Historical Threads in the Dynamical Fabric of Psychology: I. Some Holistic Traditions of the Early-Mid 20th Century

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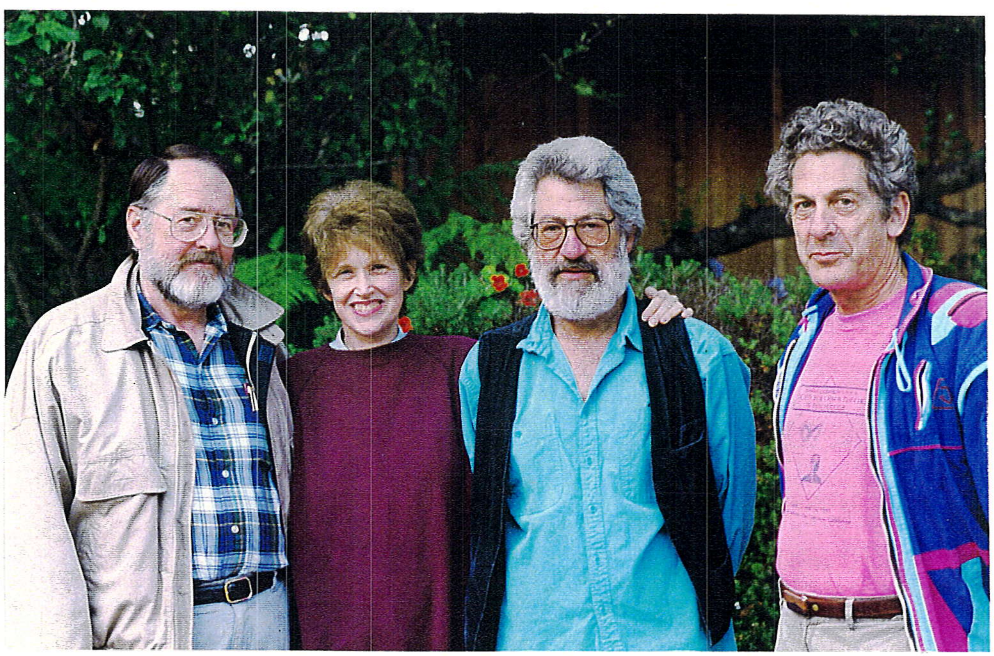
DEDICATION

David Loye has had great concern for the future, the improvement of society, the potential role that systems concepts could play in that improvement, and the significance that the history of science and psychology has played in social development. For his dedication to these concerns, and for his being a really nice person, we devotedly offer this first of four essays in his honor.



David Loye, Riane Eisler, Ralph & Fred Abraham, Carmel, 1992

This series of essays can be viewed as a biased historical sampler of some dynamical concepts in psychological science. The three main threads considered are (1) The holistic approaches of Gestalt, field, event-structure, and ecological perceptual-action theories, (2) the cybernetic-neural-behavioral-general systems approaches, and (3) the dynamical thread. This essay considers the first thread. The next two essays will consider the next two threads. The last one will consider some aspects of epistemology and philosophy of science, and some recurrent issues in psychology, namely, its humanistic mission, free will, and the balance between trends toward unification and toward diversity. Section A2 herein contains a very small first attempt at a hypothetico-deductive dynamical formalization of Lewin which Loye once requested me to undertake.

Students of psychology are familiar with most of these historical details which are highlighted for their potential relevance to the contemporary exploration of dynamical ideas in psychology. There are many ways to view significant historical threads; these, like most, may prove considerably arbitrary. This account is but a foray, a brief venture. It will include some comments on social relevance, which is important to Loye, to Lewin, and to me.

A. Gestalt Psychology

It is easy to see why this tradition is relevant even though it has faded from view. The similarities of the Gestalt and dynamics programs are amazingly syntonic. Compare some statements of their purpose:

> **Gestalt**: The fundamental "formula" of Gestalt theory might be expressed in this way: There are wholes, the behavior of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole. It is the hope of Gestalt theory to determine the nature of such wholes. (Wertheimer, 1924/1938/1950, p. 2).

> **Dynamics**: The past two decades have witnessed a revolution in its language, concepts, and techniques for dealing with complex cooperative systems evolving . . . Instead of looking at a static object or event as a thing to be explained, it looks to a set of complex evolving relationships as both the subject, the object, and the explanation, holisitc and dynamical. . . . The language of reductionism and independent and dependent variables gives

way to the language of dynamical interactive variables. (Abraham, Abraham, & Shaw, 1990, pp. I-1-2).

These are essentially equivalent statements, although there is additional explicit emphasis on temporal evolution in dynamics which is left more implicit in the Gestalt statement. This interactive process between parts and wholes is very explicit in dynamics, in that the equations of change of a system usually contain an indigenous component [$dx/dt = f(x)$] as well as components from their dependency upon other variables of the system ($dx/dt = f(y,z, \ldots)$], that is, $dx/dt = f(x,y,z, \ldots)$. That seems implied in the Gestalt statement though it is couched in terms of the whole affecting the parts without adding the obvious, that the parts have some contribution to the whole. This symmetry or mutuality between parts and wholes becomes explicit in later Gestalt and field-theoretical formulations. The dynamical statement was less explicit about the part-whole relationship; one has to remember that the properties of an attractor which a trajectory displays constitute wholeness resulting from an interactive evolution.

While these fundamental points of view are compelling as theoretical interpretive schemes for psychological phenomena, they were both early challenged to be more, that is, to motivate explicit testable theories and research programs. Here follows just a couple of examples to suggest the flavor of how research emphasis shifted with the advent of each approach.

Most students of psychology are familiar with how Gestalt focused on perception, and how they adopted more complex stimuli, more complex response modes, and more unrestrained forms of experimental design and analysis than that on which the psychophysics of the day had been focused. An examination of that literature would be very illuminating, and perhaps better justified, but there are classic examples from the study of memory as well. Selecting a couple of studies published in 1922, one associationist, the other Gestalt, will perhaps serve just as well to compare their approaches and portray the Gestalt revolution.

Much work on memory of that period followed the influence of Ebbinghaus and Müller, often emphasizing paired-associate learning. Luh, completed his dissertation at Chicago in 1920 which was home to the functionalism of

Dewey, Angell, and Carr. While functionalism was a rather liberalized version of associationism and elementism, Luh's study was typical of retention work of the day. He used paired-associate learning and his independent variables were length of time to testing and the method used to measure retention. His dependent variable, percent correct responding, tended to highlight comparative amounts of degradation of learned associations for each of the independent variables (Fig. 1). It was a well performed and well quoted study of the mid 20th century (Luh, 1922).

Wulf did his dissertation under Koffka, one of the main founders of Gestalt psychology at Geissen (near Frankfurt where Wertheimer was). Wulf used complex line drawings for stimuli, and the subject reproduced them from memory for immediate recall, or from small fragments for later recall. The experimental design was minimal, and preconceived forms of analysis of the reproductions were absent. But the analysis was careful. Accurate reproduction he called *conservation*. Distortions were of various types. One, corresponding to the degradation of memory studied by the functionalists, he called *levelling*, for a weakening. The other he called *sharpening*, for a

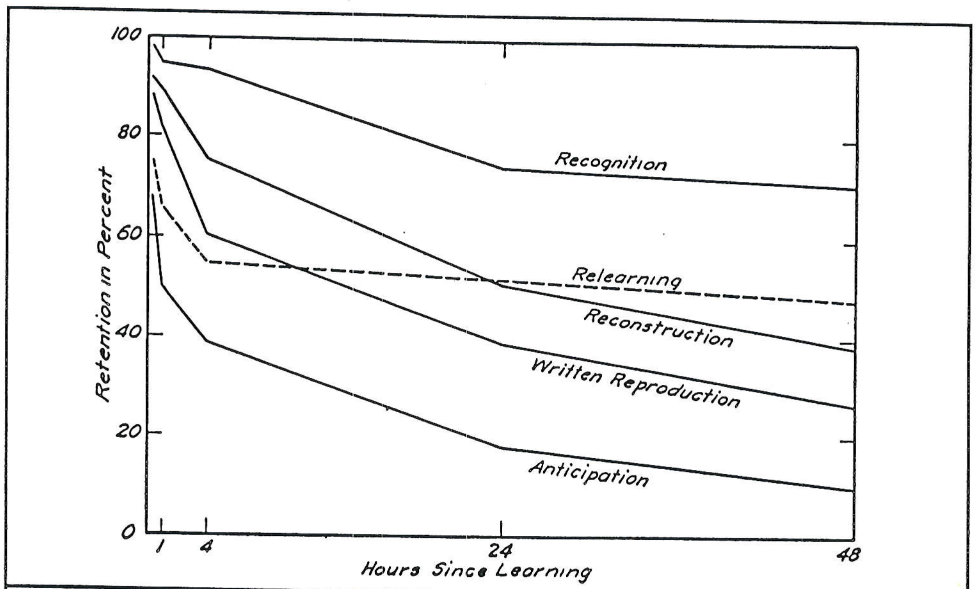


Figure 1. Retention Curves for Nonsense Syllables Obtained from Five Methods of Measurement. (Luh, 1922)

strengthening of certain details of the figures. Each of these is illustrated in Figure 2 (from the single subject of his first preliminary experiment). Sharpening is shown in the upper level (Fig. 2, part 1; stimuli on the left, reproduction on the right); line segments are longer, angles sharper, and differences between the two lines is greater. Levelling is shown in the lower level (Fig. 2, part 2) in the reduced difference between the two lines. A third type of change or distortion he called *normalizing*, in which the reproduction was made to appear more like a "well-known structure". He also noted different cognitive styles in reproduction which he called *isolative* and *comprehensive* apprehension. *Isolative* apprehension focused on physical details of the stimuli; *comprehensive* apprehension was attributed to cognitive interpretation, that is, the figures were seen as resembling familiar objects. Wulf was testing Müller's 'convergent principle' which assumed that all aspects of memory, all associations, deteriorate, become vague, and thus begin to resemble each other, thus to 'converge'. Any 'affective transformation' leading to advantages of certain features of memory Müller attributed to special attention paid to those features initially. Wulf interpreted his results

Figure 2. Figural Recall
Stimuli (left, V) and responses (right, W) for two pairs of lines. The upper level (part 1) shows sharpening with zigzag lines. The lower level (part 2) shows levelling in the greater similaity of the two curved lines. (Wulf, 1922)

as indicating dynamic memorial processes, involving tensions between parts and wholes, and the relationships between parts of the figure. He admits that 'the number of details one can recall is often quite meagre' but stresses that there is a dynamic process of attempting to reconstruct an intact memory with an increasing wholeness rather than an increasing vagueness; it proceeds to 'the good Gestalt'. He mention's Jost's second law concerning the influence of earlier learning on this process. He also talks about perceptual equilibrium depending on aspects of the whole. He concludes:

> The most general law underlying all change is The Law of *Prägnanz* according to which every Gestalt becomes as "good" as possible. In perception the "possible" is strongly determined by the stimulus complex. When freed from this influence the "engram" is able to change in ways prescribed by the law of *Prägnanz.* It is for this reason that memorial Gestalten tend towards unique forms. From this it is also possible now to understand the normalizing effect. Well known forms (structures) are themselves already stable. If the structure given in perception is such as to initiate processes proceeding along the same lines as those of already stable forms, they will eventuate in the same forms as their predecessors. the significant factor is not how frequently a form has been experienced, but whether its structure is stabilized in accordance with Gestalt laws. (Wulf, 1922).

One could substitute here the term "attractor" for "stable structure".

An even more dramatic example of such *Prägnanz* is seen in the often quoted figures (Fig. 3) from Bartlett (1932), whom Freeman (1995a,b) mentions in stating that memory is a "process of construction, not retrieval" in his discussions of the liberation of neuroscience from the 'reflex doctrine'. Bartlett's own work obtained similar results with the study of the retention of folk tales. Allport (1930), Perkins (1932), and Gibson (1929) have also

Figure 3 (opposite). Note:
As many times as I have skipped by these figures as a student (the first being in a textbook by Stagner & Karwoski used in an introductory psychology course—Loye and I both took the same course from Karwoski separated by but a very few years), their significance always escaped me; my *Prägnanz* was in another basin. From Bartlett, 1932; reproduced in Stagner & Karwoski, 1952, p. 375, and Hilgard, 1948, p. 199.)

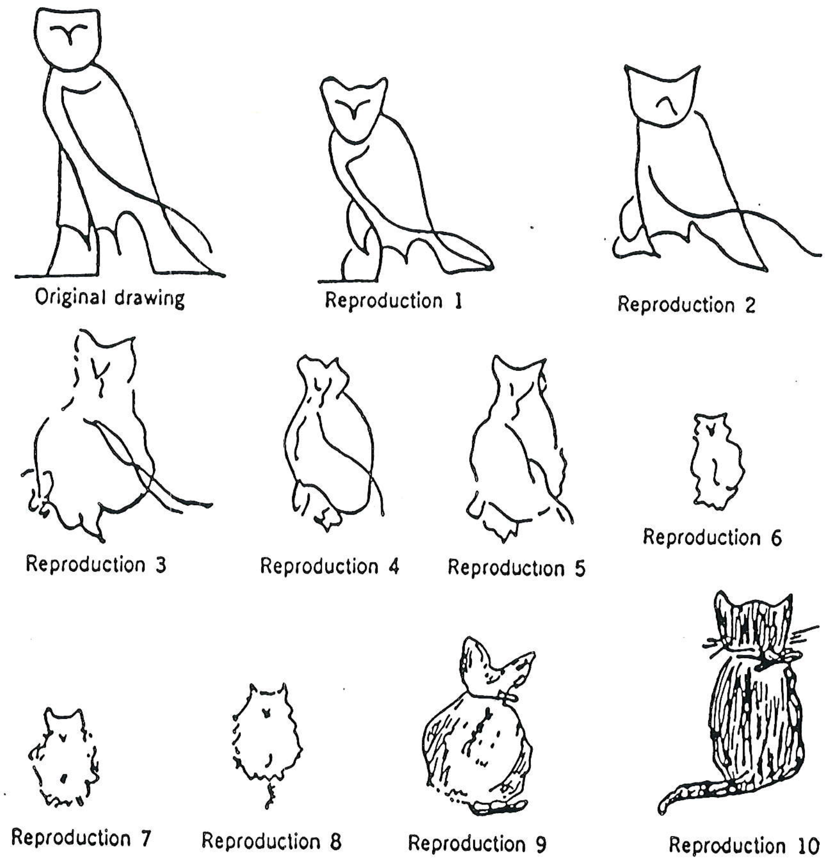


Figure 3. Bartlett's Changes in Figures with the Method of Serial Reproduction

The first cartoon is shown to one person who then draws it from memory. The resulting drawing is used as a stimulus for the next person who draws that figure from memory, and so on, through successive single drawings by different persons. Wulf had shown that any given person through successive drawings comes to a more stable figure according to the principal of *Prägnanz*. This shows what happens when a succession of different individual dynamical attempts at recall, each trying to make conceptual sense of ambiguous material, occurs. What is remarkable is that this trajectory involves a bifurcation enabling it to pass from the basin for the owl attractor to the basin for the cat attractor, becoming unstable (ambiguous, *Prägnanzstufen*) as it nears the bifurcation point, and becoming more stable after getting past the bifurcation point); there is an interplay of divergent (levelling, degradative) and convergent (sharpening, conservative) forces making for low-dimensional chaos and bifurcations.

performed experiments demonstrating dynamical factors in changes in memory over time in the Wulf tradition.

The significance of this work was noted by Hilgard:

> There is nothing to prevent association psychologists doing experiments like those of Wulf and his successors, but the suggestion that they can be done came from a consideration of factors in figural organization in perception, at the heart of gestalt theory. They therefore serve as an illustration of the way in which theory influences the kind of experiments that get performed. (Hilgard, 1948, p. 201.)

Wulf's work is also brought up here, not only for the similarities of the dynamical point of view with the Gestalt view, but even more for the similarity of their influence on research. We can take examples of contemporary dynamically driven research to show some of these similarities.

Hannah (1990) and Combs (1995) have examined mood as a chaotic attractor. The experiments were paragons of simplicity in both design and analysis. As with Wulf, independent variables other than time were lacking. Hannah and Combs both used self-rating scales to produce a single scale for mood sampled at very close time intervals for several days, and then performed simple attractor reconstruction and estimation of fractal dimension on the data to characterize mood as a low-dimensional chaotic attractor (Fig. 4). Like Wulf they used small numbers of subjects and analysis of individual results. Unlike Wulf, subjects were not free-responding, but constrained by quantitative measuring instruments focusing on a single aspect of cognitive activity. But the analysis was rather open ended, undirected by traditional forms of psychological design and analysis techniques, just an open inquiry to see what kind of picture would result; the subject painted a portrait of their mood just as Wulf's subjects painted portraits of their memory. Wulf and these contemporary psychologists all looked for information in variance that was neglected by prevailing research hegemony. Wulf by careful examination of errors in drawings, the others by dynamical analysis:

> This is one of the major contributions of chaos theory, to focus on variance and to suggest that what is often thrown away as random or error variability (assumed by the linear analysis of variance design philosophy of much of

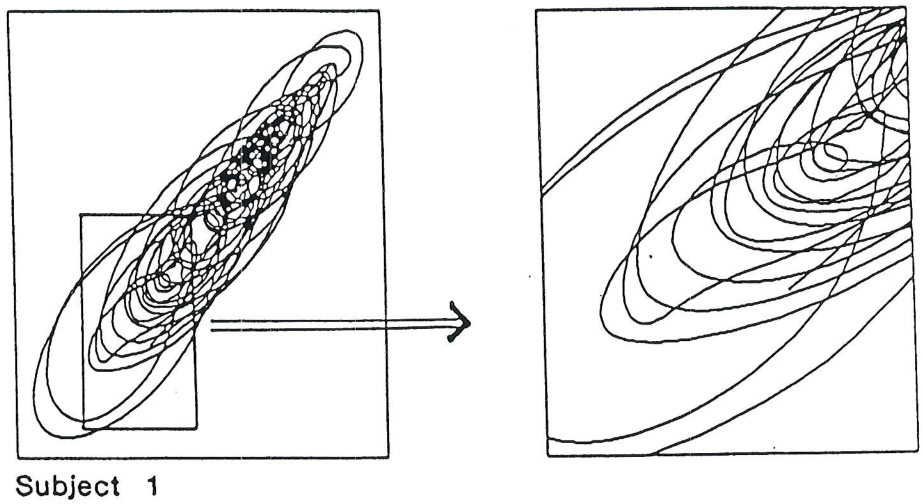


Figure 4. Mood: Attractor Reconstruction (Hannah, 1990)

our science), is, in fact, deterministic, with complex, intricate structure. (Abraham, Abraham, & Shaw, 1990, pp. III-112-113)

These contemporary studies pale by comparison to those of the Gestalt heritage, for there are few successes in understanding of the actual dynamics generating the reconstituted attractors, and attractor reconstruction and dimensional analysis are proving highly refractory to such analysis (Rapp, 1995). Multiple analysis techniques and more careful designs are just beginning to emerge which may prove more useful in psychology. Burlingame and Fuhriman are gaining insight into the group psychotherapeutic process, to wit, "the group gradually developed a stable, yet complex, nonlinear pattern of interaction that was related not only to time in the group but also to the therapeutic quality of the participant interactions." (Burlingame, Fuhriman, & Barnam, 1995, p. 102) and the Gestalt-like observation that the analysis of such complexity requires several considerations which include "the *system as a whole* and an understanding of its evolution, the *interaction* of the parts and the relationship of said *interaction* to the "evolution" of the system, . . . and *embedded patterns* of order and disorder. (ibid, p. 89).

In a study of children's categorization of ambiguous words as a function of context, Smith (1995) was able to note that the interaction of learned and unlearned forces, and of naming and attending, results in a single behavioral outcome, and that some attractors are more stable than others as evidenced by their greater compactness. Thus children, when forced to choose between ambiguous meanings, are in a process of *Prägnanz* just as Wulf observed. We adults who encounter an unfamiliar word in our reading but are too lazy to pick up a dictionary have had a similar experience. While her research design is less ideographic and more nomothetic, her analyses, like Wulf's, Hannah's, and Burlingame's, depend on innovational dynamical approaches with an emphasis on visual inspection of stability and variation in temporally geometrically organized data.

It goes without saying that besides sharing basic theoretical and research innovations, implicit in all the approaches is the self-organizational nature governing bifurcations. The control parameters of the dynamical psychological processes are in part governed by the system itself.

Predecessors of the Gestalt approach included Bretano (1874), Mach (1886), von Ehrenfels (1890) and Titchener (his core-context theory within the structuralist and associationist tradition, 1909) on the psychological side, and hermeneutics, especially Dilthey (1894) and his predecessor, Schleiermacher, on the philosophic side, to be considered later (Part IV, this series).

B. Field Theory

1. Field Dynamics

We have seen how Gestalt and contemporary dynamical approaches have shared the conceptual framework concerning multivariate interactions that form a holistic pattern and that both have shared a need to develop research programs that were essentially ideographic rather than nomothetic, and emphasized patterns evolving in time. They even shared concepts of bifurcation and self-organization, seen in Gestalt principally in the change and stability of percepts. As Gestalt matured it developed sophistications that were even more syntonic with contemporary dynamical approaches, and those developments were principally those of field theory, a topological approach developed by Lewin and his followers, most notably Judson F. Brown, Tamara Dembo, and Fritz and Grace Heider. The 1930s witnessed the emergence of major theoretical approaches in psychology, such as textural molar purposive behaviorism (Tolman and Brunswick, 1935), S-R drive-reductionist behaviorism (Hull, 1934, 1943), field theory (Lewin, 1935, 1936, 1943), and contiguity theory (Guthrie, 1935). Interestingly, despite the major battles between Gestalt-field theorists and behavior theorists, their approaches were both very dynamical; obvious in the case of the Gestalt approach, but more subtly in the case of behaviorism, as we shall see later (Part II, this series).

A major characteristic that field theory and dynamics share is their methatheoretical nature:

> Field theory is best characterized as a method: namely, a method of analyzing causal relations and of building scientific constructs (Lewin, 1943).

> Dynamical systems theory is a branch of mathematics that has evolved into a metamodeling strategy in biopsychology as well as other scientific disciplines (Abraham, Abraham, & Shaw, 1990, p. III-109).

How did the Gestalt program utilize this metamodeling strategy? First in evolving the concepts of interaction and of parts and wholes into a more definite mathematical theoretical structure, using the field concept. What is it?

> "The psychological field [*life space*] is a space construct to which descriptions of psychological behavior may be ordered. Space is a manifold in which positional relationships may be expressed. In general the manifold may be continuous or discrete, and position may be defined in terms of distance and direction as in Euclidean space or only in terms of relations as in topological space." (Brown, 1936, in 1950 p. 236)

Thus already there is the appearance of the concept of a vectorfield in a state space, and of the issue of how to deal with it when nonmetric spaces are involved. Next came the concepts of *attractors* and *repellors*, except that they used the word *goal* to indicate where the vectors pointed (toward or away from); vectors had direction and magnitude which specified a relation between organism and goal. "The behavior of an organism may be said to be directed towards a goal. The force behind the behavior may be said to have a magnitude." (ibid, p. 238) A goal could have *negative valence* (i.e, a repellor); *positive valence* (i.e., an attractor); or both (a *saddle*). Brown further mentions that Riemann (1922) "showed that the properties of a space may be dependent on the dynamics of processes within that space." (Brown, ibid, pp. 236-237)

Fields were classified as *unstructured* (no identifiable points), *structured* (discrete regions), or *infinitely structured (continuous, infinitely resolvable). For the infinitely structured space, Lewin used differential equations, which emphasizes its kinship to contemporary dynamics. In so doing, he pointed out that the vector depended only on the present moment in time. Thus* $dx/dt = f(S_t)$, that is, a change in position, x, is a function of the situation, S, at time t. Along with vectorfields came *trajectories* and *portraits.* Trajectories were called *paths* (as they often are in dynamics as well). Vectors are influenced by barriers, fluidity, and permeability within the field as well as by variables in the organism and the goal. Today, to characterize the dynamics of structured space, we would use difference equations and symbolic dynamics (stochastic trees, Markov processes, and their siblings). Paths were called *hodological space in the case of structured space.*

Brown offered an example of a psychological field (Fig. 5, ibid p. 245) for someone trying to join a club, proving a theorem, or facing some other problem. It is quite simple, with a starting position, a goal, and a couple of troublesome regions separating the two initially. Things become more interesting when we consider that the field itself is nonstationary, including to the extent of including bifurcations, even while the trajectory is progressing toward a goal (Fig. 6, Lewin, 1943, op. cit. p 307). In this respect it is quite modern, for the major forté of dynamics is the parsimonious modeling of bifurcation, the adaptability of dynamics to nonstationarity. Pushing the analogies and similarities any further runs into problems of the differences in the two approaches, which will become apparent when we attempt to

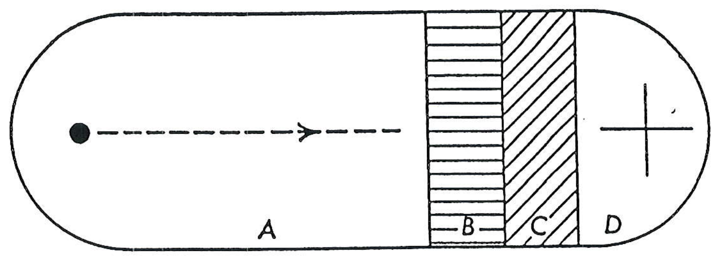


Figure 5. Psychological Field
The individual starts in region A; the goal is in region D; regions B and C are encountered during the solution to the problem. (From Brown, 1936)

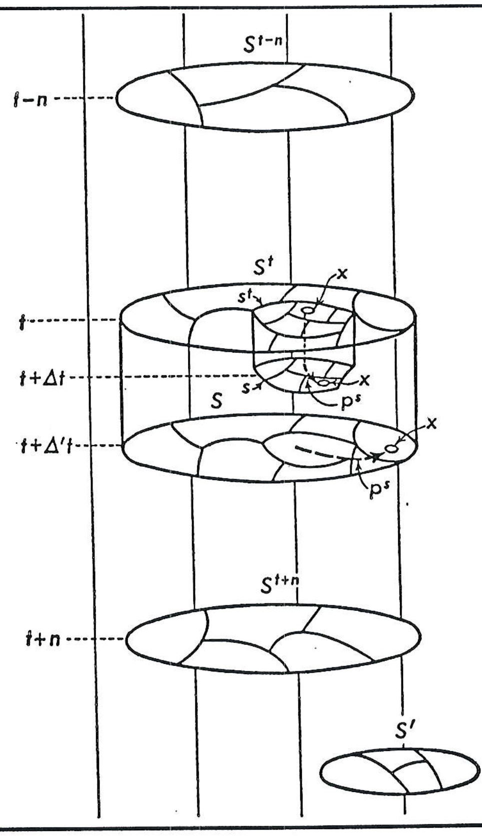


Figure ~~4~~ S during $t-n$ until $t+n$ is a "closed system"; but S is not genidentic with S'. $s^{t,t+\Delta t}$ is a small time-field-unit which extends over a relatively small area and includes the relatively small time-period t until $t+\Delta t$. $S^{t,t+\Delta' t}$ is a larger time-field-unit covering a larger area and including the longer period t until $t+\Delta' t$. p^s and p^S indicate the change in position of x during the small and large time unit.

Figure 6. Evolution of the Psychological Field
Change, p, in individual's position, x, and in the psychological field over time (progressing downward). (From Lewin, 1943)

reformulate a bit of field theory according to contemporary dynamics. Köhler (1920, 1940) also had a field-Gestalt theory that did not possess the regional topological features of Lewin's and Brown's. It did have sophisticated statements of the concept of interaction, and it did include differential equations. He was concerned with large-scale volumetric electromagnetic fields for figural perception within the nervous system which turned out to be wrong for perceptual representation, though correct in its dynamical aspect.

Space here is not sufficient to examine a majority of the other terms in field theory, nor to reconstruct this theory in terms of modern dynamics, but a miniature effort at such theory construction of a hypthetico-deductive variety might indicate some of the difficulties in undertaking such a project, and perhaps hint at some of the fruits. Before so doing, it could be of interest to mention that the debt of field theory to Poincaré is different from that with which some of us are most familiar, that is, not to his dynamics, but but to his role in the establishing the foundations of topology (Poincaré, 1895). Set theory played a role in this development, as it did in the development of hypothetico-deductive theory construction in science. Leibniz, like Poincaré, played a role in all these developments. The operational/positivistic/unification expansion in science of the 1930s probably had its strongest hypothetico-deductive following in psychology, as evidenced in drive reduction theory (Hull, 1943; Miller, 1959; Spence, 1956; and many others), stochastic learning theory (Voeks, 1954; Estes, 1959; Bush & Mosteller, 1955; Restle, 1955; and many others), and Kantor's interbehavioral psychology (1958).

Such approaches demanded that some of the terms be capable of operational definitions, and that remaining hypothetical constructs be defined by means of functional relationships to the empirically defined terms. Many critics of field theory have claimed that it failed to provide operationally definable terms, but both Lewin and Brown explicitly demand operational definition and give methods for so defining terms. For example, Lewin mentions two techniques for "defining the properties of a field at a given time", the first based on reading the history of the trajectory up to the moment (differentiating, history, anamneses), the second, based on measurement of tendencies at the contemporary moment. He favored the second.

2. Problems for Theory Reconstruction

Now we turn to consideration of an informal formalization of field theory. How to attempt it? Which approach of the many that might suggest themselves should we consider first. Most problems arise from consideration of the finite regions of the structured field case. These problems can be made more manageable by first considering the infinitely structured field case. We take this as an arbitrary initial condition of this modeling attempt.

Here is a collection of a few terms, undefined, but some capable of operational definition as the case may arise. That case arises when translated by observation or experiment into a real world situation.

Basic terms: organism, *goal*, *valence* (psychological force), *variable*, *barrier* (for parsimony, *barrier* can be eliminated by being considered synonymous to *goal*, as both terms possess the same properties of valence strength and direction), *trajectory*, *psychological state space* (*field*, *life space*), *point* (position), *vector*, and any necessary terms from dynamics, set theory, logic, algebra, calculus, analytic geometry, etc.

Assume:

Postulate 1. There exists a psychological field (state space) such that an organism at any moment is represented by a position in that space.

Postulate 2. There are goals that exert psychological forces (valences) on organisms. Variables represent the strength of those forces.

Postulate 3. The state space is comprised of those variables that represent valences for the organism.

Postulate 4. The tendency to change position in the field is given by a resultant vector of the tendencies to change simultaneously along each variable. The resultant vectors have direction and amplitude. All possible vectors of the state space comprise the vectorfield.

Postulate 5. The rules expressing the vectorfield may take the form of differential equations that express their dependence on all the variables of the state space.

Proposition. Integration of the simultaneous set of differential equations produces a trajectory over time in the psychological space for each initial position of the organism.

Example. Let there be two goals of positive valence, with variable x being a function of the distance between organism and goal, increasing with approach (approach is equivalent to a decrease in distance) to goal x and variable y similarly increasing with approach to goal y, and the rates of change of x and y be:

$$dx/dt = a - bx + x^2y - x$$

$$dy/dt = bx - x^2y$$

where a is a constant increasing the approach (that is, decreasing the distance, x, to the goal, b is a constant amplifying the effect of x, and x^2y is the nonlinear term greatly increasing x and diminishing y. These equations describe the vectorfield at all points (x,y); their integration will yield all trajectories for all points (x,y) as starting points in the field. (Brusselator model, Nicolis & Prigogine, 1984.) There is a fixed point attractor at $x = a$, $y = b/a$ if $b < a^2 + 1$, a periodic attractor when $b > a^2 + 1$, the Hopf bifurcation occurring when $b = a^2 + 1$, at which bifurcation point the portrait is an attractor-free center. When $a = 1$ and $b = 3$, the fixed point attractor is at $x = 1, y = 3$, a point that becomes a repellor when the control parameter exceeds the bifurcation point and the periodic attractor appears (Fig. 7).

This example could constitute a model for approach-approach conflict, such as deciding which of two lovers to marry, which of two candidates to vote for, or which of two vacations you will go on. However, it obviously is much oversimplified and too low-dimensional to describe any real psychological system of interest.When I first developed a nonlinear version of the approach-avoidance conflict model of Miller (Abraham et al., 1990), Loye took me into his library and showed me a paper of Lewin (1951) in which there was a similar model (this library was also the guest room and thus it took me a long time to get to sleep that night with the excitement of browsing through Lewin).

Returning now to the problem of the structured field, one solution is trivial. The variables for infinitely structured modeling are now replaced by nominal or ordinal variables and the finite mathematical equivalents mentioned are substituted. However one could conceive of an intermediate case between the structured and infinitely structured fields, where the various bounded regions within the total field have an approximately infinitely structed (that is adequately represented by variables with interval or ratio scales), so that the differential equations within each region were not exactly the same. In that case either boundary conditions would need to be set on the

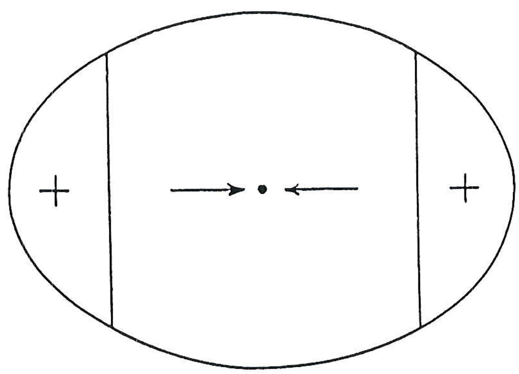


Figure 7. Psychological Field for Approach-approach Conflict Two goals both with positive valence. (After Lewin, from Stagner & Karwoski, 1952. Another figure from our former mentor at Dartmouth College, Professor Ted Karwoski.)

set of equations for each region, or control paramters would need to be identified that would define bifurcations for transitions from one region to another. That is these regions become volumes in a response diagram; regions in a self-organizational dynamical scheme or complex dynamical system.

3. Research and Action and Social Significance

There is a recent emphasis on revolutions in research in psychology brought about by sensitivity to human rights and needs. The similarity of the strategy of this research revolution to that of the dynamical program was recently emphasized in a paper on feminist psychology (Murphy & Abraham, 1995) which articulates the importance and interaction of both contextual (social) features as well as person-centered features. These approaches emphasized not only research in context, but the breakdown of the differences between the roles of subjects and experimenters even to the extent that the distinction between them lost its meaning. 'Subjects' began to participate in designing research, and experimenters took on personal and social relationships with their subjects. Similar points have been made within the context of other culturally sensitive issues of scientific research and analysis. As important as this revolution is, it is not without precedent.

With the evolution of the field-theoretic approach, the Gestalt focus on perception became broadened as the interactive factors in psychology were seen as becoming more inclusive. Field theory became the foundation for more complete personality theories (Lewin, 1935) and important developments in social psychology (Brown, 1935; Lewin, 1951; Lewin, Lippitt, & White, 1939), and contributed to the creation of the first major society in psychology devoted to social action (SPSSI, the Society for the Psychological Study of Social Issues, founded in 1936, which later became a division of the American Psychological Association).

In particular, Lewin developed what he called *action research.*

> "Action research is intended to solve problems, so that the research is tied to social action. It is usually necessary for the researcher to be deeply involved with those who are participating in the area of social action where changes in desirable directions are being sought. Only so will the results of research be used and their consequences evaluated. The emphasis [is] on field research, in actual settings rather than in the laboratory." (Hilgard, 1987, p. 587)

> "The researcher, he [Lewin] argued, has his[/her] own active life-space, as do those persons he[/she] investigates. So long as psychologists are content to observe with dispassion and passivity, what they discover will remain a worm's eye view, insulated from the significance of dedicated lives and unusable by those who act boldly upon *a priori* convictions. The challenges of real life can rarely be simulated in contrived settings and, for a whole

range of problems, the only suitable 'laboratory' must be at least a section of the real world." (Hampton-Turner, 1981, Level 5, Map 36, p. 130)

Nearly identical efforts are under way in psychology today with a renewed vigor (Crawford & Maracek, 1989; Ehrlich & Abraham, 1974; Gergen, 1988; Loye & Eisler, 1987; Murphy & Abraham, 1995). GERG (the General Evolutionary Research Group founded by Laszlo) is a small corps of dynamicists and social scientists, including Loye, dedicated to applying dynamics to the same missions of conflict reduction and other social issues (R. Abraham, 1994, 1995; Loye, 1971-1995; Loye & Eisler, 1987).

Dynamically oriented scientists are fond of criticizing the reductive/ isolationist paradigm of earlier science (the worm's eye view) in favor of the connectedness/contextual approaches empowered by the mathematical and computer developments that have enabled multivariate nonlinear simulation and analysis, but in practice these multivariate approaches are still proving exceedingly difficult to accomplish, leaving us with the intermediate study of low-dimensional nonlinear systems for the present (F. Abraham, 1993, 1995a,b; Basar, 1990; Preissl & Aertsen, 1993; Rapp, 1995).

In a final note of similarity (both theoretical and applied) of field theory to contemporary dynamics, Lewin's concept of equilibrium-tension-equilibrium of his personality theory, and later his unfreeze-change-freeze of his social theory were statements about bifurcation sequences. Dynamic equilibrium or stability is expressed by any type of attractor (including chaotic ones). Attractors destabilize near a bifurcation point, apparent in longer transients and a weakening of dampening, and are unstable at the bifurcation point. In personal growth and social change, Lewin emphasized self-organization, the importance of the system, individual or organizational, to control its own control parameters, and thus its stability and transformations. Lewin's research demonstrated that democratic decision making was more effective than autocratic (Lewin, Lippitt, & White, 1939). This research emphasized cooperative interdepence rather than competitive independence. The extent of the action approach involving Lewin in social action is evidenced by many of his activites, including his role just before WWII in getting an injunction against the Columbia University Medical School's quotas against Jews.

It is not surprising that organizational development, a principal arena of dynamics today (Guastello, 1995; Guastello, Dooley, & Goldstein, 1995; Goldstein, 1994) depends heavily on Lewin, with Goldstein especially having a compelling interest in Lewin (as well being an early President, along with Guastello and Abraham, of the Society for Chaos Theory in Psychology and the Life Sciences, an organization in which David Loye served on the founding board, 1991-1992). These arenas, dynamics, social justice, and organizations, came together in Lewin's work for the Connecticut State Inter-racial Commission where he took anti-discriminating civil leaders onto retreats where they learned that cooperative techniques helped overcome personal struggle, thus ultimately leading to social progress. Lewin's passions were undoubtedly fueled by watching his mother die in a Nazi concentration camp.

C. Post-field Perceptual Theories

There were several other theoretical approaches in which some dynamical principles also appeared. Some of these included Hebb's cell-assembly and phase sequence theory (1949), Werner and Wapner's "sensory-tonic field theory" (1949), G. Freeman's "set and motor adjustments" (1929), Tolman's molar purposive behaviorism aka "sign-gestalt" theory (1932), Helson's "adaptation-level theory" (1947), Brunswik's "probabilistic and transactional functionalism" aka "act psychology" (1943), Bruner and Postman's "directive-state theory" aka "cognitive" or "hypothesis" theory (1949), all of which, according to Allport (1955), dealt with "geometric or kinematic features of the aggregate," but these "seem to do more with the 'format' or form of assembly of the aggregate than with its dimensional or energic features." (Allport, 1955, p. 602) This sounds like he was prepared to move forward to a more dynamical theoretical position, which he did (1955, 1962).

1. Floyd Allport's Event-System Theory

Allport went the reverse route of the field theorists. He started out as a social psychologist who got curious about perception and reviewed various theories of perception very carefully and exhaustively in an influential book of the time, *Theories ofPerception* (*TP*, 1955). Finding positive and negative elements in each, he commenced some theorizing of his own, innovating as well as synthesizing elements from several of these theories, building especially upon Bruner & Postman's hypothesis theory (which in turn had a major debt to Tolman & Brunswik's purposive and probabilistic approach, 1935).

> Every act of behavior, as well as every set-stage of an act, requires two features in its descriptive model: (1) a "format" or "kinematic" aspect (geometry) of motion, connectedness, and events and (2) a "dynamic," or energic, aspect. The energy concerned, in other words, never occurs merely as a quantity or a purely scalar entity: it is always *structured (TP,*, p. 408).

We might say "vectored" rather than "structured" as that is what is meant. Like much of psychology, this quote shows that state spaces can be arbitrarily built around two classes of dimensions, those that are rather cognitively informational, and those that are primarily motivational and emotional, witness "habit strength" and "drive" in Hull's theory (1943). The dynamical representation reduces the arbitrary distinction by allowing their interaction to be defined in the portraits and attractors of theory and data. And that is exactly what Allport went on to say (though in a slightly different language).

Perception and its corresponding set (cognitive predisposition) are operations of essentially one and the same structured aggregate of physiological elements and events. With certain exceptions, the "format," or structure, of the perception and that of the set are the same thing. The passage of the set into full perception involves (1) the addition of certain items from the stimulus-object or from effector contacts with the environment, items that complete the structure, and (2) such increase of energies in the aggregate, or structure, as may be afforded by the items just mentioned. The full perception (or the behavioral act) is thus merely the completion and energic expansion of the aggregate as seen in its set-stage. (*TP*, p 418)

The perception is a stable attractor resulting from the dynamical interaction of internal sets and motivations and external stimulation, usually requiring a catastrophic bifurcation, a threshold event, for its completion.

He also talks about the sub-threshold continued life of the set dynamics:

> It has a more restricted, but still essentially the same, dynamic structure, or "format," that keeps it integrated and active, though it lacks the energic density and completeness to attain the threshold level at which the percept appears. This subthreshold operation is made possible, theoretically, by the fact that the set-perception aggregate is always regarded as a self-closed structure of ongoings and events. Continual circularity (or repetition) via proprioceptive or other circuits in the nervous or neuromuscular system gives it a certain independence of time. The set-stage of the aggregate therefore represents a kind of "storage" state of the perception or act which can later be expanded to its full energic and completeness dimensions (*TP*, p. 419)

This point of view was taken from G. L. Freeman's set theory (1929), but also posseses characteristics similar to Lashley's concepts of equipotentiality and mass-action (1929) as well. It could prove embarrassing to contemporary dynamical psychologists who think they are being original in invoking the same concept, as was done on the pages of this very journal:

> Storage may be in the shrinkage of an attractor (and that parallel neural features give it room for a nonlocalized explosive bifurcation when reactivated). (F. Abraham, 1993, p. 51)

Which was later elaborated to:

> If a process of mind is a chaotic attractor, then when it slips away from awareness to be packed away until recollected, that may well be an implosive bifurcation: it remains pretty much the same but is a greatly diminished, yet ongoing, dynamical process. Or there may be a subtle bifurcation with implosive features. The reactivation of such a memorialized attractor is the explosive counterpart. In terms of our awareness, these implosive and explosive events seem like catastrophic bifurcations, appearing and disappearing in and out of the blue, as when the whereabouts of a misplaced object suddenly reveals itself, and once put back in our pocket, is forgotten. Of course, as much of depth and dynamical psychology has stressed, there may be quite a life to the continued dynamics of the processes of these attractors while they are hidden from awareness. (F. Abraham, 1994, p. 92)

J. Skinner et al. (1990) and W. Freeman (1990, 1995a,b) have promoted similar concepts.

Allport then used difference equations to show how the internal set was changed from moment to moment in the presence of external stimulation:

$E_n = E_{n\text{-}1} + E_i$ or

$E_p = E_s + E_d$

where E_n is the perceptual aggregate-set at time *n*, and E_i is the external input; E_p is the percept, E_s the set-aggregate (one might say internal cognitive proto-percept, and E_d the same as E_i, *TP*, p. 421). In doing this he invokes concepts of nonlinearity, bifurcation, and self-organization, saying that if any manifold were linear, little could be said about the process, but that if there were reverberating afferent-efferent circuits then the energies and contributions of the parts could be evaluated. (*TP*, p. 420)

When he says "ongoings and events are the elements that make up the geometry of dynamic structure" (*TP*, p. 616), he implies that "ongoings" are continuous activity endogenous to particular dimensions of the state space, and that "events" are the points of contact, i.e., the interaction between the dimensions, and thus the "dynamic structure" is the trajectory resulting from the process.

He provides a description of a trajectory, albeit only for the periodic case, for which, all things considered, it is easy to forgive him:

> Think of a series as always coming back upon itself and completing a cycle. In order to visualize the situation let us think of a thin wire hoop, cable of being bent in any direction or shape, but always remaining a hoop, upon which are placed, at intervals, a number of cross-marks (*TP*, p. 634)

He even describes complex higher-order trajectories comprised of simpler ones developing the property of "*order*" (*TP*, p. 636).

At this point in his thinking, it is clear that he did not think that metric solutions would be forthcoming for all types of psychological laws (some yes), though he had the vision to propose patterned solutions:

> This latter type of law requires some terms other than those of quantity or dimension for its statement, . . . [but] by some kind of kinematic or geometric paradigm. The elementary principle of such a model will not be equations

> relating measured variables of conditions, forces, or outcomes, put type-patternings of ongoings and events (*TP*, p. 621)

Today that might mean symbolic dynamics for discrete processes. He separates these (continuous versus discrete) because he sees discontinuities, especially in threshold phenomenon. Because the concept of bifurcation arising from dynamics within continuous processes was not available to him, he found recourse in invoking discontinuous and probabilistic processes. Of course we still need discontinuous dynamics not to explain bifurcations, as implied by Allport, but simply because so many psychological dimensions can only be dealt with as discrete (nominal and ordinal scales). But he does describe what we could call bifurcation:

> There must be something else. Could we not infer, as a working hypothesis, that this "something else" is a structural law, or set of laws, that always works along with quantitative laws and yet is, in itself, distinct from them? If we could discover, for example, some principle by which the elements of the perceptual aggregate suddenly "come together" in a characteristic structure without entangling our explanation in dimensions and quantities, we would then be achieving a solution of our problem. Vagueness, however, will not help (*TP*, p. 631)

In discussing the emergence of order and stable perceptions and complex trajectories comprised of what he calls "*c* lays", "*n* lays", and "*r* lays", bifurcations are clearly self-organizational, resulting from feedback among the components (*TP*, p. 636), and occur despite some randomness within the system. As the "density of encounters" (of interactions within the system) increases, the "effect appears rather suddenly" (*TP*, p. 642).

He also seems to anticipate the unpredictability that accompanies *sensitivity to initial conditions* when he asks, "How can the mechanical laws account for this pattern type of prediction in which event-points in space and time do not stay put in successive repetitions of the same act, and variability is part of the act itself?" (*TP*, p. 626) How incredible! How well he states the emphasis, mentioned earlier, that many have noted about the limitations of the linear design and analysis techniques of psychology which lump both within and between subject variability into a noisy error term, throwing away much of this temporal structure.

This emphasis on variability and predictability provides a natural transition to the probabalistic concerns of Brunswik, to which we now briefly turn.

2. Brunswik's Probabilistic Functionalism

During the 1930s there was a great ferment of activity as positivism approached its apex with the unification of science movement (Neurath, Carnap, & Morris, 1938). Some of the major themes of that movement, besides the settling of some operational tenets of the philosophy of science, included a focus on the potential for generality and unity provided by (a) set theory, (b) the hypothetico-deductive construction of scientific theories, (c) linguistics and the use of language conventions in science, and (d) probability theory. While the use of probability existed in psychology in descriptive and inferential statistics for some time, it had not entered significantly into psychological theory until Brunswik, one of the main participants from psychology (along with Boring, Dewey, Fraenkel-Brunswik, Hull, Israel, Lewin, Pratt, Skinner, and Stevens) in the unification circle, made it so (1934, 1939, 1947, 1955).

Probabilistic functionalism was not particularly dynamical technically, but it shares a couple of features with psychological dynamics that are worthy of mention.

Uncertainty among environmental relationships which limited their "ecological validity" on both the input and output sides of the organism, were matched by internal probabilistic functioning within the organism (Brunswik, 1955, p. 680). In fact, this matching could be quite close and observed directly. Brunswik was the first to perform a probability matching experiment (1939), which later provided one of the first major experimental foundations for stochastic learning theories (Estes & Straughan, 1954). Probabilities of reward at two goal arms in a T-maze were matched by response probabilities of rats, despite the fact that optimal performance would have been achieved by consistently (100%) choosing the arm with the higher pay-off. Statistics were in the beast, not in the limitations of research:

> "It must be stressed once more that the probabilistic character of behavioral laws is not primarily due to limitations in the researcher and his means of

approach but rather to imperfections inherent in the potentialities of adjustment on the part of the behaving organism living in a semi-chaotic environmental medium." (Brunswik, 1955, herinafter, *B*, p. 686)

For this process, he constructed a "lens model of stabilized functional units" mediating between environment and behavior (*B*, Fig. 8, p. 678), a terminology not unnoticed by the holographically inspired (Pribram, 1990), and originally attributable to Heider (1927, 1930), and then used by Brunswik (1934). Purposive behavior was governed by a pattern in a process with two main features: stability of the final behavior, or "terminal focus" or "stabilized achievement", and the diversity of the process leading up to that stabilization, or "vicarious functioning" or "vicarious mediation", terms that suggest a sort of cognitive trial-and error and creative blending. Vicarious functioning and related ideas were topics not new to Brunswik (Hobhouse, 1926; Holt, 1915; Hunter, 1932; Meyer, 1921). He also noted that these ideas were inherent in Tolman's (1932) operational definition of "purposiveness" as "persistence through trial-and-error, and docility, relative to some end" and in Hull's concept of "habit-family-hierarchy" (1934, 1943). These ideas also seem not so different from those of the Gestalt *Prägnanz* we visited earlier. The term "blending" is borrowed from Mpitsos (1990), a behavioral neurobiologist, who used it to describe the combining of different aspects from the limited behavioral repertoire of a marine mollusk into novel

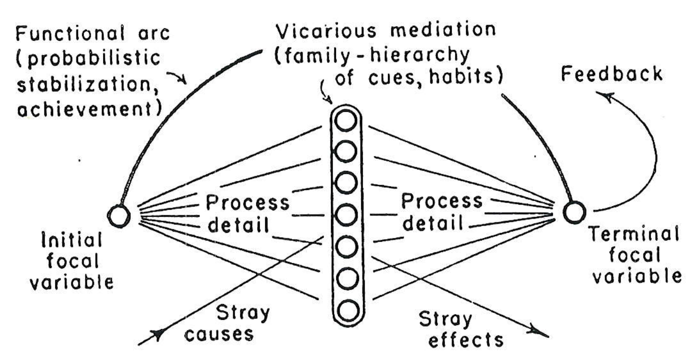


Figure 8. Brunswik's Lens Model

patterns, thus expressing another similarity between historical and modern dynamical behavioral analysis. Vicarious functioning is brought up here, not so much to have another example of a kind of self-organizational dynamical bifurcation to a stable attractor (though one cannot restrain oneself from making the observation), as to where these speculations led Brunswik.

Where they led him is yet another story of the close interactive relationship between theory and research. Like the other major participants in historical dynamics, his probabilistic and transactional functional theorizing drove him to revolutionary approaches in research, much along the same lines as Lewin's and much of modern dynamical psychological research.

> In controlling vicarious mediation, care must be exercised not to interfere with naturally established mediation patterns. These aspects of mediation must therefore be controlled "passively," that is, be studied in a permissive laissez faire manner with respect to their free dynamic flow; there must be deliberate neglect of "active" control at least up to a certain point, despite the fact that the conditions involved either are definitely known to be relevant or are at least potential mediators bridging the gap from one focus to another. In particular, mediation must not be "channeled" by allowing, say, only one of the many perceptual distance cues to function, or by providing only one path to the goal, as was the case in earlier phases of experimental psychology. Channeling of mediation leaves no room for vicarious functioning; in consequence the entire relief of focal versus nonfocal variables or regions is obscured. (*B*, pp. 684-685)

Brunswik therefore felt that the complexity of vicarious functioning required study under conditions of "normalcy, naturalness, 'closeness to life' (*Lebensnähe*), or, with a more methodological slant, that of 'situational representativeness'" which he also called "the representative design of experiments" (*B*, p. 687 & 1947). These were not as radical an approach as Lewin's action research, but nonetheless represented a considerable liberalization in research methodology.

> Brunswik points out that just as psychometricians attempt to select subjects who are representative of the populations they investigate, so experimentalists should select environmental features and responses representative of the surrounds and actions, respectively, of the individuals they study. If a research project is representative in the Brunswikian sense, one may reasonably argue that it deals with a natural system worthy of investigation and

modeling (we may even get a glimpse of the whole elephant) (Gilgen, 1995a, p. xvi).

As an example, he performed an experiment on size constancy, a type of study that had been studied under the strictest controlled laboratory conditions up to that time, a *sina qua non* of structuralist research.

> Correlations of .95 and over—high for differential psychology but probably not uncommon for functional stabilization mechanisms—were obtained between measured distal object sizes and their perceptual estimates in a representative sample of daily-life situations involving a wide variety of sizes and distances; correlations of the estimates with proximal (retinal) image sizes were low by comparison (*B*, p. 688).

A contemporary example of the dynamical field study of cognition is that of Gentry, who had students point to remembered campus locations. He then analyzed the fractal nature of the maps of their responses (fractal structures are also the result of dynamical processes) (Gentry, 1995; Gentry & Wakefield, 1991).

Brunswik shared von Mises' (1939) disdain for the applicability of differential equations except for the most constrained aspects of physics. Psychology did not fully embrace difference equations until Goldberg (1958), despite their earlier development by Boole (1872) and Milne-Thomson (1933), and the stochastic learning theorists of the 1950s (to be taken up in Part II). However, the probabilistic approach, especially stemming from the probability matching experiment of 1939, led to the emphasis on sequential analysis of individual response sequences (Miller & Frick, 1949; Voeks, 1954), again emphasizing the close relationship between innovation in research and thoery, and sharing with contemporary dynamics the emphasis on the temporal organization of behavior and cognition.

We leave for later consideration (part II, this series) the fact that by the 1950s Brunswik was quoting von Bertalanffy (1950), in turn influenced by Köhler, (1924, 1927), Prigogine (1947), and Hill (1930, 1936), and others, on general systems concepts: open systems under self-regulation acheiving dynamic equilibrium (stability) far from static equlibrium (fixed point attractors) evolving toward greater complexity. These ideas are often confused by some dynamical psychologists today; Rosen (1970, 1978, 1985) provides some of the best clarifications of these ideas for the life sciences.

To summarize, Brunswik's probablistic approach was not as explicitly dynamical as those we have previously considered, but it shared (a) an emphasis on multidimensionality of cognition, (b) a fluidity and flexibility, (c) an unstable-to-stable bifurcational character, and (d) a need of more complex experimental designs to enable complexity to emerge, to say nothing of the probablisitic nature of sequential behavior, a feature that in practice, is a hallmark of even the most deterministic dynamics, especially in 'molar' psychological and social research.

3. Ecological Psychology (Gibson), Event Perception (Johansson), Kinematic Specification of Dynamics (Runeson), and the Ecological Study of Perception and Action (Turvey et al.):

Gibson completed 50 years (1929-1979) of publishing research and theory in perception with his remarkable book, *The Ecological Approach to Visual Perception* (*EA*). In a sense, he reverses the historical process we have observed so far, that of a process theory giving rise to innovational research designs, in that he seems to say that previous research has been wrong in using the snapshot approach of attempting to analyze responses to briefly (tachistoscopically) presented stimuli.

> Is the tachistoscope an achievement? It seems to me to be a calamity. Far from reducing visual experience to its its simplest form, it prevents the visual system from operating normally (Gibson, 1985, p. 228).

In fact the first work (other than his own) that he cites in this book is Brunswik's book on the representational design of experiments (*EA*, p. 3), though he was uninterested in probabilistic aspects. He too emphasized that the study of perception should be as it is in the real world, his first study of this nature being a field study of automobile driving (Gibson & Crooks, 1938). Of course, the emphasis on research is completely intertwined with the conceptual view of the perceptual process. An aspect of this process can be seen in his definition of stimulation:

> We do not perceive stimuli. . . . A stimulus in this strict meaning [of physics and physiology] carries no information about its source in the world; that is, it does not specify its source. Only stimulation that comes in a structured array, and that changes over time specifies its external source" (*EA*, pp. 55-56).

His emphasis was on the complexity of the surfaces of the environment and its properties of both persistence and change. He felt that the abstractions of mathematics and physics, e.g., geometry and Kepler's model of optics and vision were too simple to depict these complexities (*EA*, pp. 32, 33, 59).

There is little need to cover his views in detail here because they are not yet historical nor directly dynamical, except in the sense that the conceptual view is a systems approach which emphasizes the interactive and natural flow of ongoing environmental and organismic processes. To say his views are not historical is to recognize that unlike the previous theories mentioned herein, which are of interest because of the similarity of historical ideas to contemporary ones, Gibson's have directly proved an inspiration to one of the most active and explicit areas of contemporary dynamical psychological research, that of perception-action, which has made Gibson's ideas well known. If one is to think of Gibson as historical, then it must be rather as a sort of last link in the liberalization of views on perception that empowered the mathematical development of the perception-action group who combined the ecological influences of Gibson and Johansson with the synergetics of Haken (1983). Gibson names Rob Shaw and Michael Turvey of the Center for the Ecological Study of Perception and Action at the University of Connecticut as successors, to which must be added Scott Kelso of the Center for Complex Systems at Florida Atlantic University, Bill Warren at Brown University, and Peter Kugler, Center for Brain Research and Communication Science, Radford University, and of course their many colleagues. Runeson at the University of Upssala is a contemporary successor to Johansson.

Vision is a perceptual system with constant feedback; adjustments by the eye continually alter retinal inputs during which the "eye-head-brain-body system registers the invariants of the structure of ambient light" (*EA*, p. 61). He rejects the Shannon information theoretic transmission of bits of information, "There is no sender outside the head and no receiver inside the the head", it is wrong to think of vision as optical instruments, or of the retinal image as being transmitted to the brain (*EA*, p. 64). Optical information is extracted from a "flowing optic array" (*EA*, p. 63).

Shaw reiterates this theme of continual process to avoid the infinite regression of homunculi as perceivers in the brain, for scientific theorizing as well as perceptual phenomena (Shaw & Pittenger, 1978).

Gibson continues:

> The ecological approach to visual perception . . . begins with the flowing array of the observer who walks from one vista to another, moves around an object of interest, and can approach it for scrutiny, thus extracting the invariants that underlie the changing perspective structure and seeing the connections between hidden and unhidden surfaces." To the extent that mobility is constrained and made more passive, hallmarks of reductionist research, the invariants are weakened and ambiguities are strengthened (*EA*, p. 303).

Ecological significance is "afforded" animals by the environment and its usefulness, and these imply values and meanings of things in the environment (*EA*, p. 127).

The search for invariants, in perception among the dynamic interplay between organism and environment, and in the science of psychology among the interplay between theory and research, is well captured by Bingham using dynamical language:

> How can we discover and describe nonambiguous, unique relations between local structure and global structure that enable us to recognize what is happening despite the specifically restricted nature of our observations. (Bingham, 1987, p. 13)?

To search for these invariants, theory and research must attempt a certain amount of dimensional reduction from the complex nature of the environment and the complexity of the organism moving in it. Thus Gibson's ecological dynamical concepts led to a great deal of research which combined field study and laboratory study with complications incorporating features of real-life complexity. He did a field study (literally a field, estimating the height of a distant stake in a plowed field) of size constancy (published the same year as Brunswik's, 1947; see *EA*, p. 160). In an interesting experimental variation, observers bisected distant lengths in a field by controlling a mobile cart (Purdy & E. J. Gibson, 1955), where the invariant was "equal amounts of texture for equal amounts of terrain" (*EA*, pp. 161-162). Carello (1987) has summarized the relevance of this research to Gibson's point about the importance of invariant features of a complex environment not being transmitted in a static photocopy manner:

> His early explorations of texture gradients established an important strategy for describing optical information: there must be a mapping between properties of the environment and optimal structure. The key to the mapping is to understand that properties of the environment (and animal-environmental relationship) can be specified without being copied. (Carello, 1987, p. 15).

In studies of kinetic depth effects (Brown & Voth, 1937, and some of Wertheimer's studies of phi-phenomena; see also Korte, 1915; see also studies in which depth is created by movement, Metzger, 1924; Wallach & O'Connell, 1953) "looming" with a rapidly expanding spot on a large nearby screen is treated as an impending collision by the observer (Schiff, Caviness, & Gibson, 1962; *EA*, pp. 175-176). Perhaps the best known experiments are those of Eleanor Gibson (James Gibson, in his preface affectionately states "Any errors in this book that remain are her fault as much as mine" EA, p. xiv) on the glass floor and the visual cliff with infants and kittens (Gibson & Walk, 1960) which emphasize the importance of an *affordance*, a safe versus an unsafe place for the animal (*EA*, pp. 156-157). Visual kinesis experiments (*EA*, pp. 185-187) with gliding rooms and body motions were also important, and at the time of the writing of the book, he was able to state that unfortunately there were not many experiments on visual kinesis of the limbs and hands (*EA*, p. 187). However, this is now an area of intense study by contemporary ecological dynamicists (haptic studies by Turvey's and Kelso's groups, see below).

Johansson's early studies showed that coherent motion of several dots could be perceived as motion of an object in depth (1950); that is they created the perception of an event property ("event" here is dynamical, as with

Allport's "event structure"). In later experiments (1973) these coherent dots were created by mimes wearing 12 patch-lights on their limbs creating "point-light people". These moving configurations were not only perceived as people, but the activities (bicycle riding, stair climbing, dancing, etc.) and other features (gender, fatigue, weight being carried) could be identified almost as well as fully illuminated mimes. Runeson & Frykholm (1981) similarly had people judge weights, not by lifting them, but by observing others lifting them. Johansson (1973, 1976) applied vector calculus to the analysis of such perception and concluded "that trajectories provide perceptual information about events" (Bingham, 1977, p. 4). Bingham argues that these were geometric and kinematic but not dynamic (motion of the observer being required for a full dynamical analysis). He also argues that Runeson also left a critical variable out in describing the dynamics in terms of length and time, but not mass, that is the experience of haptic motion, in his Kinematic Specification of Dynamics theory (Runeson, 1977; Runeson & Frykholm, 1981, 1983). A more complete dynamical description using

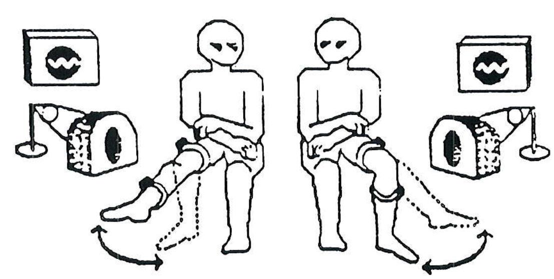


Figure 9. Visual Coupling of Biological Oscillators

If two people each oscillate a limb and try to keep it out of phase while watching the other person's limb, then this visual coupling would exhibit the same characteristics as the haptic coupling, namely, critical fluctuations should precede an hysterietic phase transition to in-phase corrdination as speed of osciallation is increased (Schmidt, Carello, & Turvey, 1987).

vectorfields and vector calculus is provided by Koenderink and van Doorn (Koenderink, 1986; Koenderink & Doorn, 1975, 1978) in which motion through the environment is taken from the observer's point of view (see Growney, 1987). Other relevant experiments are the haptic estimation of length of a rod from shaking it without seeing it, which revealed that inertia was the critical variable (Solomon & Turvey, 1987; Turvey, 1994), and the experiments of Carello (1987) in which subjects estimated the order of distance three balls could be thrown, from (a) geometric information, that is looking at them, (b) kinematic information, watching someone throwing them (without seeing how far they actually went), and (c) from throwing them at targets. Metric judgments as well as ordinal ones were quite accurate, even in instances in which no calibrating information was available.

The production of speech and sound is one that involves auditory and motor motion, and constitutes another area of research interest. For example assume a method of limits study, gradually changing a vowel sound from /o/ to /u/ or a cello sound changing from plucked to bowed through control of the attack rise time, using the cross modality influence of the sight of the sound being produced as a control parameter (McGurk & McDonald, 1976). Thus a listener "is attuned to the acoustic/visual information that specifies a particular sort of event" (Rosenblum, 1987, p. 27).

One might think that these experiments, in which apparently continuous variables of time and space are generally employed, would obviate the problems mentioned earlier of the difficulty of establishing a metric manifold in psychology (problems when there are not such nice continuous variables as interval and ratio scales). It might seem that these experiments should yield readily to dynamical analysis. But it should be apparent from Gibson's description of the ecological environment that there are great discontinuities within the visual field, and that movement of the environment and the observer involves changes in scale as well as other discontinuities, as in the collision experiment. The problems of estimating differential equations from trajectories (solutions to differential equations) are nicely characterized by Bingham (1987, Part I) as a problem in "inverse dynamics", citing several mathematical authors from 1967-1985. Bingham's main theoretical discussion (1987, Part III) raises the scaling issue, and the issue of expanding manifolds (such as represented by the mathematical analysis of Marmo, Saletan, Simoni, & Vitali, 1985) with experimental explorations. He suggests that the psychologists' modeling of the ecological or event perceptual variety, supplies the framework of the answer, deals with discontinuities, missing metrics, changing scales, and other roughness in perceiving (both scientific and ordinary), and confronts the complexity of the real dynamics. Shaw and Kugler have dealt with these issues as well (Kugler, Shaw, Vincente, & Kinsella-Shaw, 1990; Shaw & Pettinger, 1987; Warren & Shaw, 1985) in excellent analyses of these perceptual systems as intentional systems.

D. Epilogue

Today the unification of psychology movement (Gilgen, 1971, 1987; Staats, 1987) is greatly enhanced by the power of the metamodeling strategy and the visual communicability of dynamics and its account of bifurcation and chaos (Abraham, 1995a,b; Abraham et al., 1990; Gilgen, 1995b; Tryon, 1995). Dynamics could be added to the list of major tools with which the unification of science movement has concerned itself (at the beginning of section B2 on Brunswik). The history of psychology itself could be viewed as a chaotic attractor, with periods of higher-dimensional, more fragmented, and idiosyncratic proliferation of languages and theories, alternating with periods of lower-dimensional, more coherent hegemonies of perhaps too few theories (even if there were disagreements among them). Unification does not expect a single unified theory of everything; it seeks a balance of unity in language and communication, and a great deal of innovation and divergence of theory and research. The unification movement shared with Lewin and contemporary dynamics the desire to apply science to social advancement (Neurath, 1938). (This aspect is to be considered further in Part IV, this series). We have confidence that dynamics will play an important role in the development of the scientific attractor.

The historical thread that we have considered so far, the Gestalt to Ecological thread, is a very interesting one. Examination of it has revealed that:

- Dynamical concepts were explicitly woven into the historical fabric to a greater extent than we may have realized, and even when not reasonably explicit, were rather pervasive.
- The thread has had contact with many others, such as general systems theory (you may have noticed the reference to open systems in Lewin, Fig. 6; there was much in Allport and Brunswik, and in fact most of Psycholgy since the 30s even though often not explicitly recognized). Some other threads include information theory, artificial intelligence, neural nets, neuroscience, and behavioral theory (to be taken up in Part II, this series), and contemporary dynamics of the Poincaré-Thom lineage (to be taken up in Pat III, this series). Contemporary dynamics formally entered psychology rather recently, in the applications of catastrophe theory by Zeeman (1977), which we see reflected in ecological psychology.
- Its contemporary impact is now virtually in all areas of psychology (Gilgen & Abraham, 1995), and perhaps most mature in the efforts of reseach on perceiving-acting ecological psychology (*Paw Review*, 1987, see note, end of references) and neuophysiology (Abraham, 1993; Basar, 1990; Freeman, 1995a,b). The visual geometric language of dynamics, as represented by R. Abraham is brought into psychology by several people, as evidenced by our introductory text (Abraham et al., 1990; reviewed by Loye, 1991).
- While not a great deal of technical advancement might be achieved by re-examination of past efforts, nonetheless some important theoretical ideas and research could might be gleaned that could prove of value today.
- Beyond the delight of continual discovery, examination of the historical fabric of psychology reveals not merely a few important dynamical threads, but reveals that the warp and woof of psychology has been, in fact, primarily dynamical in nature.
- The mathematical attempts by Köhler, Lewin, and Brown in field theory did not really take hold, as prophetic as they may have been, partly because they were never really formalized in detail to the point of being testable and therefore strongly verified (Abraham, 1995), although the more general features of these theories were often sufficiently verified to give support to the general trend of this theorizing. This thread set the stage for the breakthrough, the bifurcation, represented by the dynamical efforts of Johansson and the contemporary ecological approach to attention and perception.
- One of the main lessons, if there are any, is to see the limitations and problems that we will have to face in making the dynamical fabric pliable enough to be worn by future psychology. Can mixed equation sets be modeled in which both continuous and finite variables, and probabilistic and deter-

ministic components, be accommodated together? Can different metrics be accommodated, and can rapidly changing scales of observation be included? Can bifurcation concepts be adapted to these demands? Can the limitations of the empirical methods of estimating dynamical properties of research data be overcome by discovering new techniques? Can new methods of modeling from data be found, and can the repertoire of models, the tool boxes that current mathematics offer us be supplemented by a greater variety? Applied mathematicians have developed solutions for these problems for quite some time (Ralph Abraham, personal communication), but their adaptability to psychological spaces and their further development, will require considerable continued effort. There are interesting challenges ahead.

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