The Place of Meaning in Perception - Introduction

1. From Object to Meaning

Vision is the ability to perceive objects and vision science concerns the problem of why we perceive a world articulated in objects and not a world made up of unorganized edges and bars. In Fig. 1, we do not perceive individual segments, unconnected and oriented in different directions, but at least three main sets of shapes alternated as follows: rhombi and irregular hexagons, on one hand, and six-pointed stars, on the other hand. If the rhombi and the irregular hexagons are perceived, then the stars are invisible and *vice versa*. This depends on the main figure-ground attributes demonstrated by Rubin (1921), i.e. the unilateral belongingness of the boundaries. This attribute has been also called "border ownership" (Nakayama & Shimojo 1990; see also Pinna 2010; Spillmann & Ehrenstein 2004). It states that the figure assumes the shape traced by the contour, denoting that the contour belongs unilaterally to the figure, not to the background. In Fig. 1, the two main results are reversible and switch very easily from the one to the other, just by moving the gaze in different locations of the stimulus. Nevertheless, the stars might appear stronger than the rhombi and the irregular hexagons.

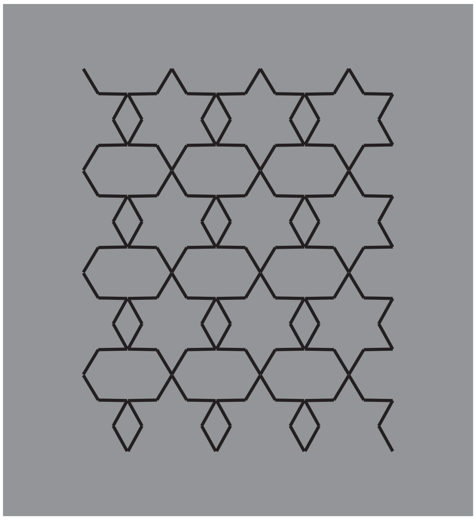

Fig. 1 Rhombi-irregular hexagons and six-pointed stars are perceived. The two sets of figures are reversible and switch very easily from one to the other.

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According to Gestalt psychologists, the fundamental issue of object perception is condensed in the still basic Koffka's question: 'Why do things (objects) look as they do?' (Koffka 1935). At present, this is a key question of vision science challenging all its main approaches, be they phenomenological, cognitive, ecological, psychophysical, computational or neurophysiological. Gestalt psychologists answered this basic question in terms of perceptual organization and, more specifically, in terms of figure-ground segregation (Rubin 1915, 1921) and in terms of grouping (Wertheimer 1912a, 1912b, 1922, 1923). Rubin identified the principles of figure-ground organization, whereas principles of grouping resulted from Wertheimer's studies.

In Fig. 1, the perceived objects can be attributed to several grouping principles simultaneously available and usually creating multistable phenomena (cf. Ben-Av & Sagi 1995; Claessens & Wagemans 2005; Gepshtein & Kubovy 2000, 2005; Kubovy, Holcombe & Wagemans 1998; Kubovy & Wagemans 1995; Kurylo 1997; Oyama 1961; Rock & Brosgole 1964; Zucker, Stevens & Sander 1983). Under our condition, they are the closure and the simplicity or *Prägnanz* principles. The vividness of the stars, stronger than the one of the rhombi and hexagons, is likely related to the latter principle and partially also to past experience. According to the *Prägnanz* principles, the visual system determines the formation of objects on the basis of the simplest, the most regular, ordered, stable, balanced, rather than the most likely, organization of components consistent with the sensory input (cf. Mach 1914/1959; Pomerantz & Kubovy 1986). This principle has assumed several related meanings (see Kanizsa & Luccio 1986; Pinna 2005) going from the preference for the maximization of "regularity" (Kanizsa 1975, 1979, 1980, 1985) to the extraction of the interpretation, whose code is of minimal length (Hochberg & McAlister 1953; Leeuwenberg 1971; Buffart, Leeuwenberg & Restle, 1981). This implies that the visual system tends to perceive patterns that provide short descriptions of the data, for example, stars or rhombi and irregular hexagons. Briefly, the simplicity of a description is measured through its length (minimum length) and, as a consequence, the final result is expected to be much simpler than the number of its members as demonstrated in Fig. 1, where the algorithmic information derived from the perceived objects (be either the stars or the rhombi and the irregular hexagons) is much reduced and simpler than the one of its components (segments and lines oriented in different directions). Some authors (Hatfield & Epstein 1985) paralleled this principle to the rationale of the *lex parsimoniae* of Occam's razor in the selection of scientific theories (Quine 1965; Sober 1975), according to which, among competing scientific hypotheses, the one that suggests the lowest number of assumptions is recommended.

By introducing the grouping principle of similarity on the basis of the reversed luminance contrast, the strength of one of the two reversible results of Fig. 1 is now enhanced to the detriment of the other, as shown in Fig. 2a, where rhombi and irregular hexagons are perceived stronger than the six-pointed stars. The opposite result is illustrated in Fig. 2b.

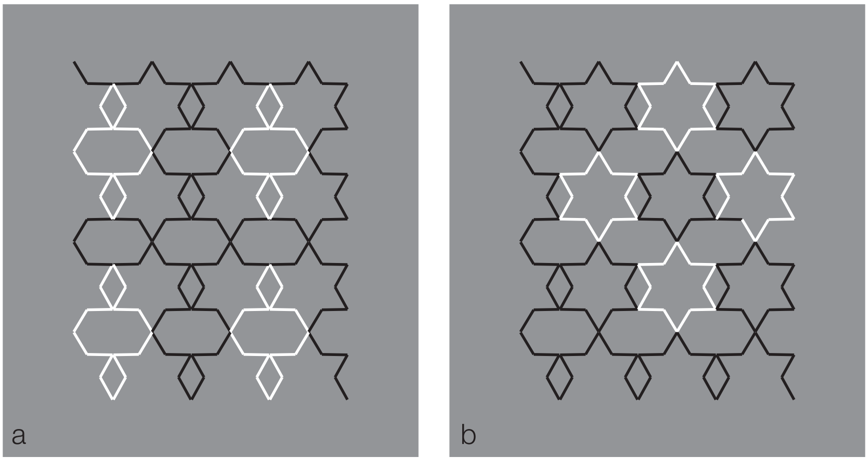

Fig. 2 *The principle of similarity* on the basis of the reversed luminance contrast strengthens one of the two reversible results of Fig. 1: rhombi-irregular hexagons (a) and stars (b).

It is worthwhile noticing that in Fig. 2 the similarity principle subsumes another principle: the accentuation (Pinna 2011). As shown in Figs. 3a and 3b, it is sufficient to reverse the luminance contrast of only one of the objects of the previous results to accentuate respectively rhombi and irregular hexagons against the stars and *vice versa*. As a consequence the perceived result of the accentuated component spreads to all the other ones, i.e. the result, due to the accentuation, is also perceived in the non-accentuated components. To better appreciate these outcomes, compare them with the results of Figs. 1 and 2.

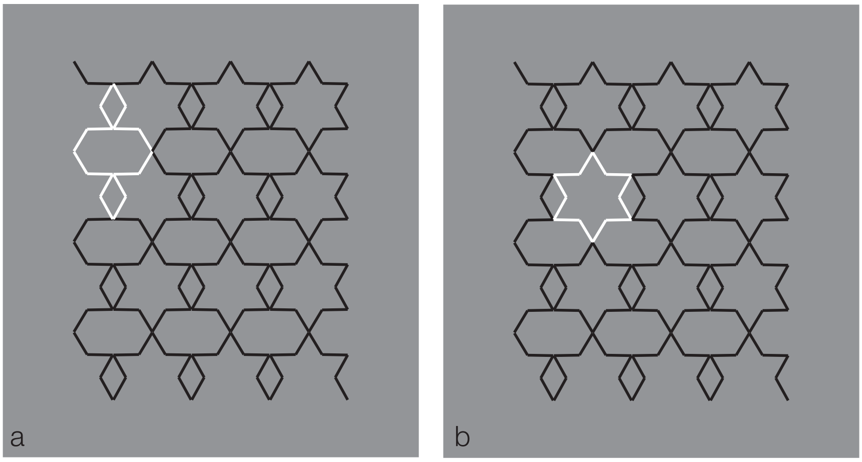

Fig. 3 *The accentuation principle*: the figure organization, due to the accentuation, is perceived also in the non-accentuated components.

The figures emerging on the basis of the similarity are not always synergistic with those due to the *Prägnanz* principle. In other words, the regularity is not necessarily maximized as shown in Fig. 4, where the white segments group in irregular figures segregated from irregular backgrounds. The strength of this figure-ground segregation is revealed by Rubin's unilateral belongingness of the boundaries showing the irregular grouping of elements in the background. Under these conditions, the similarity by reversed contrast clearly operates against the principle of *Prägnanz*.

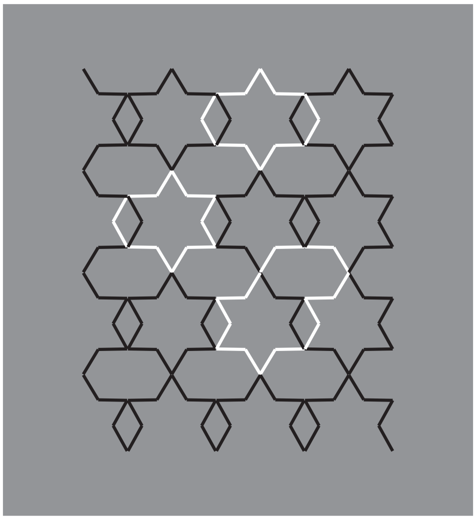

Fig. 4 The white segments group in irregular figures segregated from irregular backgrounds.

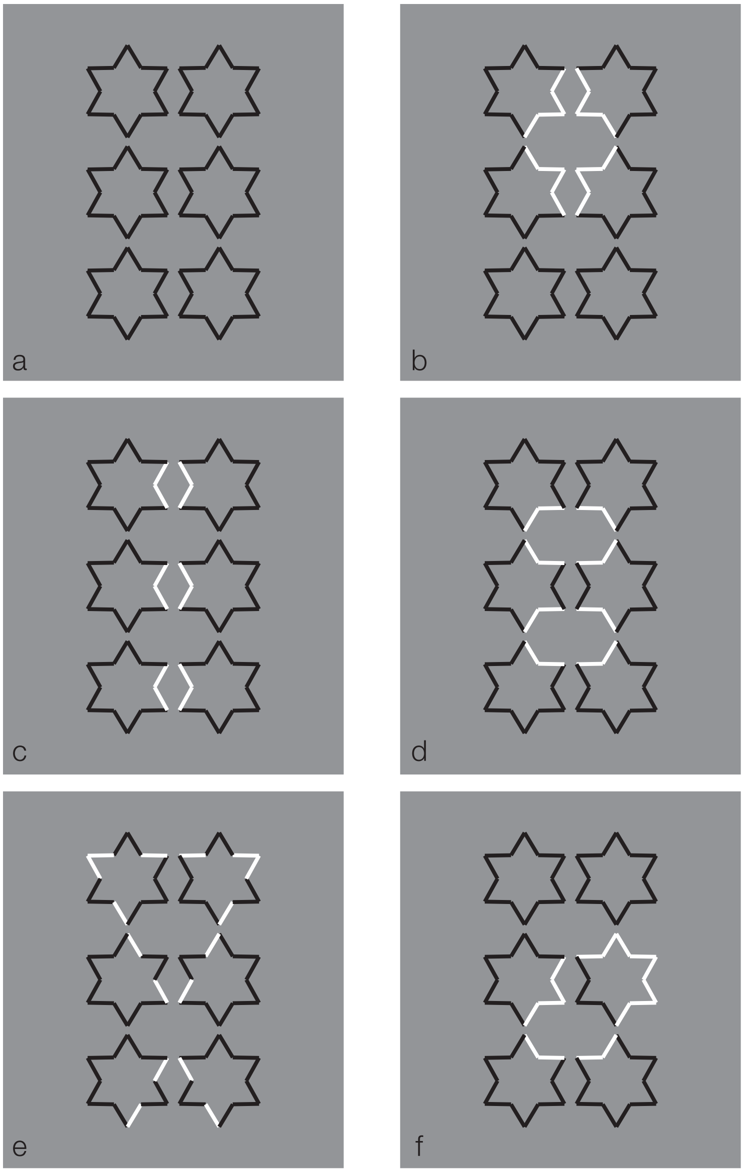

Fig. 5 New and unexpected figures emerge on the basis of the reversed luminance contrast pitted against other principles of grouping.

The outcomes of Fig. 4 can be further emphasized as shown in Fig. 5a-f, where, despite the stars being clearly and univocally perceived (see Fig. 5a as a control) due to their reciprocal separation (proximity principle) that breaks the potential shape of the rhombi and hexagons, regular and irregular, new and unexpected figures emerge on the basis of the reversed luminance contrast. It is worth noting that, in addition to the proximity and the *Prägnanz* principles, aclosure, good continuation and possibly also accentuation play a role in these figures. Opposite conditions (not illustrated), with the rhombi and the hexagons clearly separated like the stars of Fig. 5, can be manipulated in the same way to show results analogous to the ones of Fig. 5. Outcomes, similar to those achieved with the reversed contrast, can also be obtained by changing the color of the segments. This suggests that similarity by reversed luminance contrast (and color) is a principle much stronger than others (proximity, *Prägnanz*, closure). Its strength is likely due to the fact that it influences mostly the unilateral belongingness of the boundaries rather than the grouping, thus being crucial in the figure-ground segregation.

In Fig. 5 another factor can play a role. It is the regular arrangement of the stars that weaken the individuality of each single star in favor of possible alternative organizations emerging on the basis of the vertical and horizontal alignments of the sides of the stars. To favor the individuality of each star and break the alignments of the sides, each star of Fig. 5 can be irregularly rotated in opposite directions with respect to the adjacent stars (see Fig. 6a). Nevertheless, by applying the similarity, due to the reversed contrast, the perception of the stars is clearly weakened (Fig. 6b) and effects similar to those of Fig. 5 can be obtained (not illustrated). These results demonstrate the independence of each principle of organization and weaken the role of *Prägnanz* in grouping, shaping and assigning meanings to visual objects for both its acceptations, i.e. maximal regularity and minimal length.

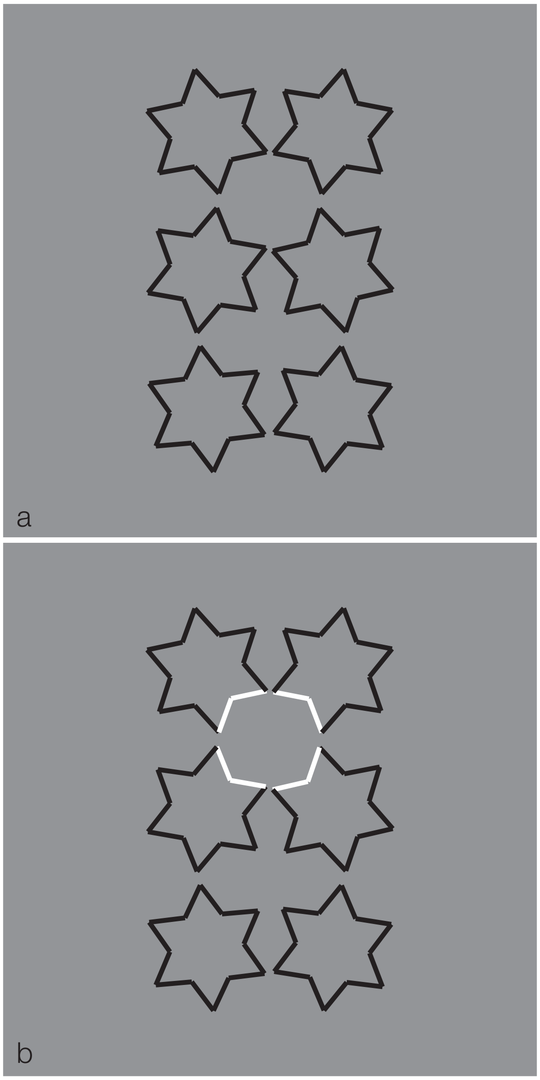

Fig. 6 Results similar to those of Fig. 5 are also perceived when the stars are irregularly rotated in opposite directions, thus favoring the individuality and the figure segregation of each star.

The previous results demonstrate that the same stimulus pattern can be perceived as many possible objects, based on the principles of grouping and figure-ground segregation and, more particularly for our figures, on the strength of the similarity by reversed luminance contrast. This implies that every stimulus pattern contains implicitly a high number of possible organizations. These implicit potential results seem phenomenally to wait to be highlighted by the figure-ground and grouping principles. However, not only do they highlight, but also assign meanings to the groups and to the figures, namely not only are they groups, but also figures with shapes and meanings. More generally, the principles of perceptual organization offer a clear framework for processing sensory data, in that they represent both syntax and grammar for the data, as well as semantics and interpretation valid across a wide variety of domains. In this way, they reflect the structure and the organization of our world. Hence, any sensory data related to these principles ought to reflect the external structure and organization.

Another general outcome of the previous figures is that when a possible object is perceived, it triggers some kind of long-range visual generalization. As a consequence the organization, due to some principles, accentuates and generalizes the same kind of organization to conditions not highlighted by the same principle. Therefore, when a grouping and a figure-ground segregation (cf. Figs. 3a-b) are perceived, the same kind of organization is generalized to the entire stimulus pattern and possibly also transposed and perceived in Fig. 1. This dynamic is reminiscent of a learning process.

On the basis of these results, it follows that Koffka's question and the problem of perceptual organization should be preceded by another question: "What is a perceptual object?". Indeed, any textbook about vision when talking about object perception takes for granted that the reader knows exactly what is being talked about. The answer to the question "what is an object?" has not been defined yet, although it is a basic scientific issue. This issue has its origins in the complexity of human perception, which goes beyond grouping and figure segregation to include the process by which particular relationships among potentially separate and meaningful elements (such as parts, features, and dimensions) are perceived (selected from alternative relationships and meanings) together with the process that creates the interpretation of those elements within a context of other elements. Therefore, a perceptual object extends the figure-ground and grouping organization to the formation of meanings. In other terms, each perceptual object is made up of element components grouped and segregated, and it also appears as a shape related to other shapes conveying one or more meanings related to other shapes and meanings, thus creating the complex world perceived in everyday life. By perceiving people, cities, houses, cars and trees, we perceive different kinds of organization at the same time culminating in the meanings grounded in perception.

The question "what is a visual object?" suggests, therefore, the following new questions: What are the relations and the differences between figure-ground segregation, grouping and visual objects? What is the meaning of a visual object? What is the meaning of a visual meaning? More generally, what is the place of meaning in visual perception?

The answers to these questions are manifold and depend on the assumptions and on the issues raised by some of the main approaches to visual perception developed in the history of psychology and reconsidered in a new light in recent years, as shortly introduced in the next section.

2. On the Place of Meaning in Perception

The understanding of the place of meaning in perception goes through the long chain of patterns of different meanings related to the question "what is a visual object?" and going from the physical objects to the information detected by our sensory receptors to our perceptions (see also Koffka 1935, Metzger 1941, 1963, 1975a, 1975b, 1982; Palmer 1999; Pomerantz & Kubovy 1986). Vision is, in fact, not only detection of sensory information but also organization into veridical percepts. The question "what is a visual object?" and the problem of "why we perceive a world of meaningful objects" raises the issue of the twofold meaning of the notion of stimulus: the distal stimulus, i.e. the pattern of energy emitted by or reflected from a physical object, and the proximal stimulus, namely the pattern of energy falling on the sensory receptors and transduced in neural signals, afterwards transmitted to the brain, where they are further processed and result in the final percept. From the perspective of these two notions of stimulus, vision science can be considered as the process of creating mental representations or phenomenal objects of distal stimuli using the information available in proximal stimuli (Gregory 1987; Metzger 1963, 1975a; Pomerantz 2003).

It is worthwhile noticing that the distinction of the two kinds of stimuli clarifies the so-called inverse problem of vision, according to which the same pattern of energy falling on the sensory receptors is caused by an infinite number of different distal objects. Briefly, the indeterminacy of the inverse problem derives from the asymmetry of the mathematical relations between the environment and its projective image. This problem can be extended to a hierarchy of inverse problems such as figure-ground segregation, binocular and motion correspondence, color and chromatic attribute correspondences, depth reconstruction and surface interpolation. The inverse problems make it difficult to consider vision as organization into veridical percepts.

How does perception derive the complex and structured description of the visual world from patterns of activity at the sensory receptors? Two alternative and in dispute theories of perceptual organization, historically very influential, have been proposed.

The first, already mentioned, is based on the simplicity-*Prägnanz* principle, according to which the visual system, like every physical system (Köhler 1920), is considered as aimed at finding the simplest and the most stable organization consistent with the sensory input (Koffka 1935). In terms of more recent computational approaches, the visual system chooses the simplest interpretation, the one defined by the least amount of information in terms of descriptive parameters due to regularities (Attneave 1954; Hochberg & McAlister 1953), namely the preferred perceptual organization is the one which elicits the briefest possible perceptual encoding (see also Atick & Redlich 1990; Barlow, Kaushal & Mitchison 1989; Blakemore 1990). Therefore, the maximization of the explanatory power is equal to maximizing the simplicity of the encoding of the stimulus. This suggests that a visual result or a description is meaningful if it carries information about the regularities of the stimulus that is, by reflecting the organization of elements and by specifying the structure of the stimulus. On the contrary, a code is meaningless if it is arbitrarily assigned to elements-strings, thus by discounting the organization within the stimulus (Attneave & Frost 1969; Buffart, Leeuwenberg & Restle 1981; Hochberg & McAllister 1953; Koffka 1935; Köhler 1920; Leeuwenberg 1969, 1971; Leeuwenberg & Boselie 1988; Restle 1970, 1979; Simon 1972; Simon & Kotovsky 1963; Vitz & Todd 1969). To model this Occam's simplicity principle, several approaches adopt descriptive coding languages, like for example the minimal model theory (Feldman 1997, 2003, 2009) and complexity metrics (e.g. theory of Kolmogorov complexity, information theory and structural information theory; see Chater 1996; Chaitin 1969; Kolmogorov 1965; Leeuwenberg 1969, 1971; Li & Vitànyi 1997; Simon 1972; Solomonoff 1964a, b). Within these views, the definition of information load (or complexity) is the number of different items extracted in order to specify or reproduce a given pattern (cf. Leeuwenberg 1969, 1971; van der Helm 1994, 2000, 2011a; van der Helm & Leeuwenberg 1996, 1999, 2004; van der Helm, van Lier & Leeuwenberg 1992).

A second important approach, aimed at solving the inverse problem and the gap between the phenomenal object and the proximal stimulus, is based on Helmholtz's likelihood principle (Helmholtz 1867, 1910/1962), according to which the sensory input is organized into the most probable distal object or event consistent with the sensory data (the proximal stimulus). This principle chooses the most likely true interpretation and assumes that the visual system is highly veridical in terms of the external world. From an evolutionary point of view, the rationale behind this principle is the need for a visual system to achieve veridical percepts of the world. In fact, if the visual system were not veridical, it would probably not have survived during the evolution. In this sense, the likelihood corresponds to the conditional probability of the distal pattern given the sensory input.

Unfortunately, it is not clear how this could be verified and how vision scientists might determine objective probabilities of real categories of distal scenes (cf. Hoffman 1998). Nevertheless, the likelihood principle and, within it, the Bayesian approach (see below) generated several solutions related to how the visual system actually determines the relative likelihood of different candidate interpretations (how to determine what is most likely) and to how such principle translates into computational procedures. On the other hand, the simplicity principle does not experience these problems, because it does not aim specifically at veridicality (van der Helm & Leeuwenberg 1991, 1996, 1999, 2004).

The simplicity and the likelihood principle are two competing theories (see Hatfield & Epstein 1985; Leeuwenberg & Boselie 1988; Pomerantz & Kubovy 1986; Rock 1983) of perceptual organization and visual meaning coding which are difficult to settle because neither of the key elements was clearly defined. The difference between the two is related to the fact that the visual system, in the case of the simplicity, obey a more general principle of economy, while in the case of the likelihood, it obeys a general principle of probability. These two terms might be only apparently different or may be considered as two sides or two different ways of considering the same visual process. In fact, Mach (1914/1959) suggested that vision acts in conformity with the principle of economy, and, at the same time, in conformity with the principle of probability. Chater (1996) demonstrated mathematically that these key elements can be unified and considered equivalent within the theory of Kolmogorov complexity (Chaitin 1969; Kolmogorov 1965; Li & Vitanyi 1997; Rissanen 1989; Solomonoff 1964a, 1964b). Feldman (1997, 2003, 2009) presented a simplicity approach, called minimal model theory, and, in agreement with Chater (1996), suggested that the visual interpretation, whose description is of minimum length, is also the one that most likely is the correct one in a real sense (the most veridical). Usually, the tendency of choosing a visual object that minimizes the description length is the same as the tendency of choosing a hypothesis that maximizes the likelihood. In brief, the most likely hypothesis about perceptual organization is, at the same time, the objects supporting the shortest description of the stimulus.

On the basis of Helmholtz's likelihood, Gregory (1972, 1987) proposed that visual objects are similar to perceptual hypotheses postulated to explain the unlikely gaps within stimulus patterns. In other words, objects are like "unconscious inferences", i.e. the results of inductive conclusions as used in the formation of scientific hypotheses. According to this approach some visual illusions, like Kanizsa's triangle (Kanizsa 1955, 1979), are considered as created by a top-down cognitive hypothesis to explain the gaps (missing sectors of the disks and missing parts of the outline triangle) within the stimulus. Following the same approach and in relation to Kanizsa's triangle, Rock (1983, 1987) proposed that fragments similar to familiar figures elicit the cognitive hypothesis that a surface is occluding missing parts of inducing elements. Symmetry, incompleteness, interruptions, gaps, alignments among interruptions, familiarity, expectations and general knowledge are cues triggering the cognitive problem-solving process. Therefore, in Kanizsa's triangle the alignment among gap terminations and the familiarity of the fragments would elicit a cognitive hypothesis of a triangle occluding three disks and an outline triangle. Finally, Coren (1972) considered the incompleteness of Kanizsa's stimulus as a depth cue that elicits the hypothesis of an occluding triangle.

Kanizsa's triangle can be clearly considered as an illusion corroborating the likelihood principle and the related unconscious inferences, however, more generally, the phenomenon of illusory figures does not necessarily supports this approach. In fact, the incompleteness is neither a necessary nor a sufficient factor in inducing illusory figures (see Pinna & Grossberg 2006). In Figs. 7a-b, it is shown that illusory figures do not necessarily complete incompletenesses. In Fig. 7a, a square array, made up of small squares with a missing element in the right upper corner, is seen. This is perception of "incompleteness" without an illusory figure (not sufficient condition). In Fig. 7b, the square array appears incomplete again but with an illusory bright square larger than the black ones and not occluding anything. Furthermore, the four crossed black squares, all around the largest bright one, do not appear incomplete or partially occluded even though they are connected through T-junctions with the illusory square and are pairwise-colinear, which is the basic constraint that often leads to amodal completion. Briefly, Fig. 7b is a case of incompleteness that is not completed by an illusory square neither locally nor globally. This result represents a logical confutation of the role played by incompleteness if incompleteness is considered as the necessary condition (Pinna & Grossberg 2006).

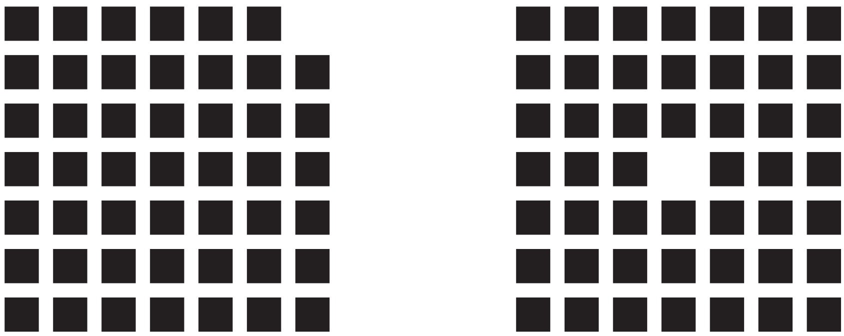

Fig. 7 Illusory figures do not necessarily complete incompletenesses (see the text for details).

Based on Helmholtz's likelihood is the Bayesian statistical decision theory, which formalizes the idea of perception as inference. This theory is considered as an optimal method for making decisions under conditions of uncertainty (Jaynes 1983; Bülthoff & Yuille 1991; Knill & Richards 1996; Landy, Maloney, Johnston & Young 1995; Weiss & Adelson 1998; Nakayama & Shimojo 1992; Mamassian & Landy 1998; Liu, Knill & Kersten 1995; Feldman 2000; Landy et al. 1995). Bayes' rule is given by:

(1) $$p(H \mid D) = \frac{p(H)\,p(D \mid H)}{p(D)}$$

According to Bayes theorem, for data D, the posterior probability $p(H|D)$ of hypothesis H (how likely H is for given D) is proportional to the product of the prior probability $p(H)$ that H occurs, i.e. the probability that interpretation H occurs independently of proximal stimulus D (how likely H is in itself), and the likelihood $p(D|H)$ that D occurs if H were true, i.e. the probability that proximal stimulus D occurs if interpretation H were true (how likely D is under H). The probability $p(D)$ that D occurs is the normalization factor.

Briefly, the Bayesian approach aims to calculate the posterior probability distribution over the hypotheses and to select the most likely hypothesis with the highest posterior probability under the prior and conditional probabilities. The normalization factor can be omitted. The prior denotes how good an interpretation is independently of the proximal stimulus, and the conditional denotes how good the proximal stimulus is if the interpretation were true. According to the previous critical considerations on the likelihood principle, we can ask: where do we get the priors and conditionals from? (see van der Helm 2011b).

Bayesian modeling of perception can be comprised within Marr's (1982) three levels of analysis: computational, algorithmic and implementation levels. The computational level specifies the problem to be solved in terms of some generic input-output mapping. The algorithm specifies how the problem can be solved. The implementation level describes the mechanism that carries out the algorithm. Bayesian models belong to the three levels (Craver 2007; Danks 2008).

Bayes' framework has been valuable in explaining how information is combined with prior knowledge in perceptual inference (see Kersten, Mamassian & Yuille 2004; Kersten & Yuille 2003; Maloney 2002; Mamassian, Landy & Maloney 2002). Some conditions related to grouping principles can also be explained from Bayesian cues of object perception (cf. Bülthoff & Mallot 1988; Landy, Maloney, Johnston & Young 1995; Rosas, Wichmann & Wagemans 2007). For example, several grouping outcomes indicate more than other possible results the presence of an object. More precisely, the reliability of a grouping can be derived from its likelihood function (e.g., Ernst & Banks 2002; Rosas, Wagemans, Ernst & Wichmann 2005). Furthermore, assumptions about the probabilities of the states of the world bias vision towards an interpretation that is, *a priori*, veridical. As a consequence, prior constraints can easily solve perceptual conditions which are otherwise ambiguous (e.g., Mamassian, Knill & Kersten 1998; Willems & Wagemans 2000). By applying formula (1) to perceptual organization, prior probability distributions $p(H)$ could represent the knowledge of the regularities of possible object shapes, while the likelihood distributions $p(D|H)$ could represent the knowledge of how objects are created through projection onto the retina.

Although this kind of application can be useful to explain "what is a visual object?" in a high number of perceptual conditions, it shows clear weaknesses in accounting for the following grouping, shape and meaning formations (see the next figures). In Fig. 8, a square grid of white lines can also be perceived like juxtaposed squares. By reversing the contrast of some components as illustrated in Fig. 8b, black and white juxtaposed squares in the left lower corner and black and white diamond shapes connected in one corner and arranged obliquely in the right upper corner of the whole shape are perceived. The diamond shapes can also be perceived like intertwined overlapped zigzags. The variation of shape within the same grid is something new and unexpected suggesting a complete independence of the reversed contrast from other principles: it operates autonomously from any regularity, simplicity or likelihood principle. In Fig. 8c, the six black squares reorganize the background in a large 8-like shape, while the separated black square on the left side of the grid favors the perception of a cross behind it. The large black squares of Figs. 8d and 8e restructure the background locally and similarly to the isolated black square of Fig. 8c. Finally, in Fig. 8f, the black components are now perceived as two snake-like contours, one of which is arranged vertically and the other horizontally. The square or grid organization of the components perceived in Fig. 8a is now very weak or totally absent. It is worth noticing that further irregular shapes (not illustrated) both in the figure and in the background can be created. A further effect, related to the reversed contrast of the components is the contrast brightness effect due to the black and white components and the color spreading of the lines that is reminiscent of the neon color spreading. These effects are not further discussed in this paper.

In the five conditions (Figs. 8b-f), the holistic-global effect coming from the surrounding reference frame of the grid is ineffective, while the local organization due to the reversed contrast wins against the whole effect. Furthermore, the results demonstrate that the outcome due to the reversed contrast is not only related to grouping but also to figure-ground segregation by virtue of the unilateral belongingness of the boundaries that gives a shape also to the background. Therefore, these results show also shape and meaning formations. The visual meanings emerge through the complex results, not described in details, of the perceived objects. Our conditions and particularly the results of Fig. 8f weaken the simplicity principle based on the briefest possible perceptual encoding and on the maximization of regularity, but also weaken the likelihood principle and the knowledge of the regularities of possible object shapes.

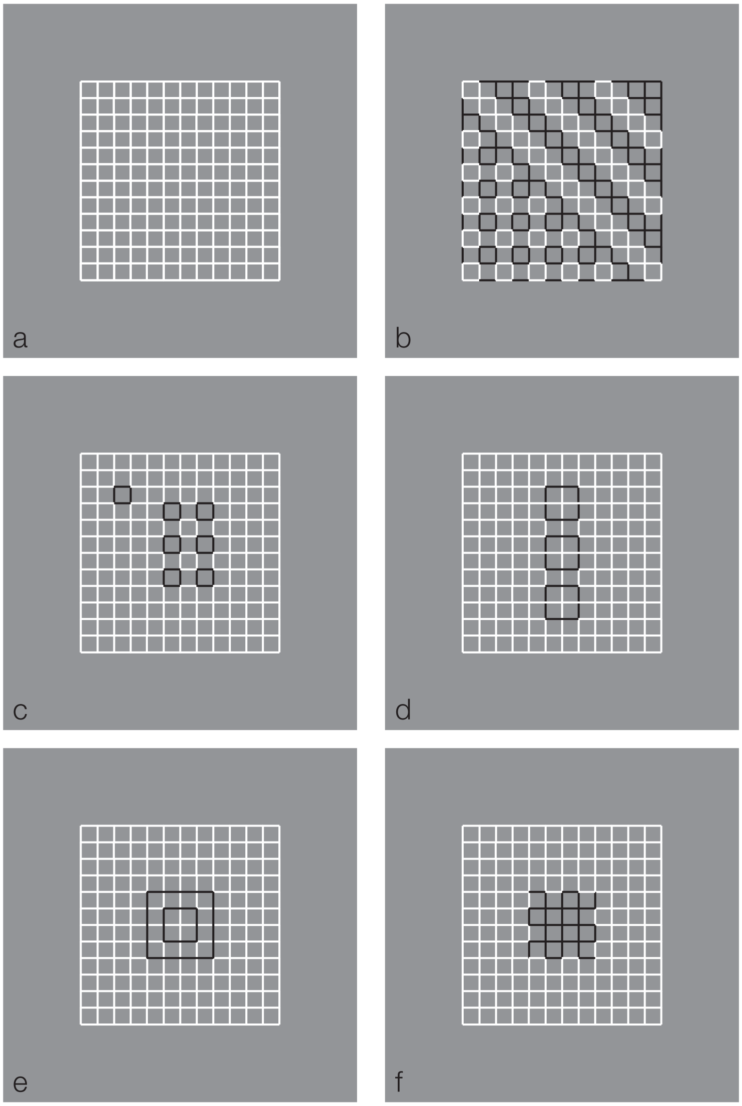

Fig. 8 Six conditions showing the strength of the similarity principle against the simplicity and likelihood principles.

In Fig. 9a, two eight pointed stars, one included in the other, are perceived. This result is enhanced by the black and white difference illustrated in Fig. 9b. In Fig. 9c, the similarity principle breaks the two stars and connects the element components in two rhomboids or diamond shapes intertwined and segregated in depth one upon the other. The regularity and likelihood of the two previous intertwined objects is made irregular in Figs. 9d-e. Much more than other

Gestalt grouping principles the similarity by reversed contrast seems to operate independently from the simplicity, regularity and also prior knowledge. Given that regularity between stimulus elements tends to bind these elements into wholes, if priors reflect regularities of the natural world, then the previous figures strongly weaken these assumptions. This suggests the following question: to what extent, does perceptual organization maximize simplicity and likelihood?

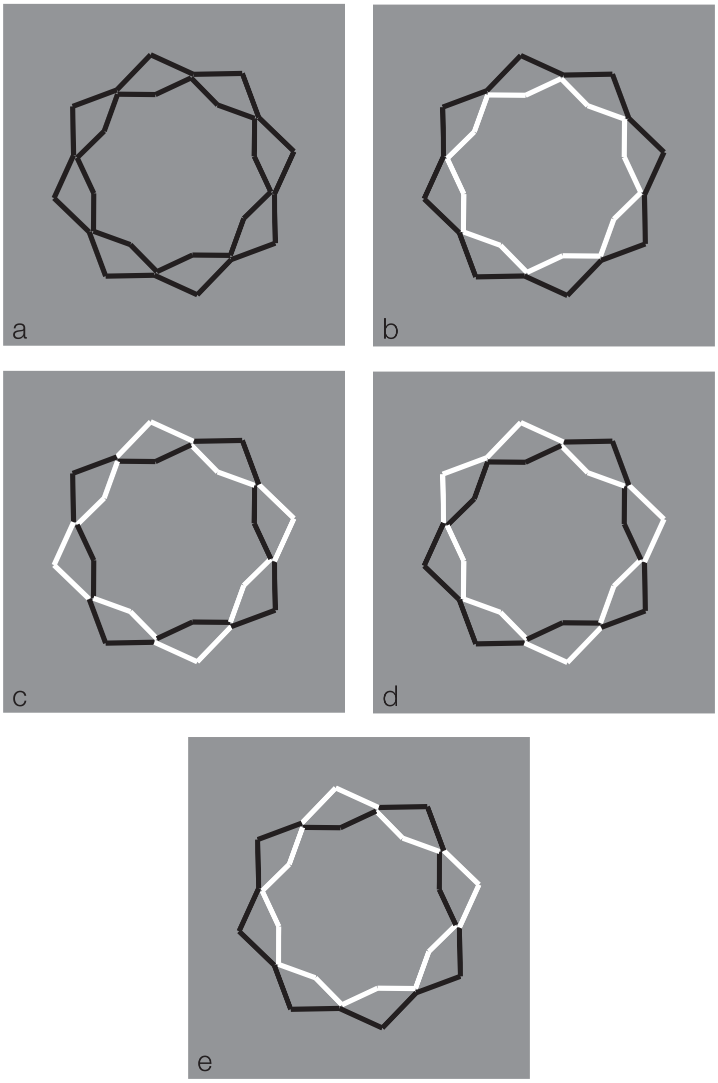

Fig. 9 The similarity principle strongly determines the figure organization.

Even more detrimental and disproving for both simplicity and likelihood principles are the conditions illustrated in Fig. 10, where the reverse contrast breaks the oneness, unitariness of the eight pointed stars and change their shapes making them appear respectively like a concave polygonal shape rather than a star in Fig. 10a, like two rotated and perpendicular square shapes in Fig. 10b, like less and less regular shapes different from stars in the other conditions (Figs. 10c-g). Fig. 10h is the control.

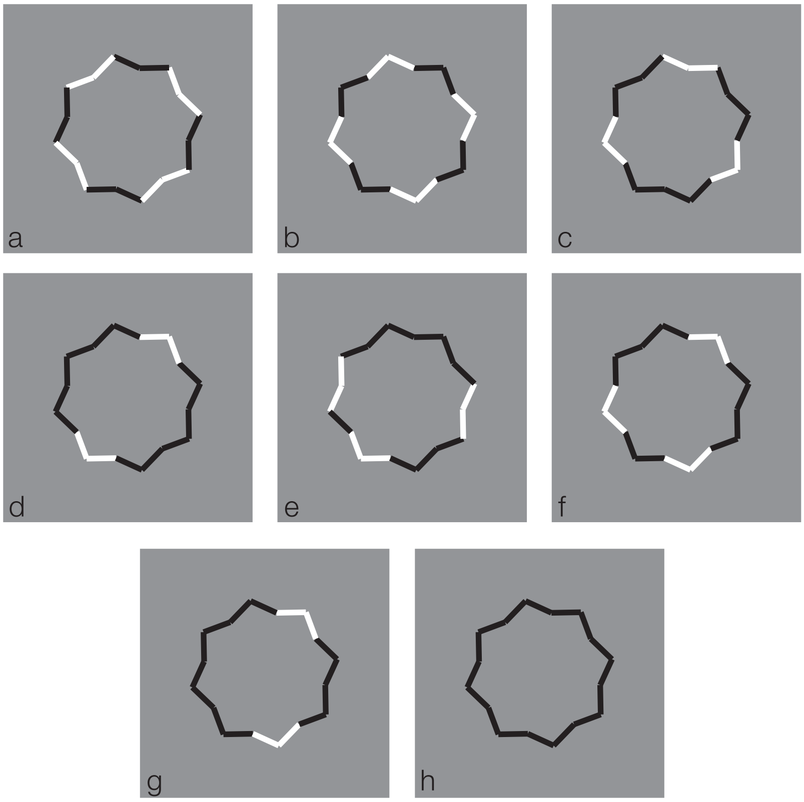

Fig. 10 More conditions based on the similarity principle disproving both simplicity and likelihood principles.

These outcomes demonstrate that oneness, unitariness, symmetry, regularity, simplicity, minimization of description length, likelihood, Kolmogorov complexity, prior constraints and knowledge, priors and conditionals can be strongly weakened. Furthermore, the irregularity of the perceived shapes support the general idea that all the kinds of perceptual organizations going from grouping to shape and meaning operate simultaneously, reveal the complexity of the visual objects and give a place to meanings within perception. In fact, by seeing the irregularity we see a visual meaning related to the regularity perceived indirectly through the irregularity, which appear like the break of the regularity due to the contrast inversion.

To conclude this section, it is worthwhile mentioning a third approach useful to solve the gap and answer the previous questions. This is the ecological approach (Gibson 1950, 1966, 1979) to visual perception, related to Gestalt psychology, which assumes that environmental surfaces structure light in complex but lawful ways. The optical information available in light, i.e. the ambient optic array, refers to the light coming toward a given location from all directions. Vision depends on the lawfulness in the optical structure of the ambient optic array. From these prerequisites emerges Gibson's idea of direct perception, which considers the optical information available in the retina of a moving organism as sufficient to convey visual perception without any mediating processes or internal representations. Such an idea denies that perception is yielded by unconscious inferences going beyond the information strictly given by sensory stimulation. According to Gibson, when the senses are considered as perceptual systems, the theories of vision are not necessary. Therefore, the main problem of vision science is no longer how the mind processes sensory data, or how past experience organize them, or even how the brain can process the inputs, but more simply how information is picked up (Gibson 1966). The results of the previous figures support this main idea. Meaningful objects are, thus, related to affordances of the ambient optic array perceived directly. This meaningful information is adequate, it is not equivocal, and does not require mental processes but only to be picked up from the ambient optic array. Briefly, visual perception is a direct and immediate single-stage process.

3. Towards a Science of Visual Meaning

The previous sections indicated that vision concerns not only detection of information and organization into percepts but also assignment of meanings based on Occamian simplicity principle promoting efficiency and the Helmholtzian likelihood principle promoting veridicality. Some theoretical limits of these historical well-known approaches were sketched and pointed out, and several new conditions put phenomenally to the test these approaches and demonstrated the complexity of object formation and visual organization, which comprise different kinds of processes (grouping, figure-ground segregation, shape and meaning). The study of this complexity, started by Gestalt psychologists, is not fully explored yet, while extensive fields of the notion of visual object and numerous issues related to its perceptual organization wait to be scientifically studied.

What is left to be discovered, understood and explained in object and meaning perception? This special issue, composed of 2 volumes., collects stimulating articles aimed (i) at a deeper understanding of further forms of perceptual organization related and consequent to grouping and figure-ground segregation; (ii) at exploring the ability and distinctiveness of the human perceptual system to organize the world through different kinds of forms and through a complex net of meanings; (iii) at understanding what is a perceptual meaning and, more generally, what is the place of meanings in perception; (iv) at studying the scientific topic of perceptual meanings from a multidisciplinary perspective.

The article by Martin Thiering addresses the question of the role of meaning in perception in spatial semantics and its figure-ground alignments. He presents data from a perceptual-driven elicitation tool used on a small number of languages, some with a non-written tradition. The results show that figure-ground relations are ever so often linguistically reversed and do not follow perceptual or objectively given clues only. This suggests a mismatch between the given gestalt and the linguistic encoding pattern. Perception is indeed more than figural grouping and extends to the formation of shapes and linguistic meaning.

Jurgis Škilters investigates three main theses and related them to the Gestalt approach to semantics. They are the following: meaning generation is inherently perceptual; meaning is an experientially-resonated and event-grounded structure; meaning is grounded in perceptually and conceptually inherent process of construal and perspective-taking. Several Gestalt assumptions are also explored in the light of contemporary cognitive science.

Jan Koenderink provides a clear phenomenological analysis of different kinds of attributes of pictorial awareness as gestalts. He analyzes very deeply different kinds of attributes of pictorial awareness (style, gist, pictorial space, picture frame, ground plane, pictorial objects, pictorial shape, material properties, pictorial grammar) and their description as different kinds of gestalts (global, local and hierarchies of nested gestalts). He demonstrated that pictorial qualities and meanings simply happen in immediate awareness and they are pre-cognitive as gestalts, simultaneously defining and being defined by their components.

The article by van de Cruys & Wagemans analyzes the predictive coding approach as an explanatory framework for perception. The idea that the brain continuously generates predictions based on previous experience is used to examine several insights from the Gestalt tradition. They also illustrate the explanatory power of this approach in aesthetic appreciation in visual art.

The work by Klaus Schwarzfischer presents a new approach towards an empirical theory, aimed to explain the aesthetic experience. This is called "Integrative Aesthetics" and is based on the relief of neuronal resources in the process of 'Gestalt Integration', when the perceptual data are re-coded (from *extensional* to *intensional coding*). The concept of "Gestalt Integration" is viewed in relation to different perspectives, like syntactic, semantics and pragmatic.

Hamburger & Röser study how much it costs to switch between different modalities when subjects have to process gestalt information in form of landmarks in wayfinding (navigation). They demonstrate that in recognition and wayfinding tasks with landmarks there is no evidence for costs in modality switching (lower performance, increased decision times). Their results challenge the notion of switching-costs in the domain of human wayfinding. They assume that the human brain already integrates the relevant Gestalt information in different modalities so that no additional costs occur at the time of information retrieval. In conclusion, a modality switch is possible at no additional cost so that landmarks may also be useful in more (different) modalities than just the visual one.

The article by Pinna aims to answer the following questions: what is shape? What is its meaning? The meaning of shape is studied starting from the square/diamond illusion and according to the phenomenological approach traced by Gestalt psychologists. It is suggested that the meaning of shape can be understood on the basis of a multiplicity of meta-shape attributes that operate like meaningful primitives of the complex language of shape perception.

The works by these authors show the complexity of the question "what is a visual object?" and suggest new questions, new scientific issues and many possible answers about the nature and the role of meaning in visual perception. What emerges is the idea that the visual system is a dynamic nonlinear and strongly integrated system where the notion of meaning can be considered in terms of perceptual organization and, as such, this notion plays a basic role in answering the question "what is a visual object?". The merit of these studies is to have started exploring systematically a new field within the domain of visual perception and, by using the methodological tools and theoretical concepts of vision science, to have contributed to develop a science of meaning. Students and scientists in vision and cognitive science will find much to interest them in this thought-stimulating collection.

The understanding of the questions "what is a visual object?" and "what is the place of meaning in perception?" is continued in Vol. 2.

Baingio Pinna

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