I thank Lothar Spillmann for translating the Summary into German.

Summary

The main purpose of this work is to introduce three kinds of perceptual organization called "form of grouping", "form of shape" and "form of meaning".
Experimental phenomenology, suggests a continuum from grouping and shape towards meaning. It can be demonstrated that a perceptual meaning (i) is emergent from normal, spontaneously conveyed vision, (ii) provides extreme reduction of the information load, i.e. many disparate components are reduced to a minimum number, (iii) results from an organization process that complements established Gestalt principles of grouping with at least two perceptual levels (modal and amodal) hierarchically structured, (iv) is a basic kernel of visually based non-verbal articulation used before spoken language, (v) creates other meanings one included in the other by creating a hierarchy of meanings that work recursively.
Meanings emerge whenever homogeneous and heterogeneous conditions are present within a stimulus. These antagonistic conditions trigger two distinct, yet complementary tendencies of amodal wholeness and modal partialness that represent the perceptual basis of the language, i.e. subject and predicate.

Keywords: Visual illusion, grouping principles, Gestalt psychology, shape perception, perceptual meaning.

Zusammenfassung

Diese Studie stellt drei Arten von Wahrnehmungsorganisation vor: Gruppierung, Form und Bedeutung.
Experimentelle Phänomenologie legt ein Kontinuum von Gruppierung und Form hin zu Bedeutung nahe. Es wird gezeigt, daß perzeptuelle Bedeutung (i) sich aus dem alltäglichen, unmittelbar übermittelten Sehen ableitet, (ii) eine äußerste Reduktion von Information darstellt, d.h. viele disparate Aspekte werden auf eine kleinstmögliche Anzahl zurückgeführt, (iii) aus einem Organisationsprozeß hervorgeht, der bekannte Gestaltgruppierungsprinzipien auf mindesten zwei hierarchisch angeordneten Wahrnehmungsebenen (modal und amodal) ergänzt, (iv) einen elementaren Kernel visueller, nichtverbaler Artikulation vor der gesprochenen Sprache darstellt, (v) weitere Bedeutungen hervorruft, die aus einer Hierarchie von impliziten Bedeutungen hervorgehen, die rekursiver Natur sind.
Bedeutungen entstehen, wenn homogene und heterogene Bedingungen in einem Reiz enthalten sind. Diese gegenläufigen Bedingungen lösen zwei verschiedene, aber komplementäre Tendenzen zu amodaler Ganzheitlichkeit und modaler Teilhaftigkeit aus, die die perzeptuelle Grundlage der Sprache darstellen, nämlich Subjekt und Prädikat.

Schlüsselwörter: optische Täuschung, Gruppierungsprinzipien, Gestaltpsychologie, Gestaltwahrnehmung, Wahrnehmungsbedeutung.

References

Attneave, F. (1968): *Triangles as ambiguous figures.* American Journal of Psychology 81, 447-453.

Bayerl, P. & Neumann, H. (2002): *Cortical mechanisms of processing visual flow - Insights from the Pinna-Brelstaff illusion.* Proceedings of 4th Workshop Dynamische Perzeption, Bochum.

Boudewijnse, G.-J. (2004): Form and Meaning. *Gestalt Theory 26,* 151-168.

Broerse, J. & O'Shea, R.P. (1995): Local and global factors in spatially-contingent coloured aftereffects. *Vision Research 35,* 207-226.

Broerse, J., Vladusich, T. & O'Shea, R.P. (1999): Colour at edges and colour spreading in McCollough effects. *Vision Research 39,* 1305-1320.

Da Pos, O. & Zambianchi, E. (1996): *Visual illusions and effects.* Milan, Guerini.

Ehrenstein, W. (1925): Versuche über die Beziehungen zwischen Bewegungs- und Gestaltwahrnehmung. *Zeitschrift für Psychologie 96,* 305-352.

Ehrenstein, W. (1930): Untersuchungen über Figur-Grund-Fragen. *Zeitschrift für Psychologie 117,* 339-412.

Ehrenstein, W. (1941): Über Abwandlungen der L. Hermannschen Helligkeitserscheinung. *Zeitschrift für Psychologie 150,* 83-91.

Ehrenstein, W. (1954): *Probleme der ganzheitspsychologischen Wahrnehmungslehre.* 3rd. ed. Leipzig: J.A. Barth Verlag.

Ehrenstein, W.H. (2008): *Gestalt psychology. Encyclopedia of Neuroscience.* Springer Verlag.

Fermüller, C. & Malm, H. (2004): Uncertainty in visual processes predicts geometrical optical illusions. *Vision Research 44,* 727-749.

Gibson, J.J. (1977): The theory of affordances, in Shaw, R. & Bransford, J. (eds.): *Perceiving, acting, and knowing: Toward an ecological psychology,* 67-82. Hillsdale, NJ: Erlbaum.

Gibson, J. J. (1979): *The Ecological Approach to Visual Perception.* Boston: Houghton-Mifflin.

Giovannelli, G. (1966): Stati di tensione e di equilibrio nel campo percettivo. *Rivista di Psicologia 60,* 327-335.

Goldmeier, E. (1937): Über Ähnlichkeit bei gesehenen Figuren. *Psychologische Forschung 4,* 146-208.

Grossberg, S. & Mingolla, E. (1985): Neural dynamics of perceptual grouping: Textures, boundaries, and emergent segmentations. *Perception & Psychophysics 38,* 141–171.

Gurnsey, R., Sally, S., Potechin, C. & Mancini, S. (2002): Optimising the Pinna-Brelstaff illusion. *Perception 31,* 1275-1280.

Helmholtz von, H. (1866): *Handbuch der Physiologischen Optik* (Part III), Leipzig: Voss.

Hering, E. (1861): *Beiträge zur Physiologie, I, Zur Lehre vom Ortsinne der Netzhaut.* Leipzig: Engelman.

Hüppe, A. (1984): *Prägnanz. Ein gestalttheoretischer Grundbegriff.* München: Profil Verlag.

Jastrow, J. (1891): A study of Zöllner's figures and other related illusions. *American Journal of Psychology 4,* 381-398.

Kanizsa, G. (1972): "Errore del gestaltista" e altri errori da aspettativa. *Rivista di Psicologia 66,* 3-18.

Kanizsa, G. (1985): Seeing and thinking. *Acta Psycologica 59,* 23-33.

Kanizsa, G. (1991): *Vedere e pensare.* Bologna: Il Mulino.

Kanizsa, G. & Luccio, R. (1986): Die Doppeldeutigkeiten der Prägnanz. *Gestalt Theory 8,* 99-135.

Kanizsa, G. & Luccio, R. (1989): Fenomenologia della formazione di un ordine autonomo della percezione. *Rivista di Psicologia 3,* 28-46.

Katz, D. (1911): Die Erscheinungsweisen der Farben und ihre Beeinflussung durch die individuelle Erfahrung. *Zeitschrift für Psychologie, Ergänzungsband 7,* 6-31. Leipzig: Barth.

Katz, D. (1930): *Die Erscheinungsweisen der Farben,* 2nd edition [Translation into English: MacLeod, R.B. & Fox, C.W. (1935): *The World of Color.* London: Kegan Paul].

Köhler, W. (1920): *Die physischen Gestalten in Ruhe und im stationären Zustand.* Eine naturphilosophische Untersuchung. Braunschweig: Vieweg.

Köhler, W. (1938): *The place of value in a world of facts.* New York: Liveright.

Kopfermann, H. (1930): Psychologische Untersuchungen über die Wirkung zweidimensionaler Darstellungen körperlicher Gebilde. *Psychologische Forschung 13,* 293-364.

Kristof, W. (1961): Versuche mit der Waagrechten Strecke-Punkt-Figur. *Acta Psychologica 18,* 17-28.

Mather, G. (2000): Integration biases in the Ouchi and other visual illusions. *Perception 29,* 721-727.

Metzger, W. (1941): *Psychologie: die Entwicklung ihrer Grundannahmen seit der Einführung des Experiments.* Dresden: Steinkopff.

Metzger, W. (1963): *Psychologie.* Darmstadt: Steinkopff.

Metzger, W. (1975a): *Gesetze des Sehens.* Frankfurt/Main: Krammer.

Metzger, W. (1975b): Die Entdeckung der Prägnanztendenz. Die Anfänge einer nicht-atomistischen Wahrnehmungslehre, in Flores D'Arcais, G.B. (ed.): *Studies in Perception,* Festschrift for Fabio Metelli, 3-47. Firenze: Giunti-Martello.

Metzger, W. (1982): Möglichkeiten der Verallgemeinerung des Prägnanzprinzips. *Gestalt Theory 4,* 3-22.

Michotte, A. (1951): *Une nouvelle énigme de la psychologie de la perception: le «donné amodal» dans l'expérience.* International Congress of Psychology, Stockholm.

Michotte, A., Thinès, G. & Crabbé, G. (1964): *Les compléments amodaux des structures perceptuals.* Studia psychologica, Louvain: Publications Universitaires. Repr. in Thinès, G., Costall, A. & Butterworth, G. (1991): *Michotte's experimental phenomenology of perception.* Hillsdale, NJ: Lawrence Erlbaum.

Morgan, M. (2002): Running rings around the brain. *The Guardian,* Thursday, 24 January 2002.

Müller-Lyer, F.C. (1898): Optische Urtheilstäuschungen. *Archiv für Anatomie und Physiologie, Physiologische Abteilung 2,* 263-270.

Oppel, J.J. (1854-1855): Über Geometrisch-optische Täuschungen. *Jahresbericht des Physikalischen Vereins zu Frankfurt am Main,* 37-47.

Orbison, W.D. (1939): Shape as function of the vector-field. *American Journal of Psychology 52,* 31-54.

Palmer, S.E. (1980): What makes triangles point: Local and global effects in configurations of ambiguous triangles. *Cognitive Psychology 12,* 285-305.

Palmer, S.E. (1989): Reference frames in the perception of shape and orientation, in Shepp, B.E. & Ballesteros, S. (eds.): *Object perception: Structure and process,* 121-163. Hillsdale, NJ: Erlbaum.

Palmer, S.E. (1999): *Vision Science: photons to phenomenology.* Cambridge, Mass./ London: The MIT press.

Palmer, S. & Bucher, N.M. (1981): Textural effect in perceiving pointing of ambiguous triangle. *Journal of Experimental Psychology: Human Perception & Performance 8(5),* 693-708.

Pinna, B. (1987): Un effetto di colorazione, in Majer, V., Maeran, M. & Santinello, M.: *Il laboratorio e la città, 158.* XXI Congresso degli Psicologi Italiani.

Pinna, B. (1990): *Il dubbio sull'apparire.* Padova: Upsel Editore.

Pinna, B. (1993): *La creatività del vedere: verso una Psicologia Integrale.* Padova: Domenighini Editore.

Pinna, B. (1996): La percezione delle qualità emergenti: una conferma della "tendenza alla pregnanza", in Boscolo, P., Cristante, F., Dell'Antonio, A. & Soresi S. (eds.): *Aspetti qualitativi e quantitativi nella ricerca psicologica,* 261-276. Padova: Il Poligrafo.

Pinna, B. (2005a): Riflessioni fenomenologiche sulla percezione delle qualità emergenti: verso una riconsiderazione critica della teoria della Pregnanza. *Annali della Facoltà di Lingue e Letterature Straniere dell'Università di Sassari 3,* 211-256.

Pinna, B. (2005b): The role of Gestalt principle of similarity in the watercolor illusion. *Spatial Vision 2,* 185-207.

Pinna, B. (2008a): The illusion of art, in Pinna, B. (ed.): *Art and Perception: Towards a visual science of art.* Leiden: Brill.

Pinna, B. (2008b): The watercolor illusion. *Scholarpedia 3(1),* 5352.

Pinna, B. (2008c): A new perceptual problem: The amodal completion of color. *Visual Neuroscience 25,* 415-422.

Pinna, B. (2009): Pinna Illusion. *Scholarpedia, 4(2),* 6656.

Pinna, B. & Albertazzi, L. (in press): From grouping to visual meanings: A new theory of perceptual organization, in Albertazzi, L., van Tonder, G. & Vishwanath, D. (eds): *Information in perception.* Cambridge, Mass./ London: The MIT Press.

Pinna, B. & Brelstaff, G.J. (2000): A new visual illusion of relative motion. *Vision Research 40,* 2091-2096.

Pinna, B., Brelstaff, G. & Spillmann, L. (2001): Surface color from boundaries: A new 'watercolor' illusion. *Vision Research 41,* 2669–2676.

Pinna, B. & Gregory, R.L. (2009): Continuities and discontinuities in motion perception, in, G., Abram, M. & Pessa, E. (eds.): *Processes of emergence of Systems and systemic properties: Towards a General Theory of Emergence,* 765-775. New York: Springer-Verlag.

Pinna, B. & Grossberg, S. (2005): The watercolor illusion and neon color spreading: A unified analysis of new cases and neural mechanisms. *JOSA A 22,* 2207-2221.

Pinna, B. & Spillmann, L. (2005): New illusions of sliding motion in depth. *Perception 34,* 1441-1458.

Pinna, B. & Reeves, A. (2006): Lighting, backlighting and watercolor illusions and the laws of figurality. *Spatial Vision 19,* 341-373.

Pinna, B. & Reeves, A. (2009): From Perception to art: How the brain creates meanings. *Spatial Vision 22,* 225-272.

Pinna, B. & Tanca, M. (2008): Perceptual organization reconsidered in the light of the watercolor illusion: The problem of perception of holes and the object-hole effect. *Journal of Vision 8(7)/8,* 1–15, http:// journalofvision. org/8/7/8/, doi:10.1167/8.7.8.

Pinna, B., Werner, J.S. & Spillmann, L. (2003): The watercolor effect: A new principle of grouping and figure-ground organization. *Vision Research 43,* 43 - 52.

Rausch, E. (1952): *Struktur und Metrik figural-optischer Wahrnehmung.* Frankfurt: Kramer.

Rausch, E. (1966): Das Eigenschaftsproblem in der Gestalttheorie der Wahrnehmung, in Metzger, W. & Erke, H. (Hrsg.): *Wahrnehmung und Bewußtsein,* "Handbuch der Psychologie", Bd I/1, 866-951. Göttingen: Hogrefe..

Rubin, E. (1915): *Synsoplevede Figurer.* Kobenhavn: Glydendalske.

Rubin, E. (1921): *Visuell wahrgenommene Figuren.* Kobenhavn: Gyldendalske.

Schilder, P. & Wechsler, D. (1936): The illusion of the oblique intercept. *Journal of Experimental Psychology 19,* 747-757.

Schumann, F. (1900): Beiträge zur Analyse der Gesichtswahrnehmungen. Zur Schätzung räumlicher Grössen. *Zeitschrift für Psychologie und Physiologie der Sinnersorgane 24,* 1-33.

Spillmann, L. & Ehrenstein, W.H. (2004): Gestalt factors in the visual neurosciences, in Chalupa, L. & Werner, J.S. (eds.): *The Visual Neurosciences,* 1573-1589. Cambridge, MA: MIT Press.

Tanca, M. & Pinna, B. (2008): The phenomenal dissociation between coloration and object-hole effects in the watercolor illusion. *Visual Neuroscience 25,* 423-432.

Werner, J.S., Pinna, B. & Spillmann, L. (2007): The Brain and the World of Illusory Colors. *Scientific American 3,* 90-95.

Wertheimer, M. (1912a): Über das Denken der Naturvölker. *Zeitschrift für Psychologie 60,* 321-378.

Wertheimer, M. (1912b): Untersuchungen über das Sehen von Bewegung. *Zeitschrift für Psychologie 61,* 161- 265.

Wertheimer, M. (1922): Untersuchungen zur Lehre von der Gestalt. I. *Psychologische Forschung 1,* 47-58.

Wertheimer, M. (1923): Untersuchungen zur Lehre von der Gestalt. II. *Psychologische Forschung 4,* 301-350.

Wundt, W. (1898): „Die geometrisch-optischen Täuschungen". *Abhandlungen der Mathematisch-Physischen Classe der Königl. Sächsischen Gesellschaft der Wissenschaften zu Leipzig 24,* 53-178.

Zöllner, F. (1860): Über eine neue Art von Pseudoskopie und ihre Beziehungen zu den von Plateau und Oppel beschriebenen Bewegungsphänomenen. *Annalen der Physik und Chemie 110,* 500-523.

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