Gestalt Psychology and Cognitive Psychology

Riccardo Luccio[*]
rluccio@units.it

ABSTRACT

The aim of this paper is to sketch the major aspects of *Gestaltpsychologie*: Wertheimer's factors, global v. local factors, isomorphism, auto-organisation, *Prägnanz* as singularity and as a tendency towards stability. While *Gestaltpsychologie* as a school no longer exists, its lesson is yet seminal and can inspire many developments of contemporary cognitive psychology. Few examples are here illustrated: geometric psychology, non linear systems (mainly synergetics), and computational gestalts.

1. The Characteristics of *Gestaltpsychologie*

It is almost trivial saying that Gestalt psychology has been the most consistent and successful psychological school developed in the past century in Europe as a reaction against elementism and associationism, typical of the beginning of scientific psychology in the last decades of XIX century. As a school, after the death of its principal exponents (Wertheimer, Köhler, Koffka) the Gestalt psychology, doesn't exist anymore. Nevertheless, the lesson of this psychological school is such that still today it cannot be ignored, at least by students of perception and thinking. In the same time, the ideas of Gestalt psychologists were very often misunderstood, and this has given room to several mistakes and wrong interpretations.

In this paper first I will try to point out, beyond trivialities and misunderstandings, which actually were the main issues of Gestalt psychology that determined a real turning-point in the history of psychology of this century. It is important to identify this, as distinguished from the main

[*] Dipartimento di Psicologia "Gaetano Kanizsa", Università degli Studi di Trieste, Italy.

misunderstandings that, overall through a number of misinterpretations by American psychologists, have followed the diffusion of Gestaltist concepts. One must in any case point out that these misunderstandings have been sometimes facilitated by some theoretical weakness of Gestalt psychologists. However, we will see how Gestaltist ideas have deeply influenced contemporary cognitive psychology, and how such influence has been particularly evident in the last years. At the beginning of the so-called "cognitive revolution", there were several attempts to translate Gestalt ideas in terms of information theory (Attneave, 1954, 1959; Garner, 1962). After these attempts, which have only a historical interest today, other approaches emerged. Specifically, I will sketch three examples of them, showing first the place of a very important metaphor, like the concept of field, in contemporary theorising about perceptual invariance, above all in the so-called "geometric psychology" developed by Hoffman (1966, 1977, 1984); second, we will see how the theory of dynamic formation and recognition of pattern, as elaborated in the framework of synergetics by Haken (1990; cf. Kelso, Ding, & Schöner, 1992; Kelso, 1995) can be seen as a natural development of Gestalt ideas; third, I will present in short the major ideas developed in the field of computer vision under the name of "computational gestalts" (for a comprehensive review, see Desolneux, Moisan, & Morel, 2006).

It is obvious that it is absolutely impossible synthesizng the essential ideas of Gestalt psychology in few pages. Thus, I will confine myself to few basic ideas developed by this school.

2. Wertheimer's Factors of Perceptual Organisation

The first point I want to clarify is the relationships between whole and parts. It is well known that Wertheimer (1923) stressed the importance of the *von oben nach unten* processing in perceptual organisation. With this expression, he claimed that the global configuration has a prevalence on the parts that compose a totality. The psychology most influential at the time in which Gestalt psychology appeared, the wundtian psychology, claimed the opposite way of organisational processing, *von unten nach oben*. This opposite way was what Wertheimer called a "summing up" of parts, leading to a "mosaic" perception.

It is unfortunate that the English translation of the above expressions, respectively *top down* and *bottom up*, has assumed in cognitive psychology a quite different meaning: top down is considered equivalent to *concept driven*, and bottom up to *sense driven*. However, both directions of processing were, according to Wertheimer, sense driven (Kanizsa & Luccio, 1987). In other words, according to Gestalt psychology all perceptual organisation depends only on "autochthonous" factors, that is, on factors that are all in the stimulus, thereby they do not depend on previous knowledge, expectancies, voluntary sets, intentions of the observer. But what means exactly *nach oben von unten*? Simply, the meaning of the parts is determined *von oben nach unten*, by the whole to which they belong. An apt example is the famous research of Wertheimer (1912a) on stroboscopic movement. He presented to his observers two lines, before the vertical one, and after switching off this, the horizontal one. With suitable interstimuli intervals, the observer viewed only one line, moving from vertical to horizontal, and vice versa. Two points must be stressed: first, the global situation created an *identity* between the two lines, that now were *one* thing; second, in the physical situation there was no movement at all, from a physical point of view: again, the global situation created *nach oben von unten* an apparent motion, that, with suitable conditions of stimulation, could be isolated from the moving object (*phi* phenomenon).

From the above point of view, it is thus easier to understand the very meaning of the so-called "laws" (better, principles or factors) stated by Wertheimer (1922, 1923), ruling the formation of perceptual forms. Let us review briefly these laws, bearing in mind the importance of the *von oben nach unten* principle of perceptual processing.

According to Wertheimer, when an observer is presented a perceptual field, and he looks at it in an absolutely natural way, without any effort and any scrutiny, the field segregates itself in different perceptual units, constituted by the elements present in the field, which tend to aggregate themselves according to certain factors. These are (i) *proximity*, (ii) *similarity*, (iii) *continuity of direction*, or *good curve*, (iv) *common fate*, (v) *past experience,* and (vi) *Prägnanz.*

All these factors are well known, but let's discuss shortly the last two. It is not easy to explain what Wertheimer meant for past experience, because Gestalt psychologists used this expression to indicate something of quite different from what was meant in traditional empiricist tradition (till today, in the neo-helmholtzian theorising). According to Gestalt pyschologists, nor past experience neither more generally evolution (Köhler, 1950) can alter the general principles of perception, which are a consequence of the physical properties of the neural substratum. They claimed that brain is a physical system ruled by physical laws, which cannot be modified; only the constraints in which the dynamics of the system can evolve.

The principle of *Prägnanz* is the most widely accepted among cognitive psychologists, and many attempts were made to formulate it in other terms, for example, in terms of information theory (Attneave, 1959; Garner, 1962). The principle states that there is a tendency towards the formation of Gestalts which are maximally regular, simple, symmetric – *ausgezeichnet*, according to Wertheimer's term; "good", as they are often said. As Kanizsa & Luccio (1986) pointed out, however, the term *Prägnanz* is defined ambiguously, as a characteristic of a percept, and as a process; and as a multidimensional attribute (as in Rausch, 1966) or as a point of discontinuity, singular (as in Goldmeier, 1982). This point will be discussed at length below.

3. Physical Gestalten and the Concept of Field

Among the several metaphors that Gestalt psychology utilised in describing the dynamics of cognitive processes, the concept of "field" (and related "field forces") has been the most celebrated, and in the same time the most widely criticised. This concept was elaborated mainly by Wolfgang Köhler; the first idea can be found, however, in the "transversal flows" hypothesised by Wertheimer (1912b).

In Köhler's opinion (1920), in the physical world one can observe several different systems that tend to evolve dynamically, according to a minimum principle, towards a state of equilibrium, in which the energetic level is as low as possible. The prototypical example of such a "physical Gestalt" is given by soap bubbles. The brain is one such system, and his functioning can be well described in terms of electric states evolving in the nervous matter. Köhler (1940) supposed that within the brain electric fields act, and he suggested as a basis of these fields the action of chemical mediators; the figural after-effect and other perceptual phenomena fitted very well to this model, that in Köhler's days was plausible.

Wolfgang Köhler fully developed Wertheimer's insight in his book "Die physischen Gestalten in Ruhe und im stationaren Zustand" [*Physical Gestalten in rest and in stationary state*]. Köhler wrote the book when he was in Tenerife, Canary Islands, during the First World War, studying apes. As Köhler (1969) remember, when he was in Tenerife, he read the great "Treatise on Electricity and Magnetism" written fifty years before by J. Clerk Maxwell (1881), and he was "great relieved to find so fundamentally similar an approach" (Köhler, 1969, p. 75) between great physicists, like Maxwell, or Max Plank (Köhler had been a student of him), or Kirchoff, or Eddington, and Gestalt psychologists. One must add that in Köhler's book was obvious the influence of another eminent physicist, Ernst Mach.

The book is complex, and it is almost impossible to sketch here an account of it. We will confine ourselves only to a glance on its content. We recall that von Ehrenfels (1890) had defined *suprasummativity* (the parts are "poorer" than the whole, in Köhler's words) and transposition as key concepts for Gestaltqualitäten. The point of departure of Köhler consists in individuating the same properties in an electric field, that is, in the distribution of electric charges around a conductor. The second step is to hypotesize that, in the brain, there are chemo-physical fields having the same properties. The final step is individuating the same system properties [*Systemeigenschaften*] in domains, the experience (the phenomenal field) and the brain. In particular, according to Köhler there are four properties that are similar in phenomenal and in brain fields: (1) the total processes appear in both fields as units with dynamic properties: (2) in both the unity is compatible with a structured articulation [*Gliederung*] of the component parts: (3) in both one can individuate gradients because of the distance from one region to another that consent to consider the regions as independent from the ones that are faraway: (4) in both we can individuate limited regions (Gestalten, in the phenomenal field) on a ground.

Essentially, then, the perceptual field is a physical system, a system of interacting forces, in which any object that enters modifies the equilibrium of the forces, and thus acts over any other object that is present in the field. The evolution towards this optimal level corresponds to the tendency towards the *Prägnanz*. The best attempt to render this metaphor less vague was made by Brown & Voth (1937). They describe the visual field as a spatial construct to which the phenomena of visual experience are ordered, with differences in intensity at various loci. The structure of the field is the configuration, or "gestalt", of the intensity distributions within it. It is a *vector field*, and the dynamic processes within it are produced by field-forces. It can be thought of as a four-dimensional manifold, having three spatial and one temporal dimension.

Brown and Voth hypothesise two kinds of forces, having the nature of vectors: *cohesive* and *restraining field-forces*. The cohesive forces ***C*** attract objects, the restraining forces ***R*** tend to maintain them in their place. Physiologically, the cohesive forces are largely peripheral, retinally-conditioned, while the restraining ones are centrally-conditioned. The cohesive forces allow to explain the phenomena of motion and grouping, the restraining ones the phenomena of stability of contours, figural properties of objects, etc.

Brown and Voth have successfully tested their model in experiments on perception of real and apparent motion. Orbison (1939) has extended it in the case of stationary configurations. According to Orbison, if two objects are brought into the visual field, they will be acted upon the cohesive and restraining forces whose magnitudes are functions of the physical properties of the stimulus pattern. To test this model, Orbison has created several geometrical figures (called *geometrical fields*).

The work by Brown and Voth and by Orbison was mainly at the phenomenological level, and the physiological level was not worked out. The physiological counterpart of the phenomenal level was the one above mentioned elaborated by Köhler. One must mention that Köhler had stated the principle of the *isomorphism*, according to which there is a structural correspondence between what occurs at the physiological level and what happens in the phenomenal field, a mapping on the events of a level onto the other. This principle will be discussed below.

Lashley, Chow, & Semmes (1951) and Sperry, Miner, & Myers (1955) tried to test Köhler's neurophysiological theory, but their results led to a rejection of the field theory. It is fair to add that Köhler (1958) raised serious objections against these experiments, without receiving any answer. The scientific community of psychologists accepted, very superficially indeed, as decisive such counter demonstrations, and this was the end of the brain field theory.

4. Is *Gestalttheorie* a Representational Theory?

The most influential author that was at the beginning of the antiassociationist reaction in the XIX century was Franz Brentano, with his writings (*Psychologie* [1874] was one of the most seminal books of all the century) and his teaching: notice that among his pupils we can list Meinong, Marty, von Ehrenfels, Stumpf. Wertheimer was a student of Marty and von Ehrenfels in Prague; it is well known that all major Gestalt psychologists were directly pupils of Carl Stumpf in Berlin: Wertheimer, Köhler, Koffka, Lewin. In other terms, they did not have any direct contact with Brentano (that resigned from teaching in 1895, before the beginning of studying of all of them).

Brentano was strongly anti-elementist: according to him, there are no psychological elements but only psychical acts, which could be distinguished in three fundamental kinds, to whom experience is reducible: representation (ideating), judgment, and loving-hating (feeling). And it is equally well known that the very first use of the term Gestalt in the technical sense in psychology is due to von Ehrenfels, in his celebrated paper on *Gestaltqualitäten* (1890). So, in many textbooks of history of psychology the trivial equation is ready made: Gestalt psychology derives directly from Brentano, via the concept of *Gestalt* introduced by von Ehrenfels, and the teaching of Stumpf upon his leading exponents. This equation, however, is too simple, and in many respects it is misleading. It is very rare to find quotations of Brentano in the papers of Wertheimer and associates, and when this happens it is mainly done to distinguish the position of Gestaltists from the one of Brentano.

A crucial difference between Brentano's and Gestalt ideas concerns the very representational nature of his psychology. A point that originated a great deal of debate on the turning of the century is the "intentional inexistence" of the psychicalwhich differentiates it from the physical. Brentano derives this concept from the Scholastics of the Middle Ages, for whom intentional inexistence had to be understood as immanent objectivity (for a discussion of intentional inexistence, and of the consequences of the introduction of this concept on the semantic debate in our century, see Coffa, 1989). So, psychical acts were phenomena that intentionally contained an object; this immanent objectivity uniquely distinguishes them from the physical phenomena that they "intend".

In my opinion, the very idea of "representation" is alien to *Gestaltpsychologie* (see also Luccio, 2010). We can ask to ourselves why, if *Gestalttheorie* is a representational theory, the authors almost never use the term "representation", or its many German synonyms (*contra*, see Lehar, 2003a, 2003b; Scheerer, 1994). And one could use it safely in different contexts, also without any theoretical commitment to a representational theory. But also there, the Gestalt psychologists preferred other terms. For instance, in the paper on thinking of primitive peoples, referring to the mental constructs of numerical structures, Wertheimer (1912a) prefers to speak of *Gebilde*.

Note that according to Lehar, Gestalt theory is a representationalist theory *qua* perceptual theory. According to Scheerer, the very fact that we believe in a transphenomenal word is sufficient to argue that our cognitive system is representational. I do not think that to call the mediating brain processes "representations" is correct, because to speak about representations, I must be aware of them.

Gestalttheorie rejects the idea of representation, or, at most we can say that the Gestalt authors had an *indifferentist* stance on this problem (Luccio, 2003b). For them, the contents of the directly accessible world do not stay for something else, as "representation" would imply, but stay for the contents themselves. Here, it is important to stress the difference that Köhler proposes between *subjective* and *objective* experiences, both "results of organic processes" (Köhler, 1947, p. 23), when the subjective experiences are the contents of the phenomenal world that are felt as belonging personally to the subject, and are

> in so far subjective, such a dreadful fear upon a certain occasion [...] For instance, a chair as an objective experience will be something there outside, hard, stable, and heavy. Under no circumstances will it be something merely perceived, or in any sense a subjective phenomenon. (Köhler 1947, pp. 20–21)

Still clearer is Wolfgang Metzger (1941, c. 2.), in his classic treatment of the psychic reality [*seelisch Wirklichen*]. According to Metzger, the first distinction that one must perform is between the physical or metaempirical world [*physikalische oder erlebnisjenseitig Welt*] and the phenomenal or lived world [*anschauliche oder erlebte Welt*]. These are the first and second meanings of psychic reality, and according to Metzger in psychology there is often confusion between these two meanings. But there is another dangerous confusion that often occurs, and it is between the second meaning and a third, the represented world [*vergegenwärtigte Welt*]. The real world in the second meaning has the characteristics of the "met" [*Angetroffene*]. The met things, events, actions, beings, are a reality of things, events, actions, beings as such, while when represented are felt completely different, as "pointing to" [*hinweisend auf*] another reality.

5. Isomorphism

The origin of isomorphism is not in Köhler, but in Wertheimer (the so-called "Wertheimer's problem"). It is in his well-known account of the *phi* phenomenon, and precisely in his neurophysiologic hypothesis of the *Querfunktionen* (cross functions) and of the physiological *Kurzschluß* (short-circuit) (Wertheimer, 1912b, pp. 246 f.). The idea of a hypothetical physiological explanation of the stroboscopic movement went to Wertheimer from observations of several investigators before him: Exner (1875), Marbe (1898), Dürr (1900), Wundt (1902-1903), Schumann (1907). According to Max Wertheimer, the present (at the time) physiological research was indeed sufficient to assume

> as likely that to excite a central point *a* elicits a physiological effect in a definite area around it. When are two the points *a* and *b* that are excited, a similar effect in both points should result.
> When the point *a* is excited, and after the point *b*, within some specifically short time interval, then a sort of physiological short-circuit from *a* to *b* should occur. There is a specific passage of the excitation in the space between the two points. If for instance the extent of the disturb in the area around *a* has reached the maximum of the temporal curve of its process, and the disturb in the area around *b* takes place now, then the excitation flows (a specific physiological event), and its direction is determined by the fact that the excitation around a occurred first. (Wertheimer 1912b, p. 247)

As every idea in the history of science, isomorphism too had noteworthy antecedents (e. g., Grassmann, 1853; Lotze, 1852; Lipps, 1900). One considers correctly Hering (1878) one of the most direct forerunners of *Gestaltpsychologie*, mainly with the ideas of *assimilation* and *dissimilation*. The concept of assimilation is not original: it is the well-known physiological mechanism that allows to the organism to replace the substances that it has lost for metabolic activities when stimulated. Hering, for analogy, calls dissimilation the creation of the catabolic products. Assimilation and dissimilation are well demonstrated for visual sensation. The vision is a chemical sense, and the metabolic processes that take place here are well known; in particular, the dissimilation, that is the decomposition of the photochemical substances under the influence of the light, has been largely studied. But it would be curious if only the dissimilative side should be influential in the perceptual process. And more curious when this process would be exclusive of vision.

The importance as a forerunner of isomorphism of Georg Elias Müller, however a fierce opponent of Gestalt psychology (see Müller, 1923), refers to its famous 1896 paper on the five psychophysical axioms (Müller, 1896), particularly the second one: to every equality, similarity, or difference of a sensation corresponds respectively an equality, similarity, or difference of the underlying psychophysical process, and vice versa [*umgekehrt*]. This axiom holds not only for sensation, but for every state of consciousness. This axiom is at the basis of the first formulation of the doctrine of the isomorphism by Köhler. However, as Vicario (2001, p. 88 f.) points out, the *umgekehrt* of the second axiom is unnecessary, unproved and unmotivated.

Note that Ernst Mach in the *Analyse der Empfindungen*, from the 1900 edition on, in discussing the psychophysical parallelism, said (p. 50): "Das hier verwendete Princip geht über die allgemeine Voraussetzung, dass jedem Psychischen ein Physisches entspricht und *umgekehrt* in seiner Specialisirung hinaus." [The principle here used in its specific form goes beyond the general premise that a physical fact corresponds to each psychical fact, and *conversely*]. However, Mach never quotes Müller, and the sentence doesn't appear in the first edition (1886), appeared nine years before Müller's paper. Despite the coincidence, it is unlikely that Mach was in this inspired by Müller. Instead, both shared the same feeling on this matter. However, Köhler never accepted the *umgekehrt* as such.

In mathematics, we say that between two domains, there is an *isomorphism* if there exists bijective morphism, which is a *preserving structure mapping*. One can argue with some reason that the choice of this term by Köhler was not fortunate. Köhler himself used this term late, only in1929 (see Scheerer, 1994), and used it only parsimoniously in his written works (see von Fieandt, 1983), often designing the corresponding principle with different terms, for instance, "congruence". Köhler stated clearly that the isomorphism applies only to the "system properties" (*Systemeigenschaften*) of the two domains considered, that is experience (phenomenal world) and physiological processes. But, which are the system properties at play?

6. *Prägnanz*

Only few natural objects have a regular structure, and the most are amorphous or ill-shaped, so, few phenomenal objects and events have a special status, have a "good" shape, are in this sense "better" than others, are experienced as perfect, well done, *ausgezeichnet*. Gestalt psychologists have created for this category of phenomena the term *Prägnanz* or *goodness*. This concept is one of the cornerstones in their theoretical system; however, the concept was never clearly defined, so it has not a univocal meaning. This ambiguity is the origin of more than one misunderstanding, so we need a few distinctions and specifications.

An important distinction is that between (i) *Prägnanz* as a *phenomenal* characteristic (ii) and *Prägnanz* as the property of a *process*. *Prägnanz* is definitely a cardinal concept in Gestalt theory, but it has, nevertheless, given rise to a number of misunderstandings (Kanizsa & Luccio, 1986). The Gestaltists have often been criticised for having turned Prägnanz into a key to open all doors, without ever having given it a strict definition. The concept was introduced by Wertheimer (1912a) in his essays on thought processes in primitive peoples, in which he speaks of privileged, *ausgezeichnet* or "prägnant" zones in numerical series. However, Wertheimer spoke of a "law of Prägnanz" only two years later, affirming that amongst many "Gestalt laws" of a general type, there is a "Tendenz zum Zustandekommen einfacher Gestaltung (Gesetz zur '*Prägnanz* der Gestalt')" (Wertheimer, 1914). In Wertheimer's 1922/1923 essays, the first very systematisation of Gestalttheorie, traces can be found of the origins of some of the ambiguities in the concept of *Prägnanz* which will accompany Gestalt Psychology over the years. Here *Prägnanz* is defined as *Ausgezeichnetheitheit*, which is a quality possessed by certain specific objects, forms or events belonging to our immediate perceptual experience, and which makes them "unique", "singular", "privileged". All the shapes which are phenomenally singular or "privileged" are "good Gestalten":

it is the case of the equilateral triangle, of the circle, of the square, of the sinusoid, etc... In this sense, "prägnant" indicates phenomenal structures, which are "regular"; they are endowed with internal coherence; all their parts go well together, and can be said to "belong" to each other by mutual necessity.

But Wertheimer gave also a second sense of *Prägnanz*: that of the lawfulness of the process leading to the formation of visual objects. According to this second meaning, the term Prägnanz is used by Wertheimer to indicate the fact that rather it is a "meaningful" (*sinnvoll*) process. The principles of organisation act as precise laws, to which the process is forced to obey, overall in the sense of maximum economy and simplicity. Its result is a perfect balance of the forces at play, and thus has also a maximum of stability and of resistance to change.

According to Wertheimer, the process is such that any "almost good" Gestalt should end to be perceived as a prägnant one. For example, he says:

> ... that things are so is clearly demonstrated in experiments where the consistency of a tendency to a prägnant configuration is remarkable. If an angle is tachistoscopically presented, even if its margin of difference from the right angle is noticeable the viewer often simply sees a right angle, assimilating the shown angle to the pregnant one. (Wertheimer, 1923, p. 318)

After Wertheimer, the Gestalt psychologists used the concept always in the descriptive sense, to indicate the "singularity" of a phenomenal outcome, or in the explanatory way, to indicate the conformity to rules of the perceptual process and its tendency towards a final state of stable equilibrium. The two concepts are not at all equivalents, in that a phenomenal result can be completely stable but not necessarily at the same time ausgezeichnet in the sense of phenomenally "singular".

Very rare were the attempts to distiguish between the two meanings. Among them, A. Hüppe (1984) suggested such a distinction, calling phenomenal goodness *Primarprägnanz* and conformity of the process to rules and stability of the result *Sekundarprägnanz*. *Prägnanz* in the former sense, that is, "singularity" or figural "goodness", is then a given phenomenal fact, corresponding to a reliable description of visual experience, which was destined to play a leading role in later Gestalt theorising.

Anyway, after Wertheimer the most important and interesting contributions to the development of the concept of Prägnanz in its first sense were made by Rausch (1966), that lists seven *Prägnanzaspekte* (bipolar dimensions). Rausch (1952) also distinguishes three zones around each point of Prägnanz: the zone of formation (*Verwirklichungsbereich*), which the exact point occupied by figures assimilated to the category of the prägnant one, but which are experienced as badly made, "bad", and the derivation zone (*Ableitungsbereich*), to which belong the figures which are categorically different from the prägnant ones, whilst referring to them in a relationship of derivation.

Opposite is the view put forward by E. Goldmeier (1982). Goldmeier's analysis differs from Rausch's one in degree of importance given to other two possible meanings, which may seem in a certain sense contradictory, of the concept of the *Prägnanz*. Goldmeier emphasizes the fact that the zones of *Prägnanz* mark the points of discontinuity in a qualitative series. For Rausch, on the contrary, Prägnanz is above all a scalar property that can take on all the values of intensity lying between the two poles of the seven dimensions he distinguished.

For Goldmeier, the most salient characteristics of Prägnanz, which he significantly translates as "singularity", is the "uniqueness" possessed by some configurations in virtue of their having a quality that all others in a given series lack. As stressed in Goldmeier's view, one peculiar characteristic of our perceptual system highlighted by singularity is that it has a high sensitivity to change. In the near singularity zone (which corresponds to Rausch's "approximation" zone) the slightest fluctuation of a singular value is noticed, whilst the threshold of discrimination rises considerably for those values which fall outside this area, where we are no longer able even of noticing great differences between two adjacent elements in a series. But, note, this observation, which is very easy to check, is in full contradiction with the claimed "tendency to *Prägnanz*", in the terms of the quotation of Wertheimer that we have above reported. And it is in contradiction with all other Gestalt theorists that claim that a tendency to *Prägnanz* exists, when Prägnanz is meant as singularity (Köhler, 1924, p. 531; Metzger, 1941, p. 207).

So, Gestalt theorists use the term *Prägnanz* to mean both a tendency of the perceptual process to assume the most regular and economic course, given the constraints (*Randbedingungen*) present in each specific case, and a tendency towards the maximum Ausgezeichnetheit in the concrete phenomenal result of the process itself. It seems quite evident that for such theorists, there is a close logical connection between these two facts. In general, scientists tend to take for granted that in nature processes governed by a minimum principle tend to produce regular, symmetrical results (Mach, 1885). The regularity is particularly apparent when we notice some kind of symmetry in the natural object. One finds beautiful cases of axial or central symmetry in the inanimate world (crystals, snowflakes, etc.), as well as in life's kingdom (leaves, flowers, butterflies, etc.). Such instances are shown as conclusive evidence that natural phenomena have a character which is not casual, but strictly conforms to laws.

When one can agree until this point, the confusion arises when is claimed that the tendency towards *Ausgezeichnetheit* is a natural consequence of the tendency towards the economy of the process. Also in nature only few natural objects have a regular structure, and the most are amorphous or ill-shaped; so few phenomenal objects and events have a "good" shape and are in this sense "better" than others, well done, *ausgezeichnet*.

According to Kanizsa, it is convenient to distinguish two different levels in the perceptual process, primary and secondary processes: the first process determines an immediate segmentation of perceptual field, that, therefore, appears to awareness as being constituted by many phenomenal objects, distinguished from each other, before and irrespective of the attribution of a meaning to them, attribution, which is allowed by the secondary process. There is a logical reason to distinguish these two processes. As Höffding (1887, pp. 195–202) emphasized, it is impossible to recognise an object if it is not already present. As a matter of fact, it is evident that the formation of a visual object as an entity distinct from other objects must take place before the object can be recognised, and this is a logical requirement that cannot be refuted on the grounds that it is impossible to observe in a natural cognitive act a phase in which the visual data has not yet been identified.

The implications of Höffding's argument (or "step", as it is often said) were mainly developed in the Gestalt field (e.g., Köhler, 1940, pp. 126-130; Wallach, 1949). According to Köhler, the argument could be stated so: Let we take two associated mental contents, *a* and *b*. Let us now suppose that a new event *A* occurs, endowed with the same properties as *a*. Now, *A* leads to the revocation of *b*: and yet, *A* is not *a* and is not associated with it. The only way to explain the activation of *b*'s trace following *A*'s presentation is that *a* is activated because of its similarity links with *A*. In other words, Höffding's argument affirms that before an external event can be recognised and placed in the pertinent category, it must be constituted in such a way that it is endowed with characteristics, which allow it to come into contact with the trace of a similar event.

A consequence is that the tendency to *Prägnanz* is then well recognisable only in the products of the secondary process, especially in transformations which are the fate of memory traces, and that a tendency to Prägnanz as the singularity does not exist at all. In my view, the behaviour of the visual system is not characterised by a tendency to singularity, but by a tendency to stability. Though proximal stimulation undergoes a continuous process of transformation, our phenomenal world is usually a stable world, constituted by objects that preserve a high degree of constancy as to size, shape, colour, identity. The stability is the result of a capacity of self-organisation displayed by the visual system. The system self-regulates according to principles that are essentially the ones that Wertheimer individuated (proximity, similarity, common fate, and so forth). The synergetic or conflicting action of such principles tends to a perceptual result that is better in the sense of maximal stability (i.e., less reversible, less ambiguous), and not to the better result in the sense of the aesthetically agreeable, prototypical, or singular. The most cases that are referred to in the literature as evidence of a tendency to singularity are, according to Kanizsa and Luccio, casual results of these organisational principles. The possibility of a phenomenally "singular" appearance is only a by-product. The phenomenal solution preferred by the visual system does not show characteristics like regularity, symmetry, prototypicity, which are the peculiarities of Prägnanz, if understood as the singularity (cf. Luccio, 1998).

7. Global and Local Factors

My opinion, many times implicit in these pages, is that the segmentation of the perceptual field results from an autonomous process, through a dynamic self-distribution of the interacting forces in the field. Therefore, we believe that the perceptual field appears to us segmented through a global process, in which any element interacts with all the other elements. However, this is far from meaning that the action which any element exerts on the others is identical in any part of the field.

A strong counterdemonstration to the supposed tendency to *Prägnanz* as the singularity is given by experiments on perception of movement. It is possible to demonstrate that highly singular components of the perceptual field could be concealed, with a perceptual result which is all but *prägnant*.

It is known that often the perceived movement of an object does not correspond to its physical motion. This is true for speed: because it varies at the variation of the frame of reference inside which the movement occurs (Brown, 1931). It is true for the direction also, as Ames' oscillating trapezoid (1955) and Johansson's analysis (1950) proved. The description of what one sees looking at a rotating wheel is very simple and univocal: the wheel accomplishes a movement of linear translation; and meanwhile all its parts accomplish circular movements around the axis of the wheel itself. Indeed, only one point of the wheel, its centre, goes on a "physical" path that corresponds to the phenomenal path. All other parts accomplish motions that are different from what one sees. No physical path is circular. To see the actual motion one needs to isolate a single part from all other parts, as Rubin (1927) and Duncker (1929) first did. One can accomplish this in a very simple way fixating a little lamp or a phosphorescent dot somewhere on a wheel. Then, one lets the wheel roll in the dark along a plan. If the light is placed on the perimeter of the rolling wheel, one sees it running a path built up by a series of loops. This corresponds to the path physically followed by the lighted dot in the space. Mathematicians call this path a cycloid. In this case phenomenal path and physical path coincide. If one adds a second light to the periphery of the wheel, it isn't any more so easy to see the two cycloids: phenomenally, a rotatory movement of each point around the other prevails (Cutting & Proffitt, 1982). This phenomenal result stabilises itself and becomes coercive if we increase the number of the lighted points on the perimeter. Although it is still true that all the lighted points actually trace cycloids, we are quite unable to see them. We see, on the contrary, the points that rotate around an invisible centre and that displace themselves all together along another invisible plain. This phenomenal decomposition of the actual cycloid motion in a rotatory and a translatory component has been often considered a particularly convincing proof of the existence of a tendency to the *Prägnanz* in the perceptual system.

Indeed, a circular movement is certainly "better" in the sense of regularity and fluidity, than a discontinuous and jerking cycloidal motion.

One counterexample can be demonstrated for the perceived shape of the path of a movement. If three dots move along three circular paths partially overlapped, we don't succeed in seeing the actual paths. What we see is an elastic triangle rotating and twisting in space. Increasing the number of the dots moving on each path from one to five, the patterns are still invisible. In the area in which the circular paths overlap, the dots form continuously transforming and disrupting groups. The overall impression is of great disorder.

The observer succeeds in detecting the circular motions only when there are more than six dots on each path. Obviously, there is a problem of relative distance between dots. Note that the observer is quite aware of the existence of the three distinct circular paths: his or her task is precisely to succeed in detecting them. The phenomenal impression is one of confusion, of Brownian motion of dots upsurging from the middle of the configuration. This phenomenon was first seen by Kanizsa and Luccio informally in 1984. More precise conditions were established by Kanizsa, Kruse, Luccio, & Stadler (1995).

In a paper on the minimum principle and perceived movement, Cutting & Proffitt (1982) stressed the importance at the distinction between absolute, common, and relative motion. It is very clear what absolute motion is, mainly after the seminal work of Rubin, (1927), Duncker (1929), and more recently Johansson (1950, 1973). However, ideas are less clear about relationships between common and relative motion. The first is the apparent motion of the whole configuration relative to the observer, and the second is the apparent motion of each element relative to other configure ones. Cutting and Proffitt, however, have shown that there are two simultaneous processes that correspond to common and relative motion. In both the minimum principle is involved. The prevalence of either is a matter of which process reaches first a minimum.

In this context is relevant a research on alternation between common and relative motion (Kanizsa, Kruse, Luccio, & Stadler, 1995), on the basis of an informal original observation made by Kanizsa & Luccio (1986). If three dots move along three partially overlapping circular paths, we are unable to see the actual paths. What we see is an elastic triangle rotating and twisting in space. If the number of dots moving along each path is increased from one to five, the paths are still invisible. In the area in which the circular paths overlap, the dots form continuously transforming and disrupting groups. The overall impression is one of great disorder.

The observer is able to detect the individual circular motions of the dots only when there are more than six dots on each path. Obviously, there is a problem here of the relative distance between dots. Note that the observer is quite aware of the existence of the three distinct circular paths: his or her task is detecting them. The phenomenal impression is one of confusion, of movement of dots surging from the middle of the configuration. This situation has been more precisely analysed in a series of controlled experiments, which show that when there are one or two points on each path, the subjects see the apexes of one (respectively two) virtual triangle(s) rotating (together) on the screen. With three dots, the subjects see a sort of pulsation, with dots moving alternately inwards and outwards with reference to the centre of the figure. With four to five dots all regularity disappears: the subjects see something like a chaotic motion in the centre of the figure or dots which spring up from the centre in a process of continuous new generation. At the periphery of the figure, the individual dots may trace fragments of circular paths, but these paths are completely lost towards the middle. With six to fifteen dots, the circular paths grow ever clearer as the number of the dots increases. We can say that up until two dots (and in some sense, three dots) for each path the subjects see a common motion, while with six dots or more they see a relative motion. According to Cutting & Proffitt (1982), the former is the apparent motion of the entire configuration relative to the observer, while the latter is the apparent motion of each element relative to others.

Similar results can be obtained by leaving the number of dots per path constant but distantiating the paths; or by either reducing or increasing their radiuses. In any case, when the average distance of each dot from the dots of the *other* paths is clearly less than the average distance of each dot from the other dots of the *same* path, the common motion prevails. When the opposite is the case, relative motion prevails. Thus, the proximity of dots proves to be a crucial factor in the perceptual organisation of phenomenal motion. When attempting to interpret this result in terms of 'synergetics' (see below; Haken & Stadler, 1990), it appeared that the difference (or the ratio, as we were able demonstrate in subsequent studies: Leonardi & Luccio, 1999; Luccio, 1999) between the average distances appears to be the relevant control parameter. If the first distance is clearly less than the second one, the order parameter of common motion emerges and the system is in a stable attractor state. If the second distance is clearly less than the first one, the order parameter of relative motion emerges and the system is in a totally different stable attractor state.

8. The Tendency to Stability

The world which surrounds us is normally perceived as a highly *stable* world. Therefore, if one wants to speak about a tendency, one must say that there is an autonomous tendency of the field to *stability*. In my opinion, the interpretation of the tendency to stability in terms of "minimum" principle is also very convincing; today this concept is again in the lime-light, after a long time (see Hatfield & Epstein, 1985; Zimmer, 1986).

Notice that, apart from some very special cases of multistability (the ambiguous figures), nearly any stimulus situation, although it is, in principle, plurivoque, and can therefore give rise to many phenomenal outcomes, tends *to come perceptually to a unique outcome*: not towards the most singular solution, but in general towards the most stable one. This probably occurs because the structural factors, which in any stimulus situation are usually numerous, are often in antagonism with each other (proximity *vs.* closure *vs.* continuity of direction, etc.); therefore, the more stable situation is the one with the maximum equilibrium between the tensions generated by the counteracting factors. Such tensions, however, find a point of balance in configurational structures, that only by accident have also the property of the figural "goodness". Only in special cases, particularly those in which only one factor acts, could one presume that the tendency to stability coincides with the tendency to *Prägnanz*. But the more numerous the interacting factors are, and consequently, the more complex the occurring configurations, the more rarely does the stable solution coincide with the prägnant one.

We think that the tendency to *Prägnanz*, to a singular outcome, actually exists: not at the level of what Kanizsa (1979; see above, § 5) defined a primary process (cfr the *preattentional* processes by Neisser, 1967), but at the level of the secondary process. The tendency to *Prägnanz* is then well recognizable in the products of secondary process, especially in transformations which are the fate of memory traces, also in the short term. Moreover, the individuation of this tendency to *Prägnanz* in secondary process is one of the fundamental contributions that psychology of Gestalt has provided (see Goldmeier 1982 on memory).

9. Lie Transformation Group Approach to Neuropsychology

An attempt to give a more precise mathematical formulation of the structure of the field was made by Hoffman (1966, 1977, 1984), who had as the starting point the model elaborated by Brown and Voth. The mathematical instrument used by Hoffman was Lie's group algebra. (One can mention that already Musatti (1957) had proposed to use group algebra to study perceptual invariants.) The vector-fields described in this way by Hoffman are a description of the functioning of the nervous system, in terms of isomorphism with the phenomenal field. For this reason, Hoffman (1977) utilises the abbreviation LTG/NP (Lie Transformation Group Approach to Neuropsychology).

According to Hoffman (1984; cf. Hoffman & Dodwell, 1985), we can describe both the retina and the cortical retina as a mathematical *manifold*, and at least in the central area, there is a retinotopic correspondence between the two manifolds, with "Mexican hat" centre-surround cellular response fields. At the cortical level, there is also an orientation preference; that is, the response fields are oriented direction fields, or vector fields. Such vector fields can be considered as unions of spaces locally tangent to the manifold.

The task of the visual system is to seek to trace the contours of the objects present in the field, by assembling the local tangent elements which correspond to the contour. In other words, the system can be represented in terms of Lie derivative operators that generate the appropriate curve which fits the contour.

Recall that Lie's continuous transformation groups are topological, parametric and analytic (for details, see Hoffman 1966, pp. 67–69). The main interest of Hoffman is then to find out what are the Lie groups that can explain the basic perceptual invariances. Thus, for shape constancy, he identifies affine or special linear groups, that is, horizontal and vertical translations for invariance of location in the field of view; rotation for invariance of orientation; pseudo-Euclidean (hyperbolic) rotations for invariance in binocular vision;

time translations for invariance of form memories. For size constancy, he identifies the dilatation group, for spiral effects. And so forth.

Apart from invariants, Hoffman & Dodwell (1985) have tried to interpret the principles (factors) of Gestalt psychology in terms of Lie transformation groups. The list of Gestalt principles utilised by Hoffman and Dodwell do not coincide with Wertheimer's, and it is, in some sense, a little bizarre. Beyond the latter, there is *symmetry* (more symmetrical the shape of a region of the field is, more it tends to be unified as a figure), *orientation* (the alignment with the horizontal and vertical axes of the frontal plane enhance the perception of a figure), *completion* (as an instance of *continuation*), *area* (smaller a closed region of the field is, more it tends to be perceived as a figure). Also *transposition* is considered a factor of figural unification. The definition that they give of *Prägnanz* is a little surprising: «perceptual organisation takes place in such a way as to yield percepts that have maximal definition, symmetry, and recognisable form under any given situation» (p. 514). In any case, in this "geometric psychology", as they call it, the different Gestalt principles are referred to a partitioning of the visual manifold into equivalence classes, through some equivalence relation.

10. Non-linear Systems

The geometric psychology developed by Hoffman appears more a description of the perceptual field than a truly interpretive theory. The picture which emerges is static enough, and above all, what is missing being the aspect of auto organisation, which is peculiar of Gestalt theorising. In this sense, other approaches recently developed in cognitive psychology appear more promising in treating Gestalt problems.

As Stadler & Kruse (1990) point out, there is continuity between Gestalt theorising on autonomous order formation (above all in Köhler's formulation) and the currently fast developing theory of self-organising no equilibrium dynamic systems. To this effect, a prominent role has been especially played in the last few decades by Hermann Haken (1883a, 1883b) with his *synergetics*. Let us then consider briefly this approach concerning the problem of dynamic pattern formation (Kelso, 1995).

According to synergetics, pattern formation can be described in terms of evolution of state vectors. The evolution is described in terms of their time derivative. Haken's analysis leads to identify a nonlinear function ***N*** according to which the temporal changes occur; this function depends on a *control parameter*. Internal and external fluctuations are instead described by a function *F(t)*. However, the dynamics of the whole system is governed by *order parameters* alone; this means that, if describes the system at the micro-level, the high-dimensional equation could be reduced at the macro-level to equations for the order parameter. Such reduction corresponds to Haken's slaving principle: near an instability, the macroscopic behaviour of the system is dominated by few modes, which suffice for its description. What happens, is that when the control parameter changes, the old status is replaced by a new one, which can assume positive or negative values. So, the solution from the starting point can be decomposed in two parts, the first one, for positive *eigenvalues*, which amplitude is the order parameter ξ_u; the second one, for negative *eigenvalues*, the stable mode, which amplitude is the order parameter ξ_s.

The typical representation of what happens in a system of this kind can be so represented. At the beginning, when the control parameter is under a critical value, there are fluctuations in the system that determine a mild increase in the order parameter, that tend to relax ate towards a stable state. When the control parameter exceeds the critical value, the first state is replaced by two possible ones; there is a breaking of the symmetry and a bifurcation in the two possible states, and only one is chosen.

This kind of evolution can be seen very easily in many kinds of physical, chemical, biological, and psychological systems. A classical example (indeed, the very starting point of Haken's theorising) is the laser paradigm. When a laser-active material is excited (when the lasing begins), for instance, by being irradiated with light, if the excitation's degree (the control parameter) exceeds a critical value, we can note that the atoms cooperate emitting a coherent wave without any noise; with a greater excitation, this wave, firstly, breaks in ultra short laser pulses, and after a chaotic motion occurs. The changing of the control parameter determines a qualitative change of the system.

The application of this model of *no equilibrium phase transition* to behavioural problems, and overall to perceptual problems. The situation of multistability, as Kruse & Stadler (1990, 1995) point out, is obviously a privileged field of research. Similar phenomena were individuated in many perceptual domains (e.g., speech categorization), and are assumed to be a strong support for nonlinear dynamic models of perception (cf. Tuller, Case, Ding, & Kelso, 1994). If we present the phoneme *s* followed after a while by the diphthong *ay*, according to the length of the inter-stimulus interval the subjects will perceive either *say* (long gap) or *stay* (short gap). The transition between the two percepts is abrupt, as in all cases of categorical perception, also when the variation of the length of the gap is continuous. Here we have an evident non linearity, with a phase transition from a first attractor (the first linguistic category, here *say*) to another attractor (the second linguistic category, here *stay*). We can describe this process in terms of direction and tilt for the potential $V(x)$, where x is the perceptual form, deriving it from the ordinary motion equation:

$$\dot{x} = -\frac{dV(x)}{dx},$$

where $\dot{x}$ is the time derivative of x. Tuller *et al.* (1994) find a fit with the following function:

$$V(x) = kx - ax^2 + bx^2.$$

(In fact, their function is a little more complicated, but this form is sufficient for our purposes). This equation describes the so-called 'saddle-fork' attractors. The best fit is obtained here with $a \approx 0.5$ and $b \approx 0.25$. k is the control parameter, and k is a monotonically increasing function of the gap duration. When $k < 0$, the prevailing attractor corresponds to *say*, when $k > 0$, the prevailing attractor corresponds to *stay*. When $k = 0$, neither attractor prevails.

On this theoretical view of the experimental data, moreover, it can be predicted that a *hysteresis effect* can be demonstrated by gradually approaching the phase transition from *say* to *stay*. Indeed, the phase transition from one category to the other is produced at different points according to whether we begin with long gaps that are progressively shortened, or with short gaps that are progressively increased (ascending and descending series): what in psychophysics is known as the *starting position effect* (see Luccio, 2003). In ascending series we have transition with longer gaps than in descending series.

With G. Leonardi, I applied this model to the problem of overlapping paths (see § 5). We found that it fit very well with our data, with closely similar values of the parameters. In our case, *k* was a monotonically increasing function of the ratio between the two distances (Leonardi & Luccio, 1999; Luccio, 2004). But which is the function?

Note that in our situation, too, we have hysteresis in passing from the stable common motion to the stable relative motion in ascending and descending series. If we calculate the cumulative curves of the responses to the two types of motion, we obtain two spaced S-shaped curves. The area between them, which can be easily calculated by integration once the exact function has been determined, is the measure of the hysteresis.

In the last few years, together with my collaborators I have investigated many bistable situations: alternating stroboscopic movement, alternating Latin and Greek crosses, spatial boundary formation (see Shipley & Kellmann 1994; Bruno, 2001), the breathing illusion (see Bruno & Gerbino, 1991), the perception of causality with Spizzo's effect (see Spizzo 1983; Luccio & Milloni, 2004), acoustic streaming (see Bregman, 1990); and so on. For a survey, see Chiorri (2002). In most cases, the above model fitted pretty well. What is interesting is the fact that the S-shaped curves just mentioned were on many occasions similar to logistic ones, something like:

$$y = \frac{a}{1 + e^{-kx}}.$$

The presence of the letter *k* here is not accidental. This parameter often proves to be the control parameter in the above model. But to clarify this issue, much experimental work has still to be done.More generally, this approach offers a very powerful tool for interpreting the processes of autoorganisation of the field, in Köhler's sense.

11. Computational Gestalts

The last approach that we can quote in this vein is the approach of the computational gestalts. This promising attempt was undertaken in the last ten years or so, by a group of French mathematicians mainly interested in computer vision; among them (Morel, Cao, Almansa, etc.), the leading figure today is Agnes Desolneux (et al., 2006; Luccio, 2008). The theory of computational gestalts that they are building is centred on three basic principles: i) *Shannon-Nyquist, definition of signals and images*: any image or signal, including noisy signals, is a band-limited function sampled on a bounded, periodic grid. ii) *Wertheimer's contrast invariance principle*: image interpretation does not depend upon actual values of the stimulus intensities, but only on their relative values. iii) *Helmholtz principle*, indeed stated by Lowe (1985): Gestalts are sets of points whose (geometric regular) spatial arrangement could not occur in noise. (Don't pay much attention to the names given to such principles!)

The meaning of these principles could be stated so. Given the discreteness of the visual field (first principle), and given the prevalence of the relative over the absolute values of the stimuli (second principle), it is possible to determine an expectancy value ξ_s for whom all the stimuli whose expectancy is less than ε will tend to group together (third principle).

The starting point is the attempt made by Gestaltists (especially Wertheimer) to find the basic laws that contribute to the formation of shapes, on the basis of several common properties. These properties (*partial gestalts,* Desolneux, Moisan, & Morel, 2001), correspond at least in part to the result of the functioning of the classical principles stated by Wertheimer (1923); their applications converge in forming larger groups, according also to some other less classic principles, like the *articulation without rests* (Metzger, 1941; Kanizsa, 1979). Then, Gestalt theory predicts that the partial Gestalts are recursively organized with respect to the grouping laws. The algorithms are non-local, since alignments, common fate, similarity and so on between some partial features have to be considered for the totality of the perceptual field.

Let's examine the detection of good continuation (Cao, 2004). Given a curve and a number of other curves with different levels of smoothness, the participant has the task of making what they consider is a meaningful assembly, indicating which curves can belong to each other. We can thus work out the false alarm rate; in such a detection task the parameters reduce to this rate, such that under the null hypothesis, it is a fair measure of probability. The algorithm is, in consequence, parameter free – or, at least, the parameterization could be considered negligible.

We must stress that the verb "decide" could be misleading, if one assumes that it implies some sort of ratiomorphic explanation with reasoning about the grouping (for example, according to smoothness) as a perceptual result. Instead, the process has, in some sense, an automatic exit. In other terms, it could be considered as the output of a sort of "smart mechanism", in the sense of Runeson (1977): in this case, as we will see soon, the primary process is the output of a smart mechanism that is able to assess probabilities to segment the perceptual field according to the result of this assessment, without any need for the perceptual mechanism to know anything about the theory of probability.

As we said, the so-called Helmholtz principle was introduced by Lowe (1985). In very general terms, we can state the principle in this way: we are able to detect any configuration that has a very low probability of occurring only by chance. So any detected configuration has a low probability that implies that every improbable configuration is perceptually relevant. Lowe stated the principle thus: « ... we need to determine the probability that each relation in the image could have arisen by accident $p(A)$. Naturally, the smaller that this value is, the more likely the relation is to have a causal interpretation». A more formal statement of this principle was first given by Desolneux, Moisan, & Morel (2003): «We say that an event of type 'such configuration of points has such property' is ε-meaningful if the expectation in an image of the number of occurrences of this event is less than ε».

What do we mean by ε-meaningfulness? Let's assume that in an image n objects (parts, regions) are present and that, at least in part (let's say, k of them), they share a common feature – same spatial orientation, same shape, same color, and so on. Under the null hypothesis, this must be due to chance. So, our perceptual mechanism acts as a genuine "Fisherian statistical operator", determining the conditional probability associated with the actual pattern, given that the null hypothesis is true, $p(\text{pattern} \mid H_0)$, assigning a very low value to the null hypothesis, and trying to falsify it. If such probability is less than some little α (in statistical inference theory we usually call this the critical level of probability α, the probability of a first type error, and put it equal to the magic number 0.05), the Gestalt establishes itself. Only in this sense can we speak of "decision", in the sense of a statistical decision, and not of an inferential process. The above expectation ε is strictly related to the conditional probability p, that is p times the number of tests that we perform on the pattern.

In conclusion, the theory of computational Gestalts appears a very promising way to afford the problem of definition of what Kanizsa' s primary process must be. Of course, if in computer vision the approach can be considered a well-established theory, in experimental psychology we have yet much work to accomplish. The theory of computational Gestalts, which I have outlined here, appears highly promising.

12. Conclusion

The contribution of *Gestalttheorie* to contemporary psychology is still valuable. Its theoretical ideas have in many respects been truly seminal: auto-organization, isomorphism, field theory, *Prägnanz,* distinction between global and local factors, and so on. It invites us to continue with the task of identifying the rules and constraints that enable us to see the world as it appears. These ideas have proved seminal in several fields of contemporary cognitive psychology: field dynamics, non linear systems, computational Gestalts. But one could refer to many other approaches. Of course, this approach is in no sense the *Gestalttheorie* as it was conceived by its early authors, but the results that we, its direct and indirect pupils, have obtained indicate that we may be working in the right direction.

REFERENCES

Ames, A. (1955). *An Interpretative Manual. The Nature of Our Perceptions, Prehensions, and Behavior.* Princeton: Princeton University Press.

Attneave, F. (1954). Some informational aspects of visual perception. *Psychological Review*, *61*, 183–193.

Attneave, F. (1959). *Applications of Information Theory to Psychology*, New York, NY: Holt.

Bregman, A.S. (1990). *Auditory Scene Analysis: The Perceptual Organization of Sound.* Cambridge, MA: MIT Press.

Brentano, F. (1874). *Psychologie von empirische Standpunkt.* Leipzig: Duncker & Humboldt.

Brown, J.F. (1931). The visual perception of velocity. *Psychologische Forschung*, *14*, 199–232.

Brown, J.F., & Voth, A.C. (1937). The path of seen movement as a function of the vector-field. *American Journal of Psichology*, *49*, 543–563.

Bruno, N. (2001). Breathing illusions and boundary formation in space-time. In T. Shipley, & Ph. Kellmann (Eds.), *From Fragment to Objects.*

Segmentation and Grouping in Vision. Amsterdam: Elsevier Advances in Psychology Series, 402–427.

Bruno, N., & Gerbino, W. (1991). Illusory figures based on local kinematics. *Perception*, *20*. 259–274.

Cao, F. (2004). Application of the Gestalt principles to the detection of good continuations and corners in image level lines. *Computing and Visualization in Science*, *7,* 3–13.

Chiorri, C: (2002). *Metodologia per la ricerca sinergetica in psicologia.* Firenze: CUSL.

Coffa, J.A. (1989). *The Semantic Tradition from Kant to Carnap: To the Vienna Station.* Cambridge: Cambridge University Press.

Cutting, J.E., & Proffitt, D.R. (1982). The minimum principle and the perception of absolute, common, and relative motion. *Psychology*, *14*, 211–246.

Desolneux, A., Moisan, L., & Morel, J.M. (2001). Partial gestalts. *IEEE Transactions on Pattern Analysis and Machine Intelligence.* Available at http://www.cmla.ens-cachan.fr.

Desolneux, A., Moisan, L., & Morel, J.M. (2003).A grouping principle and four applications. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *25*, 508–513.

Desolneux, A., Moisan, L., & Morel, J.M. (2006). *From Gestalt Theory to Image Analysis: A Probabilistic Approach.* (Technical Report).

Duncker, K. (1929). Über induzierte Bewegung. *Psychologische Forschung*, *12*, 180–259.

Dürr, E. (1900). Über die stroboskopischen Erscheinungen. *Philosophische Studien*, *15*, 501–523.

von Ehrenfels, C. (1890). Über Gestaltqualitäten. *Vierteljahrschrift für wissenschaftliche Philosophie*, *14,* 249–292.

Exner, S. (1875). Experimentelle Untersuchngen der einfachsten psychischen Prozesse. *Archiv für Physiolologie*, *11*, 403–432.

von Fieandt, K. (1983). Reductivist isomorphism in cognitive research. *Gestalt Theory*, *5*, 30–54.

Garner, W.R. (1962). *Uncertainty and Structure as Psychological Concepts*. New York, NY: Wiley.

Goldmeier, E. (1982). *The Memory Trace: Its Formation and its Fate*. Hillsdale, NJ: LEA.

Grassman, H.G. (1853). Zur Theorie der Farbenmischung. *Poggendorff's Annalen der Physik und Chemie*, *89*, 69–84.

Haken, H. (1983a). *Synergetics: An Introduction*. Berlin: Springer.

Haken, H. (1983b). *Advanced Synergetics: Instability Hierarchies of Self-Organizing Systems and Device*. Berlin: Springer.

Haken, H. (1990). Synergetics as a tool for the conceptualisation and mathematisation of cognition and behaviour. How far can we go?. In H. Haken, & M. Stadler (Eds.), *Synergetics of Cognition*. Berlin: Springer, 2–30.

Haken, H., & Stadler, M. (Eds.). (1990). *Synergetics of Cognition*. Berlin: Springer.

Hatfield, G.J., & Epstein, W. (1985). The status of minimum principle in the theoretical analysis of perception. *Psychological Bulletin*, *97*, 155 –176.

Hering, E. (1878). *Zur Lehre vom Lichtsinn*. Leipzig: Engelmann.

Höffding, H. (1887). *Psychologie in Umrissen auf Grundlage der Erfahrung*. Leipzig. Füs's Verlag.

Hoffman, W.C. (1966). The Lie algebra of visual perception. *Journal of Mathematical Psychology*, *3,* 65–98.

Hoffman, W.C. (1977). An informal historical description of the «LTG/NP». *Cahiers de Psychologie*, *20*, 133–174.

Hoffman, W.C. (1980). Subjective geometry and geometric psychology. *Mathematical Modelling*, *1*, 349–367.

Hoffman, W.C. (1984). Figural synthesis by vector-fields: Geometric neuropsychology. In P.C. Dodwell, & T. Caelli (Eds.), *Figural Synthesis.* Hillsdale, Nl: Erlbaum.

Hoffman, W.C. (1986). Invariant and programmable neuropsychological systems are fibrations. *The Behavioral and Brain Sciences*, *9*, 99–100.

Hoffman, W.C., & Dodwell, C. (1985) Geometric psychology generates the visual Gestalt. *Canadian Journal of Psychology*, *39*, 491–528.

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

Johansson, G. (1950). *Configurations in Event Perception.* Uppsala: Almkvist Wilsell.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics, 14,* 201 –211.

Kanizsa, G. (1979). *Organization of Vision.* New York, NY: Praeger.

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

Kanizsa, G. & Luccio, R. (1987). Formation and categorization of visual objects: Höffding's never confuted bus always forgotten argument, *Gestalt Theory*, *9*, 111–127.

Kanizsa, G., Kruse P., Luccio, R., & Stadler, M. (1995). Conditions of visibility of actual paths. *Japanese Psychological Research, 36*, 113–120.

Kelso, J.A.S. (1995). *Dynamic Patterns. The Self-Organization of Brain and Behavior.* Cambridge, MA: MIT Press.

Kelso, J.A.S., Ding, M., & Schöner, G. (1992). Dynamic pattern formation. In J. Mittenthal & A. Baskin (Eds.): *Principles of Organization in Organisms*, New York: Addison-Wesley, 397–439.

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

Köhler, W. (1924). Gestaltprobleme und Anfänge einer Gestalttheorie. *Jahresberichte über die gesamte Physiologie*, *3*, 512–539.

Köhler, W. (1929). *Gestalt psychology.* New York, NY: Liveright.

Köhler, W. (1940). *Dynamics in Psychology.* New York, NY: Liveright.

Köhler, W. (1947). *Gestalt psychology.* New York, NY: Liveright.

Köhler, W. (1950). Psychology and evolution. *Acta Psychologica, 7,* 288–297.

Köhler, W. (1958). The present situation in brain physiology. *American Psychologist, 13,* 150–154.

Köhler, W. (1969). Gestalt Psychology. In D.L. Krantz (Ed.), *Schools of Psychology: A Symposium.* New York: Appleton-Century-Crofts, 69–85.

Kruse, P., & Stadler, M. (1990). Stability and instability in cognitive systems: Multistability, suggestion and psychosomatic interaction. In H. Haken & M. Stadler (Eds.), *Synergetics of Cognition.* Berlin: Springer, 201–217.

Kruse, P., & Stadler, M. (1995). The relevance of instability and nonequilibrium phase transition in the research on cognitive systems. In P. Haken & M. Stadler (Eds.), *Ambiguity in Mind and Nature.* Berlin: Springer.

Lashley, K.S., Chow, K.L., & Semmes, J. (1951). An examination of the electric field theory of cerebral integration. *Psycological Review, 58,* 123–136.

Lehar, S. (2003a). Gestalt isomorphism and the primacy of subjective conscious experience: A Gestalt bubble model. *Behavioral and Brain Sciences, 26,* 375–408.

Lehar, S. (2003b). Author's response. *Behavioral and Brain Sciences, 26,* 430–444.

Leonardi, G., & Luccio, R. (1999). La *Prägnanz* comme attracteur. In M. Zanforlin, & L. Tommasi (Eds.), *The Problem of Perception.* Padova: Logos, 69–90.

Lipps, T. (1900). Aesthetische Einfühlung. *Zeitschrift für Psycholologie, 22,* 415–450.

Lotze, H. (1852). *Medicinische Psychologie oder Physiologie der Seele.* Leipzig: Weidmann.

Lowe, D. (1985). *Perceptual Organization and Visual Recognition.* London: Klüwer.

Luccio, R. (1998). On *Prägnanz*. In L. Albertazzi (Ed.), *The Form of Shapes*. New York: Kluwer, 186–219.

Luccio, R. (1999). Dynamic systems in psychology: The case of motion. *La Nuova Critica*, *31–32*, 115–130.

Luccio, R. (2003). The emergence of *Prägnanz*. *Axiomathes*, *9*, 1–23.

Luccio, R. (2004). *Gestalttheorie* e sistemi dinamici. *Teorie e Modelli*, *9,* 75–95.

Luccio, R. (2008). Computational Gestalts and *Prägnanz*. *Gestalt Theory*, *30,* 135–143.

Luccio, R. (2010). Anent isomorphism and its ambiguities: From Wertheimer to Köhler and back to Spinoza. *Gestalt Theory*, *32,* 219–262.

Luccio, R., & Milloni, D. (2004). The perception of causality: A dynamic analysis. In R. Peruzzi (Ed.), *Psychology of Causality*. London: Benjamin, 19–34.

Mach, E. (1885). *Die Analyse der Empfindungen und das Verhaeltnis des Physischen zum Psychischen*. Jena, Fischer.

Marbe, K. (1898). Die stroboskopischen Erscheinungen. *Philosophische Studien*, *14*, 376–401.

Maxwell, J.C (1881). *A treatise on electricity and magnetism* . Oxford: Clarendon Press.

Metzger, W. (1941). *Psychologie*. Dresden und Leipzig: Steinkopff.

Müller, G.E. (1896). Zur Psychophysik der Gesichtsempfindungen. *Zeitschrift für Psychololologie*, *10*, 1–82.

Müller, G.E. (1923). *Komplextheorie und Gestalttheorie: Ein Beltrag zur Wahrnehmungspsychologie.* Gottingen: Vandenhoeck & Ruprecht.

Musatti, C.L. (1957). I caratteri percettivi degli oggetti e la teoria matematica dei gruppi. *Rivista di Psicologia*, *51*, 331–341.

Neisser, U. (1967). *Cognitive Psychology.* New York, NY: Appleton.

Orbison, W.D. (1939). Shape as a function of the vector-field. *American Journal of Psychology*, *52,* 31–45.

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

Rausch, E. (1966). Das Eigenschaftsproblem in der Gestalttheorie der Wahrnehmung. In W. Metzger & H. Erke (Eds.), *Handbuch der Psychologie. Bd 1/1. Wahrnehmung und Bewußtstein.* Göttingen: Hogrefe, riferimento di pagina mancante

Rubin, E. (1927). Visuell wahrgenommene wirkliche Bewegungen. *Zeitschrift für Psychologe*, *103*, 384–392.

Runeson, S. (1977). On the possibility of "smart" perceptual mechanisms. *Scandinavian Journal of Psychology*, *18,* 172–179.

Scheerer, E. (1994). Psychoneural isomorphism: Historical background and current relevance. *Philosophical Psychology*, *7*, 183–211.

Schumann, F. (1907). Psychologie des Lesens. *Bericht über den II Kongreß fur experimentelle Psychologie in Würzburg*. Leipzig: Barth, 153–183.

Shipley, T., & Kellmann, Ph. (1994). Spatiotemporal boundary formation: Boundary, form, and motion perception from transformations of surface elements. *Journal of Experimental Psychology: General, 123*, 3-20.

Sperry, R.W., Miner, N., & Myers, R.E. (1955). Visual pattern perception following subpial slicing and tantalium wire implantation in the visual cortex. *Journal of Comparative and Physiological Psychology*, *48*, 50–58.

Spizzo, G. (1983). La regolare associazione come fonte di connessioni causali fenomeniche. *Ricerche di Psicologia*, *26*, 221–230.

Stadler, M., & Kruse, P. (1986). Gestaltheorie und Theory der Selbstorganisation. *Gestalt Theory*, *8,* 75–98.

Tuller, B., Case, P., Ding, M., & Kelso, J.A.S. (1994). The nonlinear dynamics of speech categorization. *Journal of Experimental Psychology. Human Perception and Performance*, *20*, 3–16.

Vicario, G.B. (2001). *Psicologia generale. I fondamenti.* Roma and Bari: Laterza.

Wallach, H. (1949). Some considerations concerning the relation between perception and cognition. *Journal of Personality*, *18*, 6–13.

Wertheimer, M. (1912a). Experimentelle Studien über das Sehen von Bewegung. *Zeitschrift für Psychologie*, *62*, 371–394.

Wertheimer, M. (1912b). Über das Denken der Naturvölker. *Zeitschrift für Psychologie*, *60*, 321–368.

Wertheimer, M. (1914). Diskussion zum Vortrag von Benussi: Kinematohaptische Scheinbewegung und Auffasungsformung. In F. Schumann (Ed.), *Bericht über den VI. Kongreß für experimentelle Psychologie. I. Teil.* Leipzig: Barth, 11.

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

Wertheimer, M. (1923). Untersuchungen zur lehre der Gestalt II, *Psychologische Forschung*, *4*, 301–350.

Wundt, W. (1902–03). *Grundzüge der physiologischen Psychologie* (5th ed.). Leipzig: Engelmann

Zimmer, A. (1986). The economy principle, perceptual mechanisms and automated cognitive processes. *Gestalt Theory*, *8*, 256–27.