whether illusory figures are affected by cognitive cues that do not allow amodal completion. This was done by replacing Ehrenstein inducing lines by alphabetical letters (either normal or modified) with similar line terminators (Figure 12a and 12b). The perception of the letter of the alphabet requires a cognitive process defining the completeness of it. "*Each letter is perceived complete, but their radial arrangement induces a strong illusory circle*", thereby contradicting rule (i) whereby incompleteness as a necessary factor. Rules (ii) and (iii) are also contradicted, since "*the illusory circle is perceived coplanar and tangent to the letter terminators*". "*An illusory disk with sharp contours is perceived*" even if curved terminators (R and B) and line-end terminators are mixed.

The three rules are refuted even by rotating Figure 12b in 3D space as illustrated in Figure 12c. "*The strength and sharpness of illusory contours and the coplanarity of the illusory disk are here even stronger than previously*". The illusory figure persists even when there are misalignments and deformations both in the inducing letter and in the illusory contours (Figure 12d, 12e and 12f), or even if the letters of the alphabet appear incomplete due to their bottoms being cut in the shape of a disk.

These various results indicate that incompleteness is neither a necessary nor a sufficient condition for inducing illusory figures, and indicate the need for a different explanation. However, incompleteness carries the idea that illusory figures make the understanding of the general problem of figural organization easier. This is an important point to be considered and included within such an alternative explanation. These are topics of the next section.

4. The hypothesis of figural organization of local inductions of contours and brightness

The questions to answer in this section are: How can the previous results be interpreted? Can the incompleteness hypothesis be replaced by a new hypothesis that overcomes the previous logical and phenomenological problems of the incompleteness theories? Section 3.2 showed the role of grouping and figure-ground segregation principles in inducing illusory figures. It is proposed below that these principles involve both *boundary contour discontinuities* like the wiggly concavities of Figure 1, as well as *brightness inhomogeneities* that are induced along the same wiggly concavities or at line terminators (Figures 5, 9, 11, 12). The line terminators are a special case of boundary contour discontinuities, because of the abrupt change in contour direction. These two factors clarify the more general problem of figural organization, where illusory figures still play a leading role. The next sections propose how to overcome inadequacies of the incompleteness hypothesis in explaining figural organization in terms of how percepts are completed in response to boundary contour discontinuities and brightness inhomogeneities.

4.1. Figural organization of boundary contour discontinuities

The problem of figural organization has his roots in opposite qualities of figure and background (Rubin, 1915, 1921) that depend on a phenomenal scission between figure and background and, more generally, between object and reference frame (Koffka, 1935; Köhler, 1920; Metger, 1963); namely: (i) a border is unidirectional, and belongs to the figure (border ownership), not to the background; (ii) a figure possesses a bright, compact, and opaque surface color, whereas a background shows a diaphanous color and appears empty; and (iii) a figure appears to lie above the background, whereas the background is unlimited and continues underneath the figure.

These points are illustrated in Figure 13. Consider the "*electric plug-like shape*" of Figure 13a, showing two additions, and the "*half-circular shape*" of Figure 13b. When they are put together, as shown in Figure 13c, "*a clear illusory E is perceived and the whole pattern is read as D-ED*". "*The two Ds appear on a white background, while the E is perceived on a black background*". "*No incompletenesses are present in the component elements*". They can be defined only after the illusory figure is perceived, but this implies a paradox as has already suggested. Instead, convexities and additions, clearly perceived in Figure 13a, are not anymore perceived as such in Figure 13c, because their boundaries there belong to the E and not to the plug-like shape, in Figure 13a, and thus they become background.

Figure 13

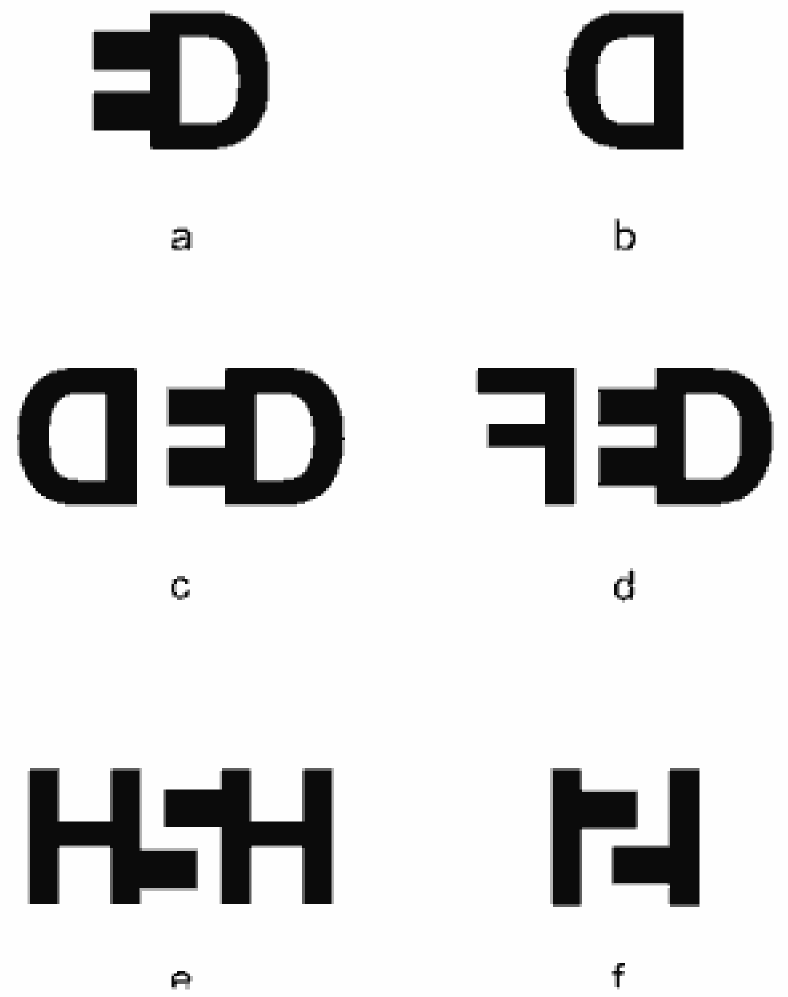


Figure-ground organization of boundary contour discontinuities. (a) Electric plug-like shape; (b) half-circular shape; (c) by putting together (a) and (b) a clear illusory E is perceived and the whole pattern is read as DED; (d) an illusory E is perceived; (e) an illusory 5 digit emerges; (f) an illusory number 2 on a black background or, alternatively, an illusory 2 on a black background with two adjacent I letters on both sides of the 2 digit.

Similar examples useful for a comparison of the strength of the illusory letters are illustrated in Figure 13d and 13e, where convexities and additions are complementary to concave discontinuities and gaps. "*The illusory E is clearly perceived in Figures 13d and the illusory 5 in Figure 13e*". While "*the concave discontinuities* (for example the three white arms of the E in Figure 13d) *tend to appear as a figure*", "*the convex additions* (for example the two black additions to the D in Figure 13d) *are grouped and perceived as a black background*". Because the same border can be perceived both concave and convex depending on the direction of the perception – that is, from the left to the right or from the right to the left – the border of the two boundary conditions belongs to complementary regions. It is worthwhile noting that the two black additions to the D in Figure 13d, perceived as a black background, are not perceived as additions anymore and, as a consequence, they split from the D, thus inducing "*two illusory vertical boundary contours that separate the two regions and that belong to the D*". These illusory contours disappear when the electric plug-like shape is perceived.

These examples illustrate that the problem of illusory figures can be considered as part of the more general problem of figure-ground organization, notably of how boundaries are grouped and ungrouped in a way that is sensitive to figure-ground constraints. Figure-ground organization plays a role in illusory figure formation even if the effects of past experience are weakened. In particular, grouping and ungrouping can influence border ownership of the ungrouped boundaries. For example, in

Figure 13f, the perceptual results were described as (i) "*an illusory number 2*", and "*an illusory reflected S both on a black background*" or (ii) alternatively "*an illusory number 2 on a black background with two adjacent I letters on both sides of the 2 digit (I2I)*". The inducing elements, observed separately, can be phenomenally described as "*two small horizontal rectangles, each connected to two larger vertical rectangles*". The percept of a 2 on a uniform black background depends on the grouping of the small horizontal rectangles with the two larger vertical ones. The percept of I2I is facilitated by the ungrouping of the small rectangles from the larger ones, due to the discontinuity in the directions of their boundaries, thus eliciting the illusory contour formation in between them, as described in Figure 13d. This ungrouping makes the perception of the illusory 2 easier, enabling the small rectangles to lose their boundaries to the illusory 2 digit and enabling the large rectangles to appear as such or as I letters, in agreement with past experience through cognitive priming of the 2.

These phenomenal results show that the role of incompleteness can be similarly explained in terms of boundary contour grouping processes and figure-ground organization, as they apply to the perception of illusory figures. Such an analysis avoids the paradoxes raised by "incompleteness" as an explanatory principle, yet also provides explanations of the phenomena that motivated this hypothesis. In particular, boundary contour grouping principles:

(i) are not restricted to specific figural conditions like incompleteness but cover multiple boundary contingencies, including additions, line terminators, and parallel contours (see in particular Sections 3.5 and 4.1);

(ii) incorporate both local and global boundary conditions, as illustrated in Section 3.3;

(iii) do not necessarily require amodal completion of inducing elements (Sections 3.3 and 3.5), but can induce illusory figures without amodal completion;

(iv) can predict opposite and complementary figure-ground organizations, as shown in Section 3.2;

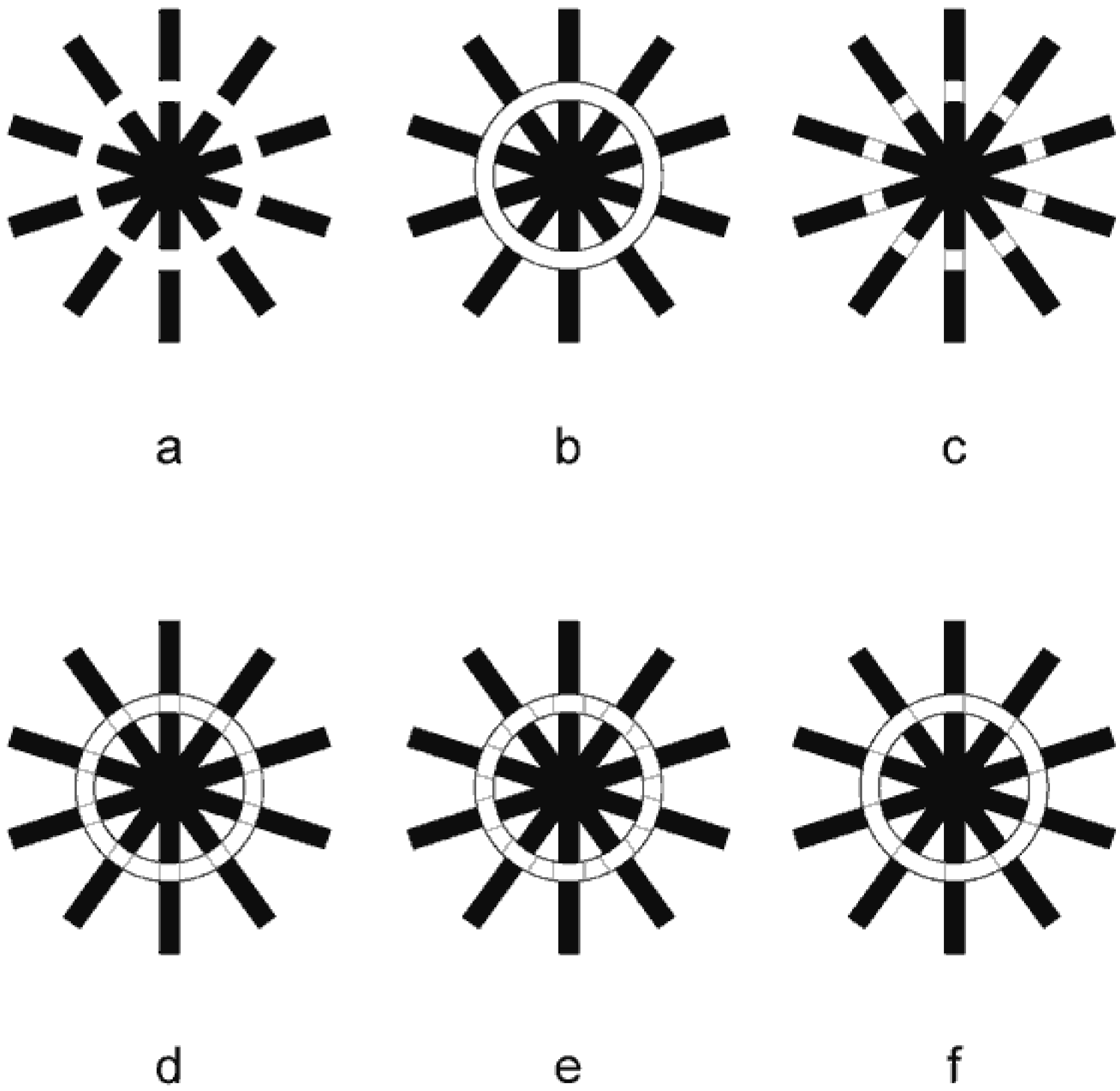
(v) predict the shape of illusory figures on the basis of the grouping of local discontinuities and their connections (Sections 3.2 and 3.4). Thus the shape of illusory contours is not necessarily equal to the shape of real contours and to the shape of incompleteness.

The figural properties of the illusory figures are accompanied by brightness enhancements along with the illusory figures that cannot be accounted for solely by the organization of brightness discontinuities. Both boundary grouping and surface filling-in processes work in parallel, indeed are represented by parallel cortical interblob and blob streams from cortical areas V1 through V4, to synergistically create the strong figural properties of real and illusory figures. The modeling articles of Grossberg (1994, 1997), Grossberg and Mingolla (1985a, 1985b), Grossberg and Swaminathan (2004), Kelly and Grossberg (2000), and of Raizada and Grossberg (2003) propose and simulate cortical mechanisms of perceptual grouping and figure-ground perception whereby these properties may be realized; see Section 5.

4.2. Figural organization of brightness inhomogeneities

In Figure 14a, "*the radial stripes appear partially occluded by an illusory bright annulus*". By replacing the illusory contours with real ones (see Figure 14b), "*the annulus loses its large brightness enhancement, although weak brightness enhancement persists within the interspace between the stripe terminators*". Furthermore, as in Figure 10, "*the inner and outer circles of the annulus appear as pointed arcs wedged in the black strips*", illustrating the illusion of angularity (Pinna, 1991). "*In Figure 14c, the brightness enhancement is stronger than in Figure 14b*", due to the pairs of lines that continue the boundaries of the stripes within the interspaces. In Figure 14d, by bordering the annulus with real contours, "*the induced brightness next to the stripe terminators pops out relative to the dark connecting regions within the annulus*". "*The brightness and darkness inductions are contained in separated sectors of the annulus*". Due to this separation, "*they are enhanced compared to Figure 14c*". Functioning as both filling-in generators and filling-in barriers (Grossberg, 1994, 1997), the separation lines stop and contain both the brightness filling-in (see Figure 14a) and the darkness filling-in (see Figure 14b) along the annulus. By widening the brightness area, as illustrated in Figures 14e and 14f, "*the brightness and darkness spreading effects are diluted, though not homogenously*", as in the Kanizsa and Minguzzi (1986) anomalous brightness differentiation and impossible staircase (Escher, 1961; Penrose and Penrose, 1958) brightness illusions, respectively, both of which are simulated in Grossberg and Todorovic (1988) by using boundary and surface interactions.

Figure 14



Figural organization of brightness inhomogeneities. (a) The radial stripes appear partially occluded by an illusory bright annulus; (b) the annulus loses its large brightness enhancement, although weak brightness enhancement persists within the interspace between the stripe terminators; (c) the brightness enhancement is stronger than in (b); (d) the induced brightness next to the stripe terminators pops out relative to the dark connecting regions within the annulus; (e) and (f) the brightness and darkness spreading effects are diluted, though not homogenously.

The conclusions suggested by these phenomenal results are the following:

(i) Brightness induction peculiar to illusory figures is elicited whether or not there are figural incompletenesses (Figures 14b-14f);

(ii) brightness enhancement is induced next to each stripe terminator;

(iii) brightness inhomogeneities are induced independently from the presence of illusory or real contours;

(iv) brightness inhomogeneities spread and fill long distances (Figures 14a and 14b);

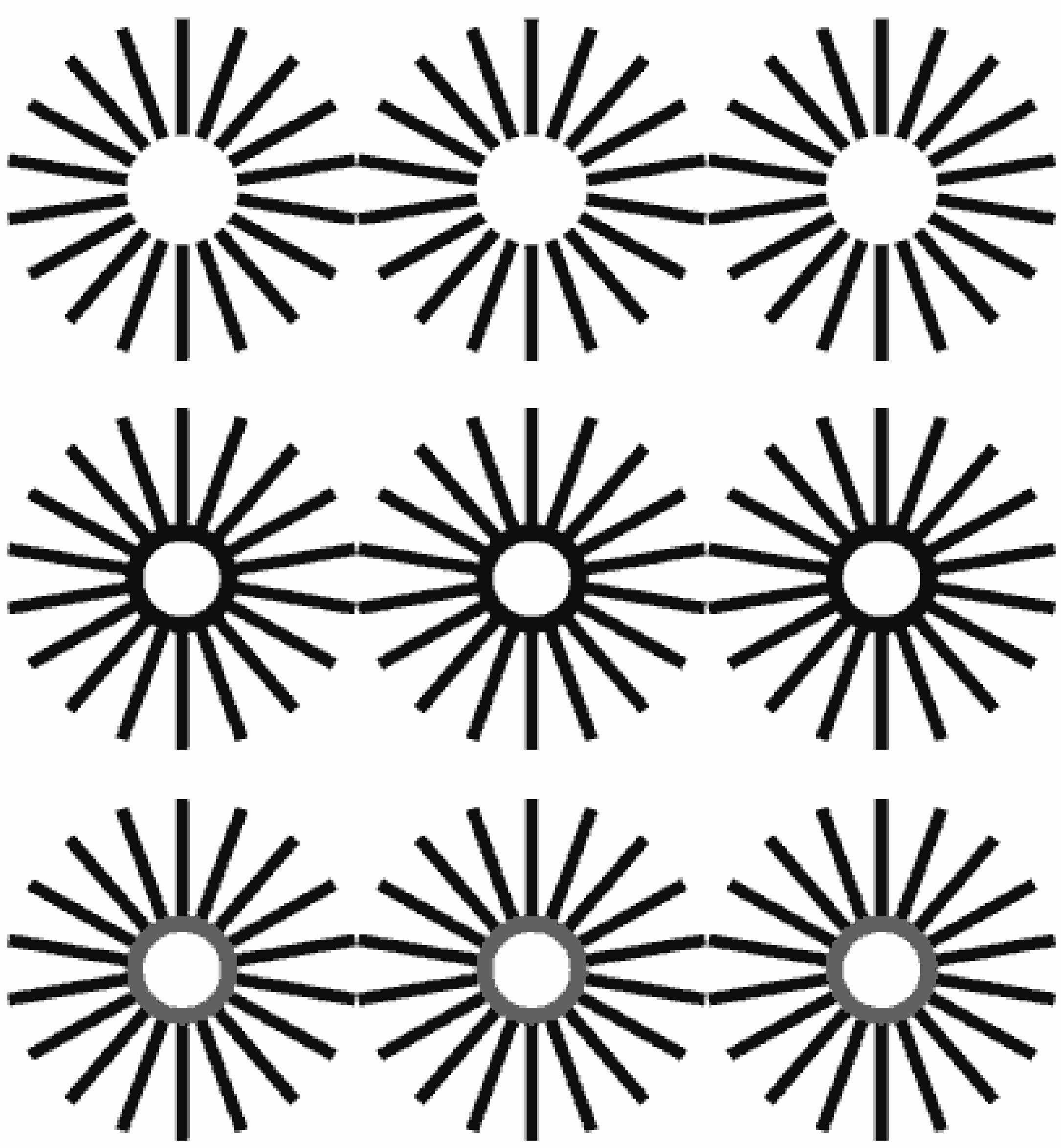
(v) brightness spreading can be contained by both illusory and real boundaries (Figures 14a-14e) acting as barriers;

(vi) among brightness inhomogeneities, darkness enhancement may be perceived, especially when a real boundary separates the respective regions (Figure 14d);

(vii) bright and dark inhomogeneities mix while they spread (Figures 14a, 14b, 14f) if they are not separated by boundaries.

The amount of brightness and darkness induction changes by replacing illusory with real contours but in a manner that does not depend upon incompletenesses. "*Going from Figure 14a to Figure 14b, the decrease of brightness*" may not depend on the completion of the gap, but rather on darkness assimilation due to the parallel black lines among the radial stripes. Figure 14d supports this hypothesis. Here, the assimilation effect is enhanced due to the presence of the pairs of perpendicular parallel lines enclosing the darkness assimilation regions and separating them from the brightness induction areas. The hypothesis of darkness induction due to assimilation processes may be only part of the explanation of the perceptual result of Figure 14d. In fact, it appears similar to the dark spots perceived at the crossroads of the Hermann grid and within the circular arrangement of triangles or zigzag elements of Kennedy's Sun Effect. This hypothesis deserves further experimental attention.

Figure 15



Chromatic assimilation effect. Surface processing occurs parallel to boundary formation, and its properties do not necessarily derive from figural incompleteness: (top) brightness enhancement conspicuously fills the central gaps between the radial lines (Ehrenstein illusion); (middle) when black rings are superimposed onto the illusory disks, the brightness enhancement largely disappears; (bottom) however, when colored annuli replace the black rings, an effect much brighter than in the Ehrenstein illusion occurs with a dense appearance comparable to a paste of bright and quasi-luminous white color added to the surface of the paper.

These examples of brightness induction, among others (Brigner & Gallagher, 1974; Frisby & Clatworthy, 1975; Day & Jory, 1978; Jory & Day, 1979; Grossberg, 1983, 1984, 1987a; Grossberg & Mingolla, 1985a, 1985b, 1987), illustrate that surface processing is a distinct process that occurs parallel to boundary formation, and that its properties do not necessarily derive from figural incompleteness properties. Figure 15 illustrates this conclusion in a vivid way. In the classical Ehrenstein illusion (Figure 15, top), "*brightness enhancement conspicuously fills the central gaps between the radial lines*". Ehrenstein (1941) showed that, when black rings are superimposed onto the illusory disks, "*the brightness enhancement largely disappears*" (Figure 15, middle). This property is in agreement with incompleteness theories. However, when wide colored annuli (e.g. purple, as in Figure 15, bottom) are used that replace the black rings, brightness cancellation does not occur. Instead, it produces "*an effect much brighter than in the Ehrenstein illusion. The white disks also show a dense appearance comparable to a paste of bright and quasi-luminous white color added to the surface of the paper*" (Pinna et al., 2003).

The cases illustrated in this section demonstrate that boundary and surface formation processes are parallel, distinct, but mutually interactive processes that together give rise to figure-ground segregation properties. Indeed, brightness inhomogeneities are especially induced next to line terminators (e.g., Figures 9a, 10a 12), as well as concave (e.g., Figures 1b and 2) and convex (e.g., Figure 12a and 15) boundary discontinuities.

5. *Conclusions*

According to cognitive and gestalt theories, incompleteness was considered as a necessary and sufficient factor for illusory figure formation. The role of incompleteness has herein been studied in terms of its inner logic and through a phenomenological analysis of new cases. It is shown that incompleteness is neither sufficient nor necessary to induce illusory figures. These problems are eliminated when the incompleteness hypothesis is replaced by concepts concerning interacting boundary grouping and surface filling-in processes during figure-ground segregation. These interactive boundary grouping and surface filling-in dynamics give rise to the three basic figure-ground properties (phenomenal scission between figure and background, see Koffka, 1935; Köhler, 1947, Metzger, 1963): the unidirectional belongingness of boundaries to the illusory figure, not to the background; the enhanced brightness of surface color under certain conditions; and the illusory figure lying above a background that continues underneath the illusory figure.

Compared to the logical and phenomenological problems coming from the incompleteness hypothesis, advantages of this new dynamic hypothesis are:

(i) Incompleteness becomes just one property to be explained, similarly to illusory figures, in terms of boundary and surface dynamics;

(ii) boundary and surface dynamics are not restricted to properties of incompleteness, and are thus not subjected to incompleteness paradoxes;

(iii) boundary formation processes can handle other kinds of discontinuities than incompleteness;

(iv) surface and boundary processes can explain both local and global levels of object representation, including both bottom-up and top-down levels of object representation.

The suggested hypothesis is consistent with neurophysiological experiments. Von der Heydt et al. (1984) and Peterhans and von der Heydt (1987) demonstrated that neurons in area V2 of the monkey cortex are respond to both real and illusory contours. Sasaki and Watanabe (2004) reported distinct fMRI signatures in the human visual cortex for illusory contours and for color spreading processes, including color spreading in V1. Zhou et al. (2000) found a substantial fraction of cells that are sensitive to border-ownership in area V2; cf., Section 4.1. Baylis and Driver (2001) found that neurons in monkey IT (inferotemporal) cortex, which are supposed to be involved in object recognition, respond differentially to figure or ground, and as a consequence to border ownership. Kleinschmidt et al. (1998) in fMRI studies on figure-ground reversals found activation over a number of areas in occipital, temporal, parietal and even frontal cortex. fMRI studies of Kanizsa squares by Hirsch et al. (1995) revealed that there was activation of the occipital cortex lateral to V1 where signals related to segmentation were present. Mendola et al. (1999) found that signals related to illusory contours were observed in cortical area V3 and also in LO, the lateral occipital area (Malach et al., 1995).

The FACADE neural model of boundary and surface formation during figure-ground segregation (Cao and Grossberg, 2004; Grossberg, 1994, 1997; Grossberg and Howe, 2003; Grossberg and McLoughlin, 1997; Grossberg and Swaminathan, 2004; Grossberg and Yazdanbakhsh, 2005; Kelly and Grossberg, 2000; Raizada and Grossberg, 2003) provides a conceptual foundation with which to replace hypotheses about incompleteness with new perceptual and neural organizational principles and mechanisms that are not subject to the problems of the incompleteness hypotheses and which have begun to provide explanations of the types of data that have been summarized herein. Various of the percepts induced by Figures 1 – 15 can be explained by using FACADE model mechanisms that were described and simulated in Grossberg (1994) and Kelly and Grossberg (2000). Several such explanations are sketched here to illustrate this claim.

Some of the percepts illustrate how Petter's principle (Petter, 1956) is realized by FACADE grouping and figure-ground mechanisms. For example, the percepts in Figures 4, 5, and 8c can be explained by the fact that bipole grouping cells (Grossberg and Mingolla, 1985a, 1985b; Raizada and Grossberg, 2003) form real and illusory boundaries via long-range excitatory connections and shorter-range inhibitory connections. Some of the shorter-range inhibitory connections ensure that the groupings form inwardly between pairs or greater numbers of (almost) collinear contours. Other inhibitory connections suppress weaker boundary groupings at nearby positions and at different orientations and depths.

In response to Figure 4a, boundary completion can occur between the exterior contours of the black disk that are interrupted by the thin white triangular shape, since the excitatory connections that group over the thin white shape have a high *support ratio* (Shipley and Kellman, 1992). In contrast, completing a collinear boundary is much more difficult between the aligned contours of two thin white triangular shapes that belong to different black disks. Here the support ratio is much smaller for the corresponding bipole cells. When the shorter-range inhibitory connections of the two classes of bipole cells compete, the boundaries within the circular disk win. This event is enough to trigger the figure-ground percept of a triangle that is partly seen through three circular holes in a white surface. The explanation is the same as the one given and simulated for Kanizsa stratification in Kelly and Grossberg (2000).

A key step in this explanation is based on a prediction made in Grossberg (1987b, 1994, 1997) that the stronger boundary can break the weaker boundary where it abuts the stronger boundary, thereby creating a gap in the weaker boundary. This step triggers depthful figure-ground percepts through a feedback interaction between boundary and surface representations. This hypothesis has been useful in explaining many figure-ground data, most recently data about how the visual cortex generates 3D transparency and neon color spreading percepts (Grossberg and Yazdanbakhsh, 2005). The predicted boundary breaks may change perceived brightnesses due to the spreading of contrast, through the boundary gap, between contiguous surface regions. Percepts of bistable transparency provide a particularly useful way to test this hypothesis, since focusing attention on the boundary of one region can cause its surface to be seen in front of the other region, and should cause a perceived change in brightness. Shifting attention to the boundary of the other figure can cause its surface to be seen in front, again with a perceived change in brightness. Tse (2005) has recently reported just such a perceived brightness change during percepts of bistable transparency.

Figure 4b greatly improves the support ratio of the bipole cells that group collinearly across a pair of black disks, since the pac man inducers are considerably larger. In addition, thickening the white triangular regions greatly weakens the support ratio of the bipole cells that might attempt to complete a boundary around each black disk. In particular, the small triangular black regions that lies between the thicker white bars provide very little support for completing a boundary across each bar. Thickening the white regions also makes the orientations of successive contours in the black region differ more. All these factors work together to enable the collinear grouping into a triangle to occur. This event triggers the percept of a triangle in front of partially occluded disks, again with the same explanation as Kanizsa stratification. Figure 4c has a similar explanation. Figures 5a and 5b have an explanation that is similar to that for Figures 4a and 4b. Figure 5c combines several of these factors by altering the relative support ratios in the left and right sides of the figure.

Several of the figures probe the properties of the bipole grouping kernel, which was designed in Grossberg and Mingolla (1985b) to already include properties that were later called *relatability* by Kellman and Shipley (1991) and *association field* by Field, Hayes, and Hess (1993). For example, in Figure 1b, the irregular bounding contours in each pair of contiguous black figures are relatable, and are capable of causing boundary completion across the intervening white regions. These boundaries can then pull the figure thereby formed forward and the black regions backwards, by the same mechanisms as in Kanizsa stratification, thereby leading to a percept of an irregular figure in front of four partially occluded black squares. Figure 1c supports this interpretation by making the irregular contours unrelatable. Figure 1d, the case of "articulation-without-rests", again enables illusory contours to form with respect to the two exterior irregular boundaries and the two ends of the rests. This case of boundary completion depends upon the fact that line ends generate a band of inducing orientations that are almost perpendicular to the line orientation (Grossberg and Mingolla, 1985b), a fact that is crucial in generating the illusory circular boundary in the Ehrenstein illusion of Figure 15c. Once these illusory contours are formed, the same figure-ground mechanisms operate again. Various cases in Figure 2, notably Figures 2b, 2c, and 2d, have similar explanations. So does Figure 7a.

The explanation of the percept derived from Figure 1b also raises the issue: Why do we not *see* the illusory bounding contour of the central figure? This property can be explained by the fact that "all boundaries are invisible" within FACADE theory (Grossberg and Mingolla, 1985b; Grossberg, 1994). That is, boundaries pool over opposite contrast polarities at each position, hence cannot discriminate between dark and light. They do this in order to create complete boundaries of objects that are seen in front of textured backgrounds whose relative contrasts with respect to the object reverse as the object boundary is traversed. This pooling of opposite contrast polarities occurs at complex cells of cortical area V1. Boundaries become visible when they separate surfaces that fill-in different surface lightnesses, brightnesses, or colors. In Figure 1b, any such difference in filled-in surface lightness or brightness is small between the irregular figure and the background white regions.

The main differences between Figure 9a and 9b can also be explained by how boundary relatability and figure-ground properties interact. In

Figure 9a, the horizontal lines that separate the circular open regions generate boundaries which are stronger than the illusory boundaries that bound the open regions. FACADE mechanisms explain how these horizontal boundaries can be seen in front. In particular, the horizontal boundary that is seen in front inhibits possible redundant copies of itself at the same positions but further depths. This across-depth inhibition is part of the surface-to-boundary feedback that is used in all FACADE figure-ground explanations. In this case, the surface is the black filled-in representation of the line itself. Such surface-to-boundary feedback ensures that perceived boundary and surface representations are *consistent*, even though the laws that they obey are *complementary* (Grossberg, 1994). Figure-ground separation is predicted to be a consequence of this consistency operation. Because the redundant copies of the horizontal boundary are inhibited at further depths, the illusory contours of the circular regions can complete behind it via relatability constraints, thereby completing the double 8 percept that is amodally perceived behind the horizontal lines.

The percepts in Figure 14 can be explained using some of the same ideas that Grossberg and Todorovic (1988) used to explain and simulate Kanizsa-Minghuzzi (1986) anomalous brightness differentiation and the impossible staircase (Escher, 1961; Penrose, 1958). One idea is that all brightness and darkness inductions combine when filling-in occurs within a bounded region. In Figure 14a, these are brightness inductions that are generated within the anular region by the black radial stripes. These brightness inductions are trapped inside the illusory annular boundaries, and can fill-in freely throughout the annulus.

In Figure 14b, the situation is more complicated due to the existence of the black circular contours that bound the annulus. Here, the black radial stripes can again cause brightness induction. However, the boundaries that are formed at the stripe-annulus *edges* are stronger than the boundaries that are formed by the thin black annular bounding *lines*. Whenever a stronger boundary collinearly abuts a weaker boundary, a boundary weakening or even a gap can form at the end of the weaker boundary, just as in the case of figure-ground separation that was discussed above. One can see the effects of such boundary gaps in percepts such as neon color spreading, where part of the explanation concerns how they are formed by sudden changes in boundary strength (Grossberg and Mingolla, 1985a). In the present case, some darkness spreading occurs from the black lines into the annular region. The brightness and darkness inductions spread during filling-in within the annulus, leading to a darker percept in response to Figure 14b than Figure 14a.

The fact that the brightness enhancement is greater in Figure 14c than Figure 14b has a similar explanation, but here the weaker line boundaries are collinear with the stripe edge boundaries. Figure 14d prevents the brightness inductions from spreading through the annulus, as in Figure 14b, but combines darkness inductions from weaker line boundaries that are collinear with the ends and the sides of the stripe edge boundaries. Figures 14e and 14f support the hypothesis that the brightness and darkness inductions can spread within their bounding contours. In particular, Figure 14f is a version of an impossible staircase.

These explanations illustrate how FACADE concepts about 3D boundary completion and surface filling-in, particularly as they lead to 3D figure-ground percepts, can be used to replace concepts about incompleteness without leading to any logical paradoxes. Percepts such as those derived from Figures 3 and 13 can be explained using similar mechanisms, with the addition that top-down attention to familiar letters from inferotemporal recognition categories can also influence the pre-attentive grouping process. How such pre-attentive and attentive factors may combine to enhance attended groupings is reviewed elsewhere; e.g., Grossberg (1999) and Raizada and Grossberg (2003).

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Abstract

Cognitive and gestalt vision theories consider incompleteness to be a necessary and sufficient factor for inducing illusory figures. The role of incompleteness is studied herein by defining the inner logic subtended by use of the term "incompleteness", presenting new cases to clarify the phenomenology of incompleteness as a necessary and sufficient condition, and suggesting an alternative hypothesis to explain illusory figures after analyzing problems with the incompleteness hypothesis. It is demonstrated that incompleteness is not a sufficient condition, illusory figures do not necessarily complete incompletenesses, the shape of incompleteness does not predict the shape of illusory figures, and incompleteness is not a necessary condition. Finally, it is noted that the incompleteness hypothesis can be replaced by concepts concerning interacting boundary grouping and surface filling-in processes during figure-ground segregation. The suggested hypothesis is consistent with neurophysiological experiments and is described in terms of the FACADE neural model of boundary and surface formation during figure-ground segregation.

Résumé

Les théories cognitives et de la vision de la Gestalt considèrent l'incomplétude comme une condition nécessaire et suffisante pour induire des figures illusoires. Le rôle de l'incomplétude est donc étudié en définissant la logique interne que l'emploi du terme «incomplétude» sous-tend, en présentant de nouveaux cas pour clarifier la phénoménologie de l'incomplétude en tant que condition nécessaire et suffisante, et en suggérant une hypothèse alternative pour expliquer les figures illusoires après avoir analysé les problèmes avec le modèle de l'incomplétude. Nous démontrerons, au contraire, que l'incomplétude n'est pas une condition suffisante, que les figures illusoires ne saturent pas nécessairement l'incomplétude, que la forme de l'incomplétude ne prédit pas la forme des figures illusoires, et que l'incomplétude n'est pas une condi-

tion nécessaire. Pour finir, nous observerons que l'hypothèse de l'incomplétude peut être remplacée par l'emploi de concepts qui concernent le groupement de contours en interaction et les procès de remplissage de surface pendant la ségrégation figure-fond. L'hypothèse que nous suggérons est cohérente avec les expérimentations neurophysiologiques et elle s'inscrit dans le modèle neural des contours FACADE.

Riassunto

Sia le teorie cognitive che quelle gestaltiste considerano l'incompletezza come un fattore necessario e sufficiente per l'induzione dei contorni illusori. Scopo di questo lavoro è (1) studiare il ruolo dell'incompletezza attraverso l'analisi della logica implicita all'uso del termine "incompletezza", (2) presentare nuove condizioni percettive utili per chiarire fenomenologicamente se l'incompletezza costituisca di fatto ragione necessaria e sufficiente e, infine, (3) proporre, successivamente all'analisi del ruolo svolto dall'incompletezza, un'ipotesi alternativa in grado di spiegare le figure illusorie. L'analisi logica e fenomenologica dell'incompletezza ha dimostrato che quest'ultima non è una ragione né necessaria né sufficiente per il costituirsi delle figure illusorie, infatti queste ultime non completano le incompletezze così come la forma delle incompletezze non può predire la forma delle figure illusorie. L'ipotesi dell'incompletezza può essere sostituita con una più efficace spiegazione basata sul raggruppamento dei contorni e sui processi di filling-in che avvengono durante la segregazione figura-sfondo. Questo tipo di spiegazione è coerente con i dati neurofisiologici ed è, in questa sede, proposta nei termini del modello neurale FACADE che descrive la formazione dei contorni e delle superfici durante la segregazione figura-sfondo.

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