COMMENTARY ON VICARIO's
ON WERTHEIMER'S PRINCIPLES OF ORGANIZATION

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Giovanni Bruno VICARIO (1998) raises provocative questions about WERTHEIMER'S principles of organization. We admire the persistence with which he pursues these sources of "unceasing discomfort" (p. 259). Over two decades ago he cast doubts "on the true significance of WERTHEIMER'S principles of organization" (VICARIO, 1975). He reiterates these concerns in the present report, adds some new arguments, and concludes "there must be something wrong" in WERTHEIMER'S laws.

WERTHEIMER on Organization of Perceptual Forms

In light of the severity of VICARIO's charges, it seems to us appropriate, before examining the basis of these claims, to turn to WERTHEIMER's classical paper on organization of perceptual forms. It began as follows (1923; from abridged translation in ELLIS, 1938):

I stand at the window and see a house, trees, and sky.

…The concrete division which I see is not determined by some arbitrary mode of organization lying solely within my own pleasure; instead I see the arrangement and division which is given there before me. And what a remarkable process it is when some other mode of apprehension does succeed!

…Or, one sees a series of discontinuous dots upon a homogeneous ground not as a sum of dots, but as figures. Even though there may here be a greater latitude of possible arrangements, the dots usually combine in some "spontaneous," "natural" articulation – and any other arrangement, even if it can be achieved, is artificial and difficult to maintain.

When we are presented with a number of stimuli we do not as a rule experience "a number" of individual things, this one and that and that. Instead larger wholes separated from and related to one another are given in experience; their arrangement and division are concrete and definite.

Do such arrangements and divisions follow definite principles? (1938, pp. 71-72)

An affirmative answer was given by WERTHEIMER in contrast to the then prevailing view that perception is arbitrary, that what we see is determined solely or mainly by "past experience", by "association," or by "contiguity." Without denying that there are conditions under which this is the case, WERTHEIMER suggested a different approach to the study of what we see. Using mainly perception of constellations of dots, WERTHEIMER described factors or principles or laws of visual

perception, noting that many also hold for auditory perception. Thus, "the Factor of Proximity…the first of the principles which we undertook to discover… holds also for auditory organization" (p. 74). But spatial proximity will not alone account for organization. The factors WERTHEIMER described included the following:

– The Factor of Proximity
– The Factor of Similarity
– The Factor of Uniform Density (or "Common Fate")
– The Tendency Toward Prägnanz
– The Factor of Objective Set (Einstellung)
– The Factor of Direction
– The Tendency Toward Closure
– The Factor of the "Good Gestalt"
– The Factor of Past Experience (or Habit)
– The Factor of Stimulus Differentiation (Inhomogeneity of the Visual Field)

We recognize that it is possible to collate and enumerate the factors differently, to omit some of the factors as duplications, or to add others. For example, should Closure and the "Good Gestalt" be put together and count as only one factor? Nor did WERTHEIMER number the factors as we did. For example, in III he referred not to one factor but to the query: "What will happen when two such factors appear in the same constellation? They may be made to co-operate; or, they can be set in opposition" (pp. 76-77).

WERTHEIMER did not claim that he had discovered or had described all the factors or laws or principles of perceptual organization. Nor did he claim that they operated under all conditions. Instead he urged study of the conditions under which each factor operated and comparison of the strength of different factors by pitting one against the other or by having them work together. If WERTHEIMER had claimed that he had found all the laws underlying perceptual organization, then he would have been wrong. But he made no such claim.

VICARIO's Arguments: On Opposites

Returning now to VICARIO's report, we note that his arguments in the 1975 paper were based on figures, which are reproduced in the present report, with some variations. Referring to his earlier report, he now writes:

"I concluded this part of my essay by stating that the same effect, like unification, cannot be imputed to opposite principles: there must be something wrong, in WERTHEIMER'S laws…

I got no reply to my observations and arguments, either on the Gestalt side, or in the opposite cognitivist field, with the remarkable exception of METZGER (1975, pp. 219-221)… and RAUSCH (1966)." (pp. 257-258)

o We are puzzled by VICARIO's use of the term opposite, as applied to schools of thought or to principles of organization. Why is the "cognitivist field" called the opposite of the "Gestalt side"? Is Gestalt psychology the opposite of cognitive psychology? A clue to VICARIO's description might lie in his contention that Gestalt psychology turned to concepts like "force" and the "field of forces" in order to escape the deterministic machinery of the HELMHOLTZEAN view ("or its today's version, cognitivism") (p. 264). However, the literature shows attempts to relate Gestalt theory and cognitive psychology (e.g., ATTNEAVE, 1959; MURRAY, 1995) rather than to treat them as opposites. For example, information theory was offered as a methodology for quantifying organization (ATTNEAVE, 1959; MILLER, 1953). MURRAY (1995) devoted a book to Gestalt and cognitive theory.

o Also, we do not know what VICARIO means by "opposite" principles for the formation of a perceptual unit. Regarding Figure 1 he writes: "if we make reference to the principle of proximity in order to explain the formation of a perceptual unit on the left, we have to call up the opposite principle of remoteness to explain the formation of a perceptual unit on the right." In Figure 2, if we refer to the principle of similarity for the left side, "we have to call up the opposite principle of dissimilarity" for the right side. In Figure 3, if we refer to a principle of order or regularity, he writes that we have also to refer to a principle of disorder or irregularity.

o We claim that such distinctions are quite different from the spirit and letter of WERTHEIMER'S laws of organization. For example, WERTHEIMER referred not just to a law of similarity but to a gradient of similarity-dissimilarity. He wrote, "Not only similarity and dissimilarity, but more and less dissimilarity operate to determine experienced arrangement" (1938, p. 76). In contrast, VICARIO holds that dissimilarity should be treated as another principle of unification, "opposite" to the principle of similarity. Thus it would not be a surprise to WERTHEIMER that dissimilarity was a factor in the way a figure was perceived. Nor should it have surprised other Gestalt psychologists, counter to VICARIO's remarks.

o VICARIO confided that he did his best to explain the perception of the figures by means of the usual Gestalt arguments. He pointed out that the elements that contributed to the formation of the perceptual units by remoteness, dissimilarity, and disorder, shared something in common. In Figure 1, a greater distance separated the elements of the figure than those of the ground; in Figure 2, colors for the figures differed from the colors of the ground; and in Figure 3, the various random distances that separated elements in the figure differed from those that separated elements of the ground. But VICARIO rejected his own arguments as well as those by RAUSCH (1966) and by METZGER (1975) which brought Figures 1, 2, and 3 to similar cases described by WERTHEIMER. We respectfully disagree with VICARIO's apparent assumption that the best way — indeed, he suggests that it is the only way — to account for perception of the figure on the right is to introduce the "opposite" of the principle that accounts for perception of the figure on the left.

o We confess that we do not see the figures in VICARIO'S report as he describes them. On the right side of Figure 1, we see as outstanding the dark, dense "ground"

while the center is rather nebulous and not a clear hexagon as it is on the left side of Figure 1. On both sides, what has the character of figure for us pertain to a set of rather densely packed elements. Thus proximity seems to us to be the major factor on both sides of Figure 1. For Figure 2, we do not see the center well delineated on either the left or right side. What is outstanding for us on the right side is the ''ground'' in which the parts go in the same direction, forming parallel rows. Thus, similarity seems to us to be the major factor on both sides of Figure 2. In Figure 3, too, we do not see a clear figure or unit.

o We are not troubled by the methodology used by VICARIO but by his conclusions. In Figures 1 and 2 he introduced changes on the left to produce what was on the right. This procedure may be regarded as in accordance with WERTHEIMER'S recommendation that additions or other changes be made in a figure in order to see which factors are operative, and that experimental variations be conducted to pit one factor against another. He had pairs of students work together to vary conditions, with one member working to maximize the strength of a factor and the other member working to minimize its strength and to enhance the operation of other factors.

o For the checkerboard frame on the left side of Figure 4, VICARIO wrote that we cannot see a figure generated by white squares and a ground generated by black squares (or vice versa). Even if this is the case for this figure, why does it justify the generalization that ''similarity cannot be a principle of unification if not accompanied by contiguity''? (p. 258).

o The right side of Figure 4 shows a white square against an otherwise black background and is described as an example of ''unit formation without unification…a perceptual unit even if it is not the result of the unification of anything'' (Ibid.). We agree with VICARIO's remark that it does not follow that an active process of ''unification'' is necessary (p. 260) but we are not sure with whom he is arguing. WERTHEIMER did not say that it was necessary and did not require a process of unit formation or unification. Perhaps if VICARIO spoke of organization rather than unification, he would not regard the right side of Figure 4 as constituting a problem or an argument against Gestalt principles. We will return to this matter in the next section.

o We disagree with VICARIO's contention: ''The mere combination of single stimuli can perhaps elicit any phenomenal 'unit' whatsoever, the characteristics of which possibly have nothing to do with the characteristics of the whole stimulation'' (p. 260). We are surprised by the anti-Gestalt nature of this assertion. And we are puzzled by the illustrations he cites of the numbers we dial (correctly) on our phone apparatus and the activation of the answering apparatus of the numbers we reach, or the holes on a hotel door card and the matching elements in the door's lock, resulting in unlocking it. Not a mere combination of facts seems to us to underlie both examples. Why does one particular sequence of digits, and not a random sequence, activate the answering apparatus? Why do the arrangements of holes in your card, but not an arbitrary arrangement, unlock your hotel door?

On Unification and WERTHEIMER's Principles

Although VICARIO's report refers in its title to laws of organization, its text refers mainly to laws of unification. This seems to be an unfortunate choice of terminology both because WERTHEIMER dealt with organization, not unification, and because the terminology may have led VICARIO to the dilemma of "the problem of unification." Admitting that he "cannot see where the problems of unification is," he believes that it takes place only after fragmentation of the process that leads from stimuli to perception. "We are used to think of the facts at the origin of percepts as separated and disjointed…and accordingly we face immediately the problem of a succeeding unification (or "reunification") of them, in order to produce perceptual facts, that are 'holistic'" (p. 259). This view is different from WERTHEIMER's call (1922, in ELLIS 1938, p. 15) for an approach "from above", from the "top-down" rather than from the "bottom-up"; i.e., from whole-properties downward toward subsidiary wholes and parts. Individual parts ("elements") are not pieces to be combined in and-summation, but are parts of wholes. "Thus the comprehension of whole-properties and whole-conditions must precede consideration of the real significance of 'parts'" (Ibid.). WERTHEIMER began, not with parts to be unified, but with subwholes of a whole – with a house, a tree, and sky, as described in the 1923 paper, and not with branches and windows and clouds, etc., to be formed into the units of a house, a tree, and sky.

Instead of principles or factors of organization, VICARIO writes about principles or factors of unification. He notes that for some theorists:

> … unit formation was equally and indifferently attributed to "principles of unification" or to "factors of unification" (WERTHEIMER calls them Faktoren). This sort of ambiguity is to be avoided, since "principles" refers to a generalization of observed states of affairs, and "factors" refer to something active that produces the observed facts. (p. 259)

o WERTHEIMER might have had such a distinction in mind. His preference for factors or Faktoren might have stemmed from their fitting the process of discovery he was undertaking, searching for the factors operative in the perception of various constellations of dots. VICARIO is correct that WERTHEIMER did not explicitly define the terms or distinguish among them. Perhaps he preferred to leave the terms undefined in the exploratory stage. It was uncharacteristic of WERTHEIMER to be ambiguous or careless with words. He was usually cocerned with finding just the right word, which contributed to keeping his publication output low.

One could ask, VICARIO writes, why unification principles vary in number according to different theorists:

> WERTHEIMER (1923) enumerates seven of them, METZGER (1966, pp. 700-714) ten. Moreover, other theorists are supposed to have discovered new factors of unification (for instance, BECK 1966…), and one can ask oneself whether there are other factors to be discovered. (p. 261)

o The variation is even larger than described by VICARIO. Within ten years of the 1923 paper, a vast literature developed on laws of Gestalten. From it HELSON

(1933) extracted 114 laws of Gestalten, all but half a dozen of which were applicable to visual forms. By combining similar laws and ignoring those "devoted to showing that a Gestalt differs from a congeries of parts [since we] can take it for granted that a visual form is a unitary whole," BORING obtained 14 laws, most of which "really specify dimensions in respect of which forms vary" (1942, p. 253), e.g., degree of articulation.

o The search for, and the discovery of new factors, would not trouble WERTHEIMER. He encouraged the processes of experimentation and discovery. In his lectures at the New School, he emphasized that he did not regard his 1923 paper as the final, the complete word. He specifically mentioned that he did not consider the factors as axioms from which all the principles of organization could be derived, and he did not claim to have used a hypothetico - deductive approach. He recognized that some factors overlapped or encompassed others.

o Even well-known axiomatic systems may be given different numbers and types of axioms by different theorists. For example, HILBERT in his Foundations of Geometry (1938) revised the number and nature of the axioms in EUCLID's geometry. Since then, others have revised HILBERT's system.

o The number of axioms may change even when it is thought that it is down to rock bottom. After a decade of intensive work, WHITEHEAD and RUSSELL published their Principia Mathematica (3 Vols.; 1910-1913), confident that they had the smallest number of necessary axioms, only to have another logician show that one of their axioms was redundant and could be derived from the others.

Some "minor" complaints by VICARIO: "principles of unification are a collection of heterogeneous fundamentals: similarity and proximity refer to simple elements, where closure, passing-by curve, articulation without rests and so on, refer to already unified wholes" (p. 260). We shall see that WERTHEIMER specifically pointed out that "simplicity" does not refer to the properties of individual parts or elements; simplicity is a property of wholes (1938, p. 83).

VICARIO further characterizes common fate and objective set as referring to perception of events whereas the other principles refer to perception of objects; Prägnanz seems not to be on the same hierarchical level as the other principles; there are major differences between past experience as an explanation and the other principles; etc.

o It might be esthetically pleasing to have all factors or principles of the same type and on the same hierarchical level, but it is not likely to be achieved, certainly not in the early stages. In EUCLID's geometry, the parallel axiom has long been recognized as different in character from the other axioms.

VICARIO starts with the assumptions that, in an act of perception, the whole and the parts, as well as their properties, are observable, and that, as usually stated, the properties of the whole influence the parts, and the properties of the parts influence the whole. He then concludes: "That means that wholes and parts have no characteristics of their own, since these characteristics are the outcome of a sort of bargaining

between the whole and the parts" (p. 261). Does he really believe that a circle does not have closure, or that the dots in a constellation cannot have the property of proximity? He formulates as follows a problem that he cannot solve: "How can we speak of unification of parts because of their proximity, similarity and so on, if parts owe to the whole their proximity, similarity etc.?" (Ibid.).

o It seems to us that the question is ill-posed. Nonetheless, we might attempt to obtain clues to an answer from the 1923 paper, even though it did not focus on unification of parts. Consider WERTHEIMER's discussion of wholes and of additions to an incomplete object:

In designing a pattern, for example, one has a feeling how successive parts should follow one another; one knows what a "good" continuation is, how "inner coherence" is to be achieved, etc; one recognizes a resultant "good Gestalt" simply by its own "inner necessity." …Additions to an incomplete object (e.g. the segment of a curve) may proceed on a direction opposite to that of the original, or they may carry on the principle "logically demanded" by the original. It is in the latter case that "unity" will result. This does not mean, however, that "simplicity" will result from an addition which is (piecewise considered) "simple." Indeed even a very "complicated" addition may promote unity of the resultant whole. "Simplicity" does not refer to the properties of individual parts; simplicity is a property of wholes. Finally, the addition must be viewed also in terms of such characteristic "whole properties" as closure, equilibrium, and symmetry. (p. 83)

Symmetry signifies far more than similarity of parts; it refers rather to the logical correctness of a part considered relative to the whole in which the part occurs. (p. 83n)

o What the above suggests is that some properties, such as closure and equilibrium, are "whole" properties; that some, like symmetry and simplicity, have different meanings when applied in a piecewise context or to the whole; while some are clearly properties of the parts, e.g., proximity. Perhaps VICARIO would care to reformulate his problem with these considerations in mind.

o VICARIO contrasts theories of "the problem of unification" that stress "external factors (association, past experiences, attitudes, thoughts, and so on)," with theories that begin to distinguish between extrinsic and intrinsic properties, and with Gestalt psychology and WERTHEIMER's principles, "for which unification is the outcome of the interaction among intrinsic properties only" (p. 265). The latter phrase seems to be a mischaracterization since WERTHEIMER recognized the operation of both extrinsic and intrinsic properties. For example, he recommended that the first author study both kinds of properties for the factor of objective set or Einstellung (LUCHINS, 1939/1940; 1942). It turned out that attitudes and assumptions play important roles, that so-called "subjective factors" are involved in "objective set." About the Factor of Objective Set or Einstellung, WERTHEIMER wrote: "In view of its great strength, this Factor must in all cases be considered with much care" (p. 80).

Concerning the Factor of Past Experience or Habit, WERTHEIMER wrote:

Its principle is that if AB and C but not BC have become habitual (or "associat-ed") there is then a tendency for ABC to appear as AB/C. Unlike the other princi-ples with which we have been dealing, it is characteristic of this one that the con-tents A,B,C are assumed to be independent of the constellation in which they ap-pear. Their arrangement is on principle determined merely by extrinsic circumstanc-es (e.g. drill).

There can be no doubt that some of our apprehensions are determined in this way. Often arbitrary material can be arranged in arbitrary form and, after a suffi-cient drill, made habitual. The difficulty is, however, that many people are inclined to attribute to this principle the fundamental structure of all apprehension….

Regardless of whether or not one believes that the relationships discussed… de-pend upon past experience, the question remains in either case: Do these relation-ships exhibit the operations of intrinsic laws or not, and if so, which laws? Such a question requires experimental inquiry and cannot be answered by the mere expres-sion "past experience." (pp. 86-87)

To use a phrase favored by WERTHEIMER in his lectures: The question calls for experimentation and not for argumentation.

On Forces and the "Field of Forces"

"Now, what in Gestalt theory was for me especially discomforting, was the un-ceasingly turning to concepts like 'force' and 'field of forces' in order to explain the formation of units in the perceptual scene" (pp. 258). VICARIO refers to the con-cept of "field of forces" as "consubstantial with the principles of WERTHEIMER, I think, as they are considered as Faktoren of unification" (p. 263).

o It was KÖHLER who highlighted the concepts of forces and field of forces in his famous work on physical Gestalten (1920/1938). The concepts played little or no role in the 1923 paper on laws of organization. We are therefore surprised that the concept of field of forces is described as "consubstantial with the principles of WERTHEIMER. Likewise, in a report on these principles of organization, it seems out of place to refer to "the unceasingly turning to concepts like 'forces' and 'field of forces'" (p. 258), since WERTHEIMER did not do so. It should be recognized that VICARIO raises some interesting questions about the meaning of "field of forces" in the temporal domain (p. 263).

o What VICARIO proposes is "a form of Gestalt theory that has no need of forc-es, either from outside, or from inside" (p. 265). He illustrates this state of affair with a figure of a thin film of oil, heated from below, where the uniform surface is replaced by the appearance of pseudo-hexagonal cells (BÉNARD's rolls). Another figure represents the simulation on a computer of the behavior of some 5,000 parti-cles in a two-dimensional field (a rectangle). Initially the particles have the same

velocity, but the velocity changes when the particles encounter the lower side of the rectangle, simulating contact with a higher temperature level and leading to the formation of vortices. It is not clear to us that in these cases there is unit formation without "forces," as VICARIO claims. Oil heated beyond a critical temperature tends to become lighter and buoyancy forces bring it to the top so that the surface becomes unstable, leading to the formation of the pseudo-hexagonal structures. The motion of the particles accelerates so that they move faster when they hit the lower side of the rectangle, resulting in the vortices, which VICARIO describes as units. We do not know what VICARIO means by "deep" reasons for the structures that arise, but such phenomena are discussed in terms of forces in mathematical texts (e.g., LIN & SEGEL, 1974, pp. 527-528). Why is a "force-less" approach more productive than one that considers forces? VICARIO recommends the study of chaotic phenomena to model processes underlying unification in perception, which seems to be a fruitful approach to the study of perceptual grouping and Gestalt principles, to judge by recent research (e.g., VAN LEEUWEN, STEYVERS, & NOOTER, 1997).

Predictions or Categories of Descriptions?

The common and major argument against WERTHEIMER's principles is that they could not support predictions about the final outcome of their synergies and conflicts. Humiliating is the admission that we can resort to their presence and intervention in the building up of a percept only a posteriori, just once all is done. (p. 262)

The conception of WERTHEIMER's principles as "factors of unification, that is real agents of some processes of which we see the outcome" (p. 262) is rejected by VICARIO as untenable. He prefers to regard the principles as "just categories of description of the parts and of the relations between the parts and the whole" (p. 262). The novelty and strength of WERTHEIMER's work lie in "having reduced the countless ways of describing perceptual facts in a few categories, reasonably suitable" (Ibid.).

Why do we call them "principles"? Because there are no better criteria to gain the same end by means of other sort of descriptions. This is the reason why I prefer to think of WERTHEIMER's laws in terms of principles of description, rather than in terms of Faktoren of unification. (Ibid.)

o We cannot object to VICARIO's preference for principles of description but we think he gives up too easily on the predictive power of WERTHEIMER's factors. Similarly, he mentions (p. 259) the failure of KANIZSA and a group of his colleagues to mathematize these factors and "to quantify their strength in specified conditions." But there have been successful efforts to do so in the last decade. We will touch on some of this research.

o We should not expect that WERTHEIMER's factors or any small set of principles would allow precise predictions for the complex phenomena of visual pattern organization. Nor should we expect to find mathematical formulas for principles of organization of perceptual forms. The principles are not laws of nature or of physics, such as NEWTON's laws of motion. The enormity of the task of vision research is suggested in a recent (July 6, 1998) email note by ROSENFELD in which he modifies WIGNER's well-known title, "The unreasonable effectiveness of mathematics in the natural sciences" to "The unsurprising ineffectiveness of mathematics in the visual sciences." Most vision problems, he adds, are mathematically ill-defined; real-world visual domains "do not satisfy simple mathematical (even probabilistic) models"; the models that are assumed are often unrealistic. On a more positive note, ROSENFELD notes that mathematical and statistical tools do have their use in formulating vision problems. Progress has been made in applying such tools to the laws of perceptual organization. We illustrate with a few of the recent studies on perceptual grouping.

A survey article with over seventy references by KING (1996) that appeared in GESTALT THEORY concluded that perceived similarity affects perceptual performance; that perception even of parts can be explained in terms of grouping; and that a physical stimulus may combine with a memorial stimulus to produce a physical-memorial group that functions as does a traditional group (Gestalt). The paper advanced the thesis that recency, long-term memory, and attention all affect perception in essentially the same way.

Next we turn to a report of research that acknowledged the need to begin with Gestalt principles of grouping, referring to the 1923 paper. It compared the relative strength of similarity and proximity by means of spatial correlations, which might be considered a "bottom-up" approach to prediction and quantification. The report by BEN-AV & SAGI (1995), based on a doctoral dissertation by the first author (1992), stated:

Any account of perceptual grouping must still refer to the pioneering work of the Gestalt psychologists (WERTHEIMER, 1923) and to their "laws of grouping".... It is still not clear how to define shape and similarity (BECK, 1966; OLSON & ATTNEAVE, 1970) and how to deal with multiple cues (e.g. similarity and proximity). Here we present a quantitative model for perceptual grouping, which is based on intensity autocorrelations. The model performance is successfully compared with data from psychophysical experiments, suggesting that at least some of the Gestalt rules of grouping (i.e. similarity and proximity) can be formalized in terms of spatial correlation. (p. 853)

Their findings are incorporated in the title of their paper: "Experimental results on perceptual grouping by similarity and proximity can be predicted by intensity autocorrelations." Proximity grouping was perceived much faster than similarity grouping, but with increasing processing time similarity dominated grouping. "The results can be accounted for by assuming a process that compares horizontal and vertical intensity autocorrelations" (Ibid.).

VAN LEEUWEN, STEYVERS, & NOOTER (1997) used chaotic phenomena to study perceptual grouping or perceptual segmentation. The running head of their paper is perceptual grouping; its keywords include nonlinear dynamics, chaos, self-organization, perceptual grouping, Gestalt, switching, multistability, and neural networks. Their study involves perceptual segmentation determined by intrinsic, self-organizing properties of dynamic systems. "Patterns of synchronized activity are obtained in the model from high-dimensional, deterministic chaos. These patterns correspond to segmented topographical mappings of the visual field…For a perceptually ambiguous pattern, the system switches between alternative meta-stable segmentations" (1997, p. 319).

Not only perceptual grouping but also WERTHEIMER's phi-phenomenon have been generalized and investigated in the past decade. For example, CHUBB & SPERLING (1989) investigated reversed-phi motion, motion perceived in a direction opposite to the displacement.

We demonstrate two dynamic visual stimuli that appear to move in one direction when viewed from near and in the opposite direction from afar. This remarkable reversal of apparent motion [reversed-phi motion] occurs because the stimuli are constructed to simultaneously activate two different mechanisms: A first-order mechanism that computes motion from space-time correspondences in raw stimulus luminance and a second-order mechanism that uses, instead, a full-wave rectified transformation (e.g., the absolute value) of stimulus contrast to compute motion. (p. 2985)

Coordinating data that emerged from various studies and paradigms, SPERLING (1989) described three stages of visual processing: light adaptation, contrast gain control, and a postsensory/decision stage. Also described were two visual systems: "Two parallel perceptual regimes jointly serve human object recognition and motion perception: a first-order linear (Fourier) regime that computes relations directly from stimulus luminance, and a second-order nonlinear (non-Fourier) rectifying regime that uses the absolute value (or power) of stimulus contrast" (p. 1).

These studies reflect the complexity of visual processes and the mathematical sophistication of attempts to understand them.

Concluding Remarks

VICARIO quotes the conclusion of KOFFKA's (1935/1962) book:

…each one of the special hypotheses advanced in this book is in need of further verification; I am doubtful about the future fate of many of them. But this attitude towards particular hypotheses must not be confused with the general principle, which is independent of special applications. Gestalt theory would not be refuted if its hypotheses of perceived motion were proved to be false. The truth of the gestalt principle will have to be tested by the course that science takes in the future. (KOFFKA, 1935/ 1962, p. 685)

VICARIO then writes about the "supreme sacrifice of the gestalt theorist KOFFKA, who declares himself 'doubtful' about the explanation of perceived mo-

tion, that is about the major achievement of the gestalt theory'' (p. 267). But we do not interpret the above paragraph to mean that KOFFKA doubted the hypotheses of perceived motion. We thought it meant that even if these hypotheses were shown to be false, Gestalt theory would not be refuted.

VICARIO continues:

…perplexities about WERTHEIMER's Faktoren may not be confused with an attack on the ''general principle'', that remains untouched. The admission that WERTHEIMER's laws are in difficulty, because their traditional formulation does not account for observable facts, does not delete the gestalt theory, but promotes a deeper insight into phenomena. When I suggest the study of chaotic phenomena, in order to see whether they can offer a model of processes underlying the fact of unification in perceptual field, I see both an escape from obscurities of WERTHEIMER's principles and an opportunity for testing such a model. (p. 267)

We agree that WERTHEIMER's factors do not cover all "observable facts." But surely they cover some of the facts and have served as the take-off point for new research on perceptual unification or grouping. The "true significance of WERTHEIMER's principles of organization" may lie in stimulating discussion and research. If VICARIO's report and our commentary lead to renewed interest in the 1923 paper, to discussion and possible reformulation of some of the principles of organization, and to new research, then his effort and ours will have been worth-while.

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