W. Tschacher   G. Schiepek   E. J. Brunner (Eds.)

Self-Organization
and Clinical Psychology

Empirical Approaches
to Synergetics in Psychology

With 156 Figures

Dr. Wolfgang Tschacher
Sozialpsychiatrische Universitätsklinik, Murtenstraße 21
CH-3010 Bern, Switzerland

Priv.-Doz. Dr. Günter Schiepek
Lehrstuhl für Klinische Psychologie
Universität Bamberg, Markusplatz 3
W-8600 Bamberg, Fed. Rep. of Germany

Professor Dr. Ewald Johannes Brunner
Universität Tübingen, Institut für Erziehungswissenschaft I
Münzgasse 22–30, W-7400 Tübingen 1, Fed. Rep. of Germany

Series Editor:
Professor Dr. Dr. h. c. Hermann Haken
Institut für Theoretische Physik und Synergetik der Universität Stuttgart
Pfaffenwaldring 57/IV, W-7000 Stuttgart 80, Fed. Rep. of Germany and
Center for Complex Systems, Florida Atlantic University
Boca Raton, FL 33431, USA

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Self-Organization in Social Groups

Wolfgang Tschacher, Ewald Johannes Brunner, and Günter Schiepek

With 8 Figures

Abstract. A systemic approach to group dynamics is discussed on the basis of self-organization theory. Groups are conceived of as nonlinear systems characterized by microscopic complexity, circular causality and openness to their psycho-social environments. One possible way of research on group patterns through recursive sculpturing is described; pilot study results with this method are presented. A computational shell for the simulation of social distance regulation is introduced which models attributes of group dynamics by showing different kinds of homeostatic behavior. Finally, consequences of the self-organizational view for the field of management and organizational theory are discussed. Options and restrictions of indirect evolutionary management are inferred from synergetics and recent trends in organizational development.

In the field of psychology a systemic viewpoint may look back upon a long tradition of theories that have been designed in a holistic or Gestalt fashion. Lately, systemic therapy, in particular, has deviated from the conventional personality-oriented thinking and has contributed to call attention to the systemic character of social interaction. In the past years systemic thinking has proved valuable in many clinical areas (family therapy, working with groups in supervision, training, or therapy), whereas the empirical foundations of this field remained insufficient (Wynne, 1988). In this context the concept of *psychological synergetics* turns out to be an innovative way of connecting a systemic approach to clinical practice empirically (Tschacher, 1990; Schiepek, 1991).

Self-organizing systems have been studied extensively in the field of the natural sciences; yet phenomena of self-organization can be observed in the field of psychology and social sciences as well. We expect that a broadened perspective may be gained for these disciplines by new methods and by the interdisciplinary approach of dynamical science.

1. Systems Phenomena in Groups

A systems approach to group dynamics has been applied on various occasions. It is an established point of view among social psychologists that group processes have their own characteristics. A group is not supposed to simply consist of the sum of the characteristics of its members. Group processes are to be regarded as functioning on a higher level of emergence. Lewin (1947) pointed out that there was "no more magic behind the fact that groups have properties of their own,

which are different from the properties of their subgroups or their individual members, than behind the fact that molecules have properties, which are different from the properties of the atoms or ions of which they are composed." Everyday language calls our attention to this fact; for example a group is said to be in a state of a "tense atmosphere"; or, "there's a good climate in the office".

Social psychologists have described many group phenomena of this kind. Examples range from the formation of group rules and norms to the extreme behavior pattern of "group think" (Janis, 1972). We also consider the development of informal groups or "cliques" to be an emergent feature of human interaction: cliques are found in all organizations – they evolve spontaneously and act seemingly independent of official structures. Informal groups have important functions for the emotional well-being of individuals in organizations (see Sect. 5.1).

A further example can be found in the stages of group decision. According to Bales & Strodtbeck (1951), during interaction, groups tend to shift from a relative emphasis upon problems of orientation, to problems of evaluation, and subsequently to problems of control. Group parameters can thus be characterized as "stationary" over certain periods of time.

Family therapists are concerned with systems processes in "natural" groups. The family system is described by a specific pattern of communication. "It is the rigid, repetitive sequence of a narrow range that defines pathology", as Haley (1976, p. 105) puts it for the case of dysfunctional interaction. Thus, family therapists strive to identify and change these communication patterns rather than individual traits or problems.

2. Towards a Systemic Theory of Group Psychology

As has been indicated, in social psychology a strong emphasis is given to the study of group phenomena. Many theorists in the field of social psychology use a systems perspective in order to describe group processes and group structures. This may be illustrated by a few examples of theoretical approaches.

A group is not merely a collection of individuals. In forming a group two or more individuals – through social interaction – depend on one another to play distinctive roles in the pursuit of common interests or goals (Lambert & Lambert, 1964). The goal-directedness which often is part of the definition of groups is connected with the fact that groups normally develop different positions for their members. Bales & Slater (1955) have shown that there is strong evidence for the natural development of role differentiation in face-to-face groups. The authors postulated for example that "the appearance of a differentiation between a person who symbolizes the demands of task accomplishment and a person who symbolizes the demands of social and emotional needs is implicit in the very existence of a social system responsive to an environment. Any such system has both an 'inside' and an 'outside' aspect and a need to build a common culture which deals with both" (Bales & Slater, 1955, p. 303).

This process of differentiation is – formally speaking – "the division of a unit or structure in a social system into two or more units or structures that differ in their characteristics and functional significance for the system" (Parsons, 1971, p. 26).

There are two ways of designing a theory for this group phenomenon; both can be related to a systems approach:

a) Groups as interaction systems. According to Bales & Cohen (1979) the theory of role differentiation can be based upon the interaction theory of small groups. The authors refer to Homans (1961) who emphasizes the exchange character of social interactions by stating that the behavior of persons in a group is related in mutual contingency and that the dynamics of this pattern can be described as circular.

Homans' analysis of interactional behavior fits quite well with systemic assumptions. First of all a social group is considered to consist of elements related in a system. Here we can refer to Hall & Fagen's definition of system ("A system is a set of objects together with the relationships between the objects and between their attributes"; Hall & Fagen, 1956, p. 18). A central point is what the "objects" of a group system might be – are they persons or are they elements of the (inter-) action of persons? Like most theorists, Miller (1978, p. 515) postulates that "the components of groups are animals – human and subhuman". According to Luhmann (1984), however, the components of a social system are the single communicative acts.

Secondly, the character of interaction in the sense of Homans is obviously circular. The basic principle underlying communicative activity is *feedback*, the process by which a system informs its component parts how to relate to one another and to the external environment in order to facilitate the correct or beneficial execution of certain system functions.

b) Cybernetic approaches to groups. The concept of feedback is the second possible way of designing a (systemic) theory of group interaction. As mentioned above, groups are considered to be purposive and goal-seeking systems. The recursive character of interaction dynamics is realized by positive and negative feedback loops. Groups are thus conceived of as information-processing systems in which feedback processes maintain the effectiveness of the groups. "When conditions are favorable and the operations are effective, the group not only survives but becomes capable of monitoring itself, altering its direction, determining its own history and learning how to learn to determine its history with the consequence that it accumulates and expands its capabilities or grows" (Mills, 1967, p. 19).

These cybernetic processes can be understood as self-organized. Groups, like all social systems, are not only open systems but also organizationally complex. The postulate of circular feedback processes, and of organizational complexity of group interactions leads us directly to the concept of groups as self-organized systems.

3. Self-Organization Theory as a Framework for Group Psychology

In this section, we will connect group phenomena – like the ones described above – to self-organization theory.

3.1 Prerequisites for Self-Organization

In order to prepare for our enterprise of modeling groups as complex systems, the following general prerequisites for self-organization must be considered.

The concept of self-organization can be applied in a meaningful way only to systems which contain very many (micro-) components; these serve as the potential building-blocks for the assembly of structure and organization. Components are in interaction with one another depending on the system's level of connectivity. From basic thermodynamical considerations we expect that given states of order (assymmetries) will dissolve with time; insofar, all evolution should be *dis*organization and follow the gradient of entropy. The result of such dynamics is a state of maximum symmetry in regard to the localization and behavior of components. This is essentially a statistical argument: all states – ordered or disordered – of a multicomponent system are equally probable in the absence of specific control from outside; so there must be far more disordered states than ordered states (patterns). Thus, macroscopic pattern is extremely unlikely.

The paradigmatic systems used by Haken (laser optics) and by Prigogine (chemical systems) in their first thorough investigations of self-organization were multicomponent systems because of the fine-grained molecular structure of matter; the systems' complexity is provided by the multitude of micro-components (components may additionally be complex in themselves, as for instance the neurons of the brain system or human individuals in societal systems). External influence consists of unspecific flows of energy or matter.

From thermodynamics we would expect that the entropy in open complex systems must increase. So why is there coherent light in the laser and pattern in a chemical solution? It becomes necessary to explain that under certain circumstances a spontaneous formation of order emerges in a system. In the meantime, much research has been conducted on such collective (as seen from the micro level) phenomena of order formation, especially in the disciplines of natural science. But in the field of biology, psychology and social science the evolution and maintenance of ordered states is even more fundamental and ubiqitous (so that this is often no longer experienced as something that needs further explanation). Put formally, in all cases of order formation the emergence of a macroscopic level has taken place (Haken, 1990) or, in terms of Nicolis & Prigogine (1987), correlations of a long range – compared to microscopic correlations – have formed. These correlations can be observed directly; this is why the macroscopic level is sometimes also called "phenomenological".

What are the aforementioned circumstances that facilitate the spontaneous evolution of macroscopic structure? First, self-organized systems are always open systems. Flows of energy, matter and information between the system and its

environment allow the system to remain in a state of (thermodynamical) nonequilibrium. Secondly, there is nonlinearity as an essential concept characterizing self-organized systems in several ways. In the case of a system that can be described analytically, the equations that map the system's behavior are nonlinear. Thus, phase transitions and bifurcations can be modeled where the system is sensitive to fluctuations (compare the sensitivity to initial conditions of chaotic processes!). At these critical points little causes may elicit positive feedback loops that rapidly carry the system into new dynamical regimes. The opposite is true for other regions of the system's parameter space; here, self-organized systems are also nonlinear – this time in the stable or homeostatic sense. Again external influences do not simply influence the system additively, but instead are finally erased by the attractor of the system. In both stability and instability the system is phenomenologically "nonlinear" because the relation between a control parameter and an observable of the system is not linear. In essence, all nonlinear phenomena are based upon circular (i.e. again not "linear") causal relations within the system.

3.2 Groups as Self-Organized Systems

Can a group be conceived as a self-organized system along the lines of these statements? To begin with let us consider some usual definitions of group.

In social psychology there is obviously little agreement about how the concept of group is to be defined: there are almost as many different definitions as there are authors. As a rule, though, it is stated that a group consists of a certain number of *persons* being in some kind of *interaction*. Starting from this rudimentary definition we might go into more detail, considering how many persons make up a group. This is a matter of convention – at any rate there will be some upper limit for a group as a social system as soon as direct communication is rendered impossible by the mere number of group members (for the effects of "distance zones" see Hall, 1966; Sommer, 1969). Additional questions arise concerning the term "interaction" in a group definition. By the quality of interaction a group can be distinguished from related concepts in social psychology – like crowd (a gathering or aggregate of individuals without interaction, structure or shared norms), mass (an unstructured large crowd with some common goal), or category (individuals with similar attributes; e.g., see Schneider, 1985; Shalinsky, 1983).

Evidently the rudimentary definition of group is analogous to Hall & Fagen's definition of a "system" as a set of objects or components together with relationships between them. Bunge (1979) defines a system as "a complex object, the components of which are interrelated rather than loose". A social system, accordingly, is "a set of socially linked animals". For many reasons it seems straightforward to choose persons as the components of psychological groups; this is usually done in psychology when a group is conceptualized as a system. Along these lines Brunner (1986) defines a social system generally "as a system, whose members are mutually dependent on one another, so that individual and collective behavior and experience are mutually and simultaneously contingent." This

systems concept is an example for an "interactional constellation of individuals" (Schiepek & Tschacher, this volume).

At this point we will try to form a bridge between this conventional conceptualization and synergetic systems. It is manifest at first sight that the former is not consistent with the view of a self-organized system which is necessarily a multicomponent system. One solution seems to be in expecting social systems to be self-organized only from a certain (large) number of members onwards. Haken (1986) points out, that villages or small communities will not produce self-organized patterns because of the small number of individuals they contain; conversely, societies might well be modeled as self-organized systems.

We therefore have to avoid modeling a group as a self-organized system in the same way as we might in the case of a society, even if both may be labelled "social systems". Society is complex on account of the large number of individuals. A model of the self-organization of society may well rest on the notion of individuals being microcomponents like in the approach of population dynamics (Weidlich & Haag, 1983).

On the other hand, we started out with the goal of studying small face-to-face groups as self-organized systems, and have listed some evidence for emergent features of groups above. As a result, we are in need of a more fine-grained resolution regarding the group's micro level. It will not suffice to say that components of a group are the persons that form the group, though this may seem appropriate when viewed from a "anthropomorphic" everyday understanding. We have to shift the focus away from personality-oriented psychological thinking in order to arrive at more fine-grained elements of group dynamics. Some approaches
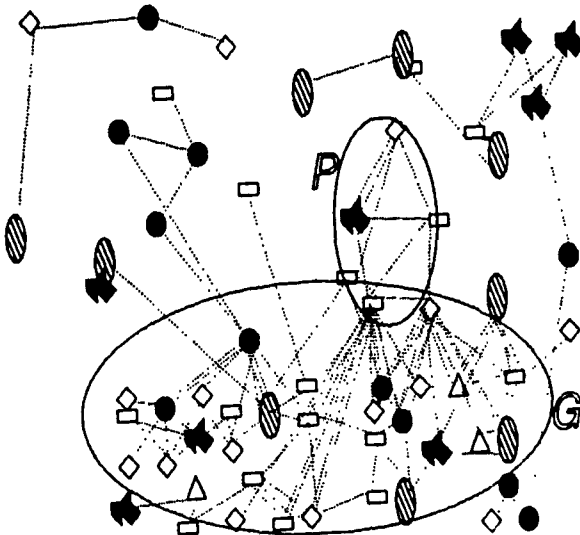
Fig. 1. Chart of a section of the psycho-social world. A group G (or person P) may be defined as an area of increased coupling between psycho-social components

in psychotherapeutic practice have already undertaken this enterprise: in the discussion of family therapy during the last decades there is a tendency to no longer put the person with his or her goals, beliefs, and actions into the center of therapeutic interventions but to reflect the whole system's activity instead. Thus, the persons *within* the system are not viewed a priori as the driving forces of interaction dynamics; in some respect they are not held responsible for group processes. A similar focus on communicative behavior is inherent in the sociological tradition; in this view, social systems build up structures in their own right – like roles and positions. Only then may persons occupy these positions (cf. Barker, 1968).

In our view the following theoretical positions result from the notion that a group is a self-organized entity: the group's micro level consists of emotions and cognitions of group members plus communications (interactions), by which emotions and cognitions are interconnected. Cognitive-emotional and communica- tive elements of this "stream of group events" can be distinguished from one another only in a superficial way. Therapeutic knowledge tells us that the information "transported" (or rather "transferred") by the various modi of communication between persons is more extensive and more detailed than can ever be consciously experienced. Many of the messages are subsymbolic: their content is not expressed in words (nor in internal language), but is nevertheless effective. The psycho-social micro level of the system "group" is virtual (or hypothetical) in that it cannot be observed directly and in detail (Fig. 1).

Where does self-organization enter into the concept of a psycho-social system with a cognitive-communicative micro level? The formation of standing patterns upon the micro level would be an indication of self-organizing processes. Processes are then not distributed equally and amorphously, but ordered in a way characteristic of a certain group, family or therapeutic system; the interior entropy does not increase. At the same time the pattern that emerges is not determined by the environment (the situational context, the goals, the task) of the system. The pattern is not "organized" or controlled by such parameters (although the degree of environmental control may vary depending on the type of group). Indeed, behavioral patterns of families and groups sometimes seem quite unadapted to the needs and constraints of the environment.

Consequently a group as a self-organized system can be summarized as follows:

i) Group dynamics is always nonlinear, i.e. characterized by recursive causal connections and feedback loops: group process is constituted by positive as well as negative feedback;

ii) a group in development differentiates itself from the environment, i.e. group behavior relates to control parameters in a nonlinear way, too (phase transitions, bifurcations);

iii) groups are open systems (e.g. concerning communication);

iv) group dynamics grows out of a complex micro level (cognitions, emotions and communications);

v) groups are hierarchical in that they form macroscopic (coherent) patterns and structures.

These attributes of groups contain the prerequisites for the emergence of self-organization (points (i), (iii), and (iv), cf. Haken, 1983, 1990; Nicolis & Prigogine, 1987).

For empirical group research a phenomenological approach is recommended because of the inaccessability of most microscopic events. Self-organizational processes can be observed on the macro level, i.e. order parameters are assessed directly through collective variables. In particular, one may study how the homeostatic behavior of a group depends on control parameters. Such macroscopic modeling is proposed by Haken (1988) as the "second foundation of synergetics". Modeling in this vein may also serve as a base for machine-implemented simulations (see below). Further experimental and observational designs that make use of mesoscopic observables have been developed in the context of a dynamical approach to psychology (Tschacher, 1990).

3.3 Group Dynamics and Group Structure

In the previous section we formulated ways in which groups may be conceptualized as self-organized systems: from a micro level perspective, a group encompasses a multitude of psycho-social components; between components structures with long range correlations are built up spontaneously.

Consequently a promising approach for group research can be derived, since the emergence of self-organizing structure presents an interface between group structure and group dynamics. By one such approach we thematized the development of groups (Brunner & Tschacher, 1991). Using the method of "recursive sculpturing" (see Sect. 4.2) we observed the formation of group constellations which arose during the interaction of persons carrying out a task. In our theory there are multiple psycho-social processes running in parallel; these build up self-organized patterns under appropriate conditions. The group's patterns present "free slots" to be filled out with individuals – personalized roles and positions offered and occupied during the formation of a group can therefore be seen as a consequence of self-organizing activity. Thus, roles are emergent features of a group.

Several scenarios of the formation of group structure have been described (Tuckman, 1965; Cissna, 1984; Gersick, 1988). Usually, this was not observed to be a linear monotonic process of increasing group cohesion, performance etc.; rather, sequences of stages with conflict-prone intervals have been reported. Such observations are compatible with models from dynamical systems theory describing "routes to chaos" that take place when control parameters are increased (e.g., the phenomenon of period doubling). "Routes to chaos" are better understood as routes to increasingly differentiated types of order: deterministic chaos is but one special case of self-organization (see Kratky, this volume). At critical points along this route we find bifurcations that function as an (irreversible) shunting during group formation (Fig. 2).

state variables   Fig. 2. Bifurcation diagram of group evolution

control parameters
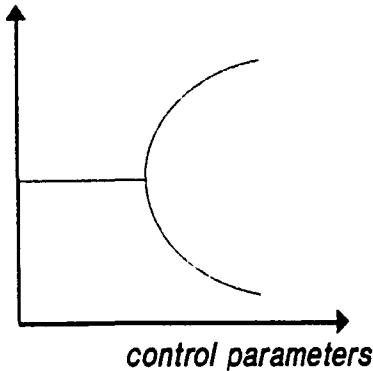
At each stage of group evolution, i.e. along the path between two consecutive bifurcations, a characteristic group structure is realized which is based upon all previous structures. Within this historical dimension of a group the traces of past events are registered in the form of group culture and tradition. The essential aspect of group memory and de facto irreversibility found in the grown structure of psycho-social systems is accounted for by the mathematical model of an irreversible dissipative system.

Thus, the structure and dynamics of a group are intimately connected: i) group structures are emergent features of self-organizing psycho-social processes at a micro level; ii) further, structures may develop irreversibly through many steps in the course of group evolution. Therefore, two corresponding types of processes in groups can be distinguished: first, pattern formation through self-organization and, secondly – on a different time scale – the evolving sequence of group patterns. At critical points in group development, phase transitions have to be expected.

4. Operative Approaches to the Study of Groups

Empirical research on group processes under the auspices of dynamical systems theory has to deal with the restrictions of data acquisition that are characteristic of psychology. Especially the phenomenon of reactivity (what is observed is influenced by the act of observation) has been considered a great problem in psychological measurement. Several theories of social influence apply to the social situation "group experiment" and "group observation": data may be biased because of reactance, dissonance reduction, opportunistic reactions, etc. Competing biases described in social psychology even make prognoses about the direction of effects uncertain. Moreover, in many instances the instruments used for measurement do not satisfy the standards of what is desirable in terms of reliability or data resolution. The acquisition of time series with conventional means like questionnaires, surveys, etc. is further aggravated since repeated applications in short intervals must be ruled out.

Thus, a restricted palette of methods remains for the acquisition of dynamical data on groups; especially observation methods seem appropriate in this respect. We shall not dwell on the broad issue of observation methods here. Rather, a laboratory method will be described that allows studying group development processes (Sect. 4.1). In Sect. 4.2 a simulation approach is presented.

4.1 Circular Causality in Groups

Pattern formation can be observed whenever persons who did not previously know each other come into interaction, either with or without a common goal. Relations previously undefined become defined and structured. Comparing pre-post states gives evidence that order has emerged spontaneously, i.e. without an impact from outside the system; but for research this comparison is insufficient since under the perspective of dynamical systems theory the process of structure formation is essential. Therefore, research methodology has to achieve the following prerequisite standards:

    i) Observability and measurability of structure formation; thus,
    ii) acquisition of continuous or discrete time series;
    iii) minimal reactivity of data acquisition in order to exclude a possible external induction of structure formation.

Substantial reactive effects would have to be expected if an ongoing process of group dynamics were to be interrupted repeatedly, for example by asking members for the completion of sociograms. It would also be difficult to interpret differing assessments of group members. An alternative to this might be in videofilming group processes in order to question members about recorded events later on (video reconstruction). Video reconstruction yields statements on relationship and communication, but also on accompanying cognitions and emotions. Qualitatively distinct phases of relationship formation can be identified quite reliably by this method, but it is difficult to reconstruct time series of quantitative variables out of the interview data.

Our effort to fulfil the above criteria sets out to simultaneously allow the process of group formation and the acquisition of data about this process. Members of a group dynamical experiment (ideally strangers to one another) are asked to position themselves within a confined area, so that distances between subjects (Ss) reflect the experienced closeness (in a third dimension, dominance and submission might be enacted by the use of pedestals, but this was not applied in our experiment). Thus, the distances group members choose lead to a *group sculpture*. Instructions are given to dissolve and reestablish sculptures in short intervals. In this way, distances between members can be measured immediately as indicators of distance regulation or, in other words, as a repeated mapping of relational structure. This method is termed iterative or *recursive sculpturing* (Tschacher, 1990; Schiepek, 1991, Chap. VIII) since each realized sculpture relates to previous sculpturing(s): the structure at time t is a function of the structure at time t–τ. Members get the opportunity to negotiate verbally the formation of the

next sculpture; verbal material can be assessed by content analysis and allows for later data gathering by video reconstruction. The group's task is merely to thematize, develop and enact its own group processes.

In this, process and data acquisition coincide insofar as the mapping of the group's dynamics (for the sake of data acquisition) incites and motivates further processes. At first sight, this is the exact opposite of a non-reactive method as stipulated in (iii) – the demonstration of group dynamics catalyzes and alters that which is demonstrated. The recursive-reactive process of sculpturing signifies itself in that both signifier and signified are identical. Methodologically, this is paradoxical: the increased reactivity of data acquisition may even lead to non-reactivity.

The logical form of this paradox is similar to the coincidential figure of so-called performative utterances (Austin, 1961; von Foerster, 1985), i.e. statements that implicitly *do* what they *say*. "I apologize" signifies the act of apologizing and, at the same time, *is* the apology. "I promise" already does the promising. Acting and signifying the action fall into one. As von Foerster puts it, language is usually related only to itself because signs only relate to other signs; the coincidence of sign and signified makes it possible for language to be free from this recursive closure, to reach solid ground.

We propose recursive sculpturing as a method for the gathering of data about self-organizing processes in groups. It can be expected that group dynamical constellations (which may initially be undifferentiated and fluctuating) will converge to a clearly structured constellation with time (i.e., the number of iterations). Groups will produce an "eigensolution" (von Foerster, 1985) or, put differently, group dynamics relaxes to an attractor. Furthermore, if it is correct to conceive of groups as nonlinear dynamical systems then – with changing control parameters – discontinuous transitions between attractors or ordered states (phase transitions) should be observable.

A further expectation – or rather prerequisite for the validity of the method – is that communicative and cognitive-emotional aspects of group processes manifest themselves in spatial distance regulation between persons. There has been much research on this issue in ecological psychology (Aiello, 1987), but also in group dynamics and family therapy practice (Kantor & Lehr, 1975; Schweitzer & Weber, 1983; for a review see Tschacher, 1990).

Figure 3 may serve as an illustration for our method. A sequence of six sculptures of eight Ss (students of pedagogy) is presented. The initial sculpture was formed in a time consuming and hesitative process. The area of the polygon spanned by group members is correspondingly large; it reflects the students' reluctancy. During the next two sculptures distances decreased, until in iteration 4 person C left the field entirely. At the same time the remaining group again increased distances; in iteration 5 three females of the group located themselves back to back in the center of the field. This was declared as the concluding constellation; nevertheless, during the last verbal exchange phase, still another constellation was formed.

It is possible to rate the group members' verbalizations between sculptures.
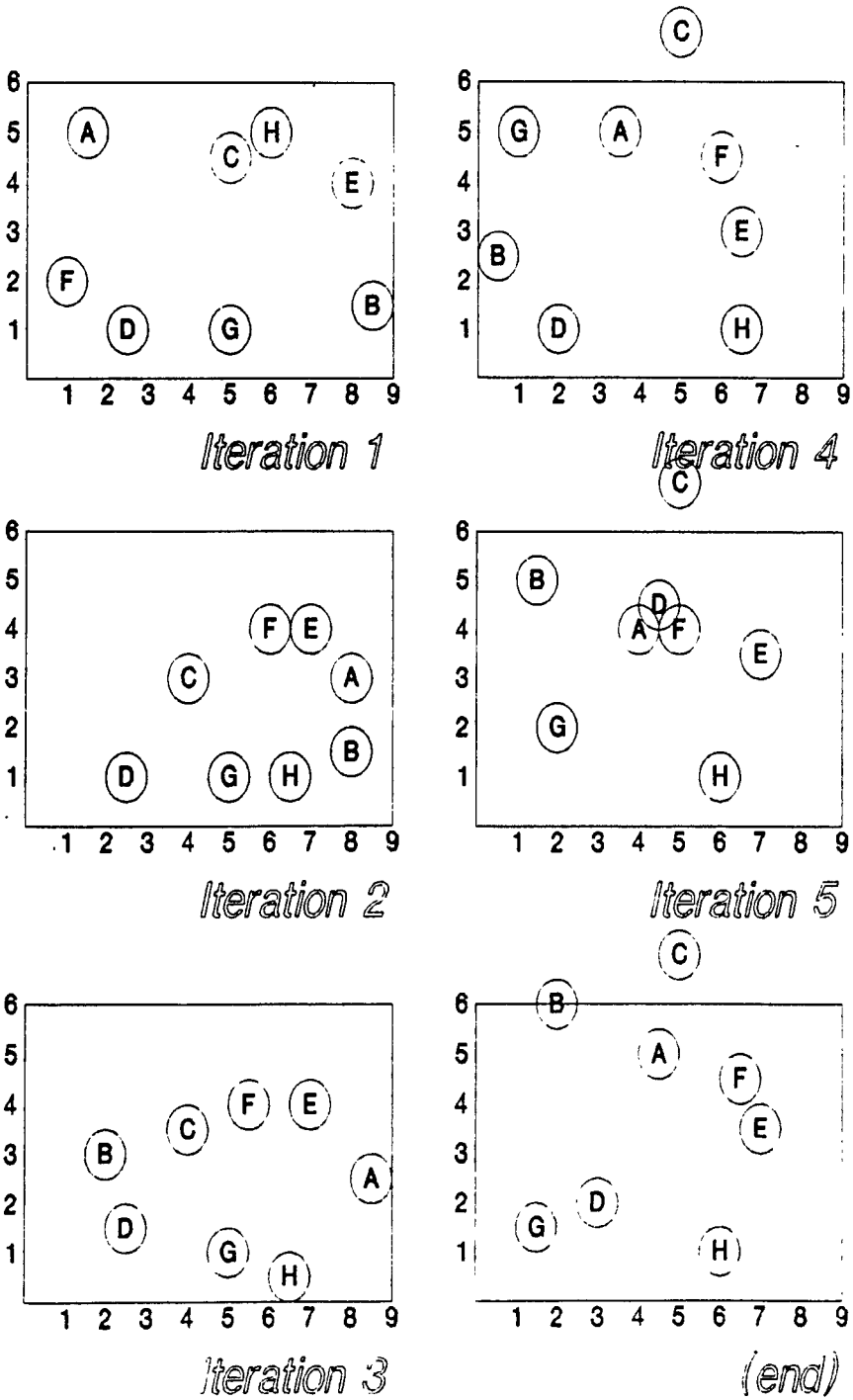
Fig. 3. Group sculptures observed in pilot study (persons A, B, ..., H in a metric field)
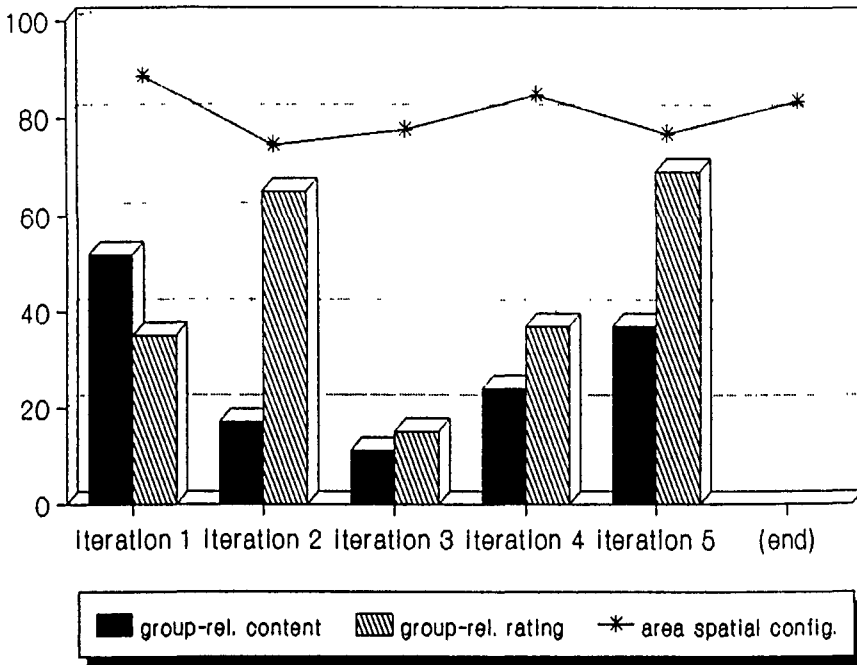
Fig. 4. Diagram of measures of pilot study variables corresponding to group sculptures. From left to right: frequency of group-related content; rating of group-related verbalizations; area of spatial configurations (areas of polygons spanned by persons in sculptures of Fig. 3)

During the five verbal exchange phases in our study, statements were coded as being either self-related or group-related. Two methods were used: i) a content-analytical approach determined the frequency by which certain words (prompts as "group", "we" vs. "I", "my" etc.) appear in the transcripts; ii) two independent raters decided for subsequent parts of the transcript which of the two categories applied (inter-rater reliability was rather low in spite of training: Cohen-Kappa K=.62 and r_{tet}=.78). The results presented in Fig. 4 shall not be interpreted further since there is little convergence between the rating method and content analysis. Moreover, the present data base is insufficient.

Consequentially, the pilot study reported gave rise to several critical questions.

1) Even with short intervals between iterations and highly motivated Ss the time series are not sufficiently long, so that complex methods of analysis (ARIMA, FFT) are not applicable. Above all, the generated series at the present do not permit one to identify group dynamical attractors.

2) Spatial distances are hard to interpret psychologically. Although psycho-emotional dynamics will in principle result in spatial behavior, it remains unknown which agglomeration of motives may lead to which interpersonal distances. For

instance, how is a person to behave in the face of both affiliation wishes and social anxiety (approach-avoidance conflict)?

3) Groups in recursive sculpturing reflect upon themselves. There are no goals, tasks or themes like in everyday communication. For this reason, the external validity and generalizability of results gained by this method are unclear.

The method's validity therefore rests more upon "pure" group dynamics realized especially in encounter or therapy groups. This is nonetheless of considerable theoretical interest to social psychology.

4.2 A Simulation Model for Group Development Processes

In order to complement the method of recursive sculpturing we designed a model of self-organizational processes in groups. The formation of spatial configurations was simulated with the help of an iterative computer program. A prototype was implemented in the following way: the field of group interaction is given by a 20x30 array. Eight out of the 600 cells are occupied by "persons" who are free to move according to given optimum distances between persons. The simulation system was inspired essentially by Dewdney (1986). A biocybernetical simulation of spatial and social structure can be found in Hogeweg (1989).

a) **Description of the simulation.** One single step in the simulation is as follows: Person A registers his distance from each of the other persons B through H and in each case computes the difference between the actual distance and the given optimum. The sum of differences serves as an indicator for A's satisfaction with his momentary position. The same computation is carried out for each of A's eight neighboring cells. Then A is moved to the cell with the highest value of satisfaction, i.e. the lowest sum of differences. An iteration is finished after all persons have completed this cycle and have migrated according to their respective values of satisfaction (or have remained in an already optimal position). A "satisfaction value" can be attached to any cell of the field, so that the field as a whole becomes a *potential landscape* for each person (Fig. 5). High satisfaction, i.e. approximately optimal distances to all other persons, corresponds to a valley or sink (an attractor), low satisfaction corresponds to a hill (a repellor).

Interaction within the group of simulated persons is evoked by the competition of eight such potential landscapes. Competition thus avoids the trivial case of all persons directly moving into the potential minima closest to initial positions. Mathematically the simulation is a discretized approximation of a system of 16 ordinary differential equations that define the changes of coordinates of eight persons in the plane. As differential equations, the system is linear since the derivatives of quadratic distance equations contain no nonlinear terms. The nonlinearity of the system stems from discretization. The simulation can be viewed as a variant of a cellular automaton. Cellular automata are discrete dynamical systems that are able to produce complex macroscopic patterns from simple local rules. Von Neumann, pioneer of the serial computer, first used cellular automata with the goal of modeling biological processes such as the self-reproduction of structures (von Neumann & Morgenstern, 1963; Langton, 1989). These automata
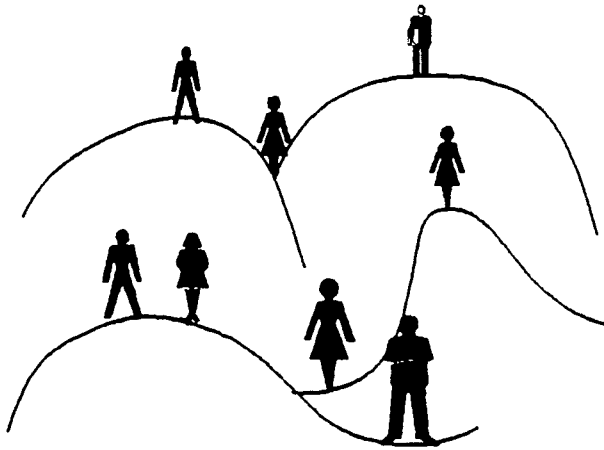
Fig. 5. Schematic representation of potential landscape in group simulation

also have been proposed recently as a paradigm of parallel processing (Kemke, 1988). From the part of dynamical systems theory it is noteworthy that cellular automata show phenomena such as breaking of symmetry, order formation, fractality and chaos (Wolfram, 1984; Toffoli & Margolus, 1987; Hayes, 1988).

b) Results of simulations. For each run of the simulation system, a number of values have to be determined: the basic potential functions can be varied widely by setting optimum distances; also the initial state of the system (i.e. initial positions of persons in the field) must be chosen. Thus a wide variety of initial conditions is offered. A phenomenological study of resulting simulations shows that there is also a multitude of discernible categories of behavior. The system depends on initial conditions quite sensibly. To give an example: let the optimum distance matrix (of the form of Table 1) be symmetrical with a common value of $d_{ij}=13$. From certain initial positions for persons a long sequence of changing constellations results, which after some 200 iterations turns into a stable configuration. When in a second run the initial position of person A with coordinates (x/y) is shifted from (5/17) to (6/17), the system enters an equilibrium state after only twelve iterations. Both resulting configurations have a similar shape (an irregular circle) as would be expected from the homogenous matrix; but relative positions of persons A to H are again different (Fig. 6).

Qualitatively different behavior is observed when optimum distances are chosen in a way that they correspond to distances of some actual configuration (for instance, the distances between A, B, ..., H realized in the first constellation of Fig. 3). The matrix is symmetrical then since distance AB=BA, etc.; there are no conflicting values for distance optima between any two persons. In such cases simulations are always *equifinal* – the original configuration (or some rotated variant) will be established from all initial system states. In other words, a point attractor is determined by the matrix that gives the control parameters.

Different behavior results from parameters that contain conflicting distance settings. In the following example, A tries to maintain high distances from all

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+ + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
+ . . . . . . . . . . . . . . . . . . . . . . . .                +
+   . .     . . . . .       . . . . . . . . . .                  +
+ . . . . .       . .       . . . . . . . . .                    +
+       . . . . . .         . . . . . . . .                      +
+       . . . . . . . .         . . . F . . . . . . .      .     +
+ . . . . . . . . . .   . . . . . . . . . . . . . . . . . .      +
+ . .   . . . . E . . . . . . . . . . . . . . . . . . .          +
+ . .   . . . . . . . . . . . . . . . . . . . . . .              +
+ . .   . . . . . . . . . . .   . . . . . . . .     .            +
+ . .   . . A . .   . . . . .     .   . . .   . .   .            +
+ . .   . . .     . .     . .   . C . . .       .                +
+ . . . . . . . . . . . . . . . . . . . . .   .       .   .      +
+ . .   . G . . . .   . . . .     . . .   .   . . . .            +
+ .   . . . . . . . . . . . .   . . . . .   .     .       .      +
+ .     . . . . . . . . . .     . . . . .     .   .       .      +
+ .     . . . . . . . . . . . . . . . . B   . . .   .       .    +
+ . . . . . . . . . . . . . . . H . . . . . . . .   . . . .   .  +
+ . . . . . . . . . . . . . . . . . . . . . . . . . . . .        +
+ . . . . D   . . . . . . . . . . . . . . . . .       . . .      +
+ + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +

+ + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
+                                                               +
+                                                          .    +
+                                                              . +
+             .           .                   .                +
+           . . . . . .       . . . .   .                       +
+                       . A   .   . C                           +
+                       . .H .                                  +
+                                                   .           +
+          .                               . . . .              +
+        F                                 .                    +
+        .                               . .                    +
+      . .                             . E                      +
+      .                               .                        +
+    .                                                          +
+                                        . . . . .              +
+          . .         .                 . .                    +
+        . . . . . . . . .         B .                          +
+          . G . D                                              +
+                                                               +
+ + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
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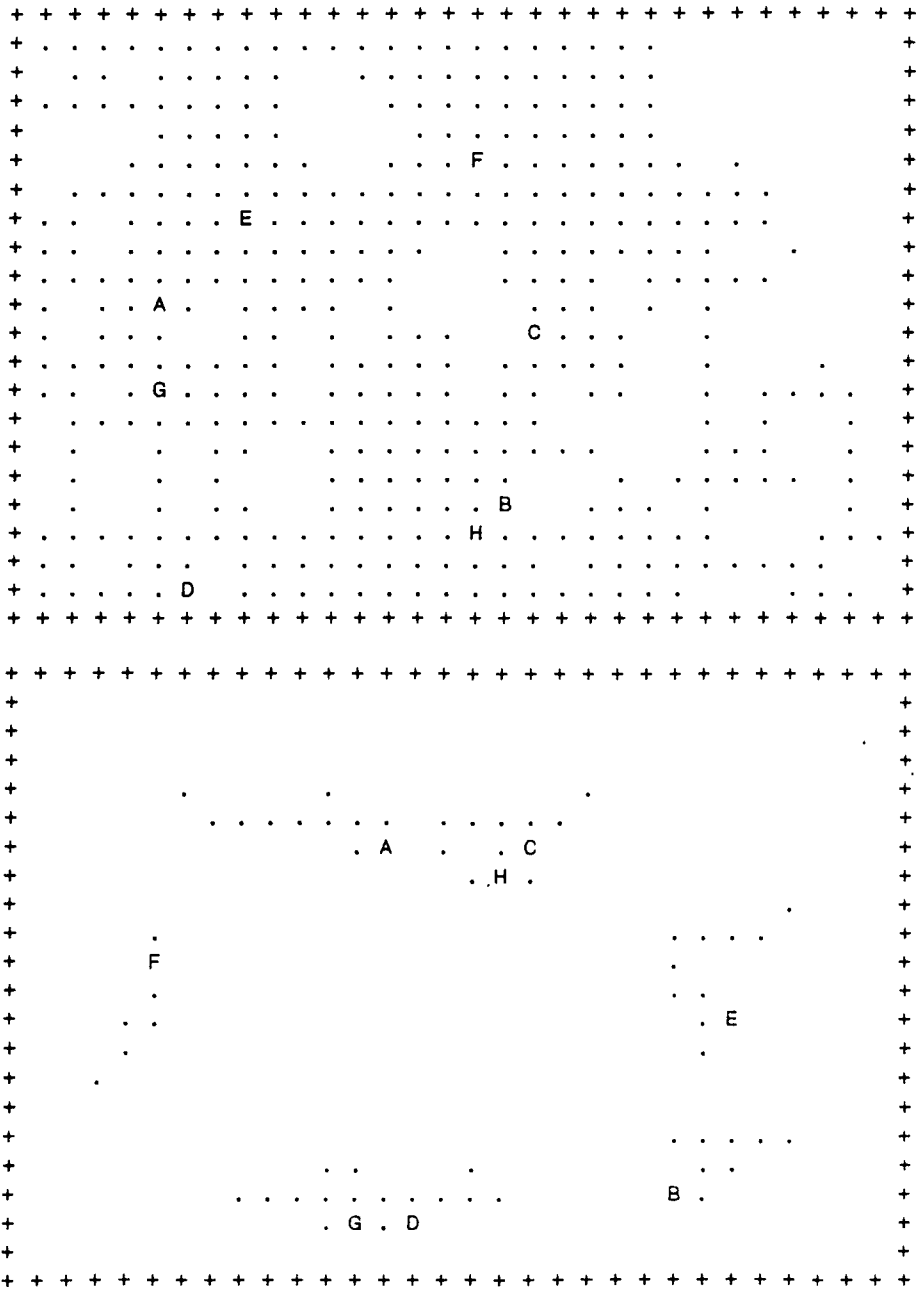Fig. 6. Configurations of group simulation with two slightly different initial values ("persons" A, B, ..., H); top: after 194 iterations; bottom: after 13 iterations

other persons; B through H as a group aim at small distances from A while having small but conflicting optimum distances among themselves. The resulting asymmetrical matrix is given in Table 1. The simulation takes a peculiar course

Table 1. Matrix of optimum distances of the simulation. Example represents conflict within the group (see text)

	A	B	C	D	E	F	G	H
A	0	11	11	11	11	11	11	11
B	1	0	2	1	3	2	1	2
C	1	2	0	2	2	1	3	2
D	1	2	2	0	3	3	3	3
E	1	1	2	1	0	2	1	1
F	1	2	3	1	2	0	3	2
G	1	2	3	1	1	2	0	1
H	1	2	2	1	2	3	3	0

while not approaching any of the usual stationary states. Persons form a close turbulent unit instead; occasionally the configuration resembles a "glider" (i.e. a stable or oscillating pattern moving through the field in a cellular automaton). The gliders get deformed at the edge of the field, go into a phase of restructuring and start moving in a different direction. A deterministic time series analysis of this example is presented in the chapter by Steitz et al.

A general phenomenological description of the simulation model yields the following categories of equilibrium states: ·

–fixed points: stationary constellations where the system remains unchanged;
–limit cycles: a terminal constellation oscillates between two or more states;
–gliders: constellations wandering through the field, sometimes oscillating;
–turbulent states (deterministic chaos not yet proven).

c) Expansion of the simulation model. From a dynamical systems point of view it seems legitimate to study the simulation model as a complex system for its own sake – nevertheless, the system was designed as a model of distance regulation in a developing group. Which is the relation between model and real group events?

The model is obviously very simple because optimum distances will not vary during simulation. In real groups we would expect distance "needs" to change continually depending on interactions during group formation. First explorative studies with groups (see Sect. 4.1 and Tschacher & Brunner, 1990) demonstrate this as a lack of one degree of freedom in the simulation. Yet we think our model shows that even simple model machinery can produce very complex behavioral patterns and equilibrium constellations and may therefore map group processes on a macroscopic level. A deep simulation of group processes is clearly beyond the reach of a computer experiment, but it makes sense to simulate phenomenological patterns with as simple a model as is possible in order to sound out formal analogies of group development. This is especially important because, in the framework of synergetics, we expect that in social systems simple patterns will evolve out of a complex psycho-social micro level.

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It is possible to design a more realistic model by adding another recursive loop: distance matrices now constant may depend on the output of the simulation; e.g., closer distances are "learned" after they have repeatedly appeared in previous iterations (in principle, any number of hidden "motivational" variables can be introduced to interact and influence spatial behavior). The potential landscape causing the group's behavior will thus be modified itself by behavior. In this way the simulation model could be expanded as a kind of multidimensional cybernetic model, as in Bischof (1985).

Another extension of the realized version would be allocating different dimensions to the "field" that the group is mapped to. Originally this simulation was designed as a spatial model of laboratory distance behavior, but there is no need to conceive the field of group dynamics as Euclidean. A conceptualization based upon topological representations of psychological and social dimensions relates to Lewin's (1947) "social field". A social field develops from the superposition of the group members' life spaces (Fig. 7).

Lewin sees as a basic property of group life the circular causal processes controlling individual and group action. In the social context perception and action are linked such that perception depends on the way a social situation is changed by action and vice versa. The proximity of this socio-topological approach to system-oriented group psychology is obvious. In the context of our simulation the social field of a group may be modeled as follows: presently potentials are defined as fixed to individuals, moving with their spatial positions; in order to represent a life space or field in the sense of Lewin stationary potentials can easily be defined which influence locomotions additionally. The field then becomes a potential
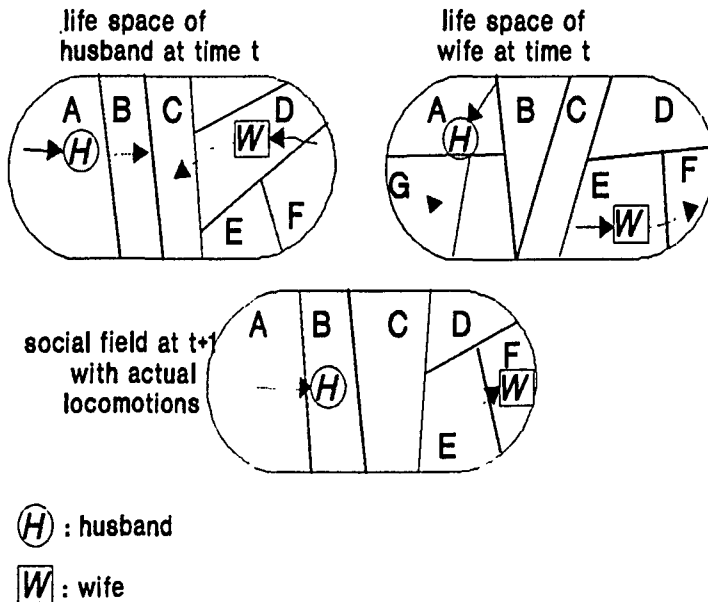

Fig. 7. The social field as a superposition of life spaces (after Lewin, 1947). Arrows in life spaces indicate intended (or expected) locomotions

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landscape built up from stationary potentials (general laws affecting on the dynamics of a group) and personal potentials (as in the distance matrices above). This will provide a computational shell which can help model therapy situations described with a synergetic potential metaphor (see Schiepek, Fricke & Kaimer, this volume). A further application is planned in connection with the "systems game" approach – here distances can be modeled as social distances (rather than metric ones) by variables of the protocols (e.g. frequencies of contact between persons, announcements of protagonists, etc.; see Schiepek & Reicherts, this volume).

5. Self-Organized Groups in Organizations: Synergy or Paradox?

5.1 Self-Organization Phenomena in the Firm

In this volume it has been stated repeatedly that phenomena of self-organization are relevant to psychotherapy theory and practice. From this point of view we will now try to contribute to the analysis of a quite different issue – the economic organization – where the dynamics of groups is of major importance.

The tension between organization and individual is commonly viewed as central for the understanding of organizations (Wiedl & Greif, 1991). We hold this to be the minor truth since the function of groups in organizations is neglected in this statement. First of all, organizations in general have started as small groups, and are composed of multiple small groups. Big companies can be described as miniature societies consisting of groups that interact in various ways. All groups are interlinked by the members they have in common (Likert, 1961) and by being involved in the same social network, the hierarchy of the organization. Each group tends to develop norms, standards, and traditions essential to the climate for work and achievement. New members that join the group go through the same stages of socialization (McDavid & Harari, 1968). On the organizational level culture and corporate identity may be established, too. Culture encompasses norms and values that characterize an organization; even rituals and behavior patterns are to a degree determined by the style of the company (Schein, 1985; Matenaar, 1989).

Today it is seen as an important aspect of successful organizations that they provide an attractive climate and identity. One of the advantages of Japanese leadership seems to be that the company's philosophy is preserved and continued independently of changes in top management (Bleicher, 1989).

In this context we want to stress the fact that culture must be seen as an emergent phenomenon caused by psycho-social self-organization which cannot be introduced or changed quasi-mechanically, "by decree". Thus, Doctoroff (1977) points out the importance of informal organization in producing *synergy effects*, for example through "unpurposeful meetings". Sprüngli (1981) counts trust, effective communication, rapid feedback and creativity among the prerequisites for positive synergistic effects.

As can be seen, the emergence of norms, standards and culture in groups and in the entire organization is to a large degree based upon self-organized processes

of group dynamics. The groups (formal and informal) are fundamental for all emergent attributes of organizations. The emergent aspects (culture, climate, philosophy) strongly influence the creativity and efficiency of the entire social system. It is therefore necessary to regard small group dynamics in questions of management and organizational development. "Not the behavior of single humans, but the behavior of social systems is the subject of management theory" (Ulrich, 1984, p. 87). From a slightly different standpoint, Schein (1985) posits that the "unique and essential function of leadership is the manipulation of culture". This begs the question of what management might look like under this supposition.

5.2 Management of Self-Organized Systems

When we apply self-organization theory to social groups and social organizations we have to keep in mind that these are purposeful and goal-oriented structures. Organizations and enterprises do not rely on spontaneous pattern formation but are founded in order to manufacture services or products in a rational way. Generally, self-organizing dynamics in goal-oriented organizations is regarded as interfering with planned processes and therefore as dysfunctional – self-organization is viewed as misorganization and is not expected to contribute to organizational goals. How can the relations between organization and self-organization be determined in this respect? How do these opposing dynamics connect?

In the social sciences, two quite contrary views are discussed in relation to the question of planning and intervening in social systems.

The extreme position of *non-interventionism* is held by some theoreticians of systemic psychology. Essentially two arguments for non-interventionism are put forward. In non-trivial machines input and output are not directly connected but are regulated by state variables of the machine; from the resulting abundance of combinations of input, state, and output von Foerster (1985) concludes that even simple non-trivial machines must be unpredictable. The second argument refers to self-reference: in social systems interventions are started from inside the system which leads to paradoxes because of a mixing of logical types; rather than observing something else, the system observes its own observation; planning becomes self-planning (Krohn & Küppers, 1990). Finally, there are outcomes from other disciplines, e.g. cognitive psychology, that confirm the difficulty of intervening in multicausal systems. Linear manipulations of complex systems are supposed to lead to negative results; this even seems to follow a "logic of failure" irrespective of the intelligence and motivation of the manipulator (Dörner, 1989).

On the other hand a position of *interventionism* thrives and dominates in everyday practice. Having diagnosed maladaptive behavior (symptoms), an interventionist would try to "cure", transform, or extinguish this behavior directly. Behavior therapy in its early naive phase, for example, posited that the behavior of individuals and groups could be shaped almost unrestrictedly by controlling stimuli and contingencies. The repertoire of methods applied has been greatly expanded in the meantime (e.g. multi-modal behavior therapy and behavior medicine) and the banishment of cognitive constructs has been given up (cognitive

learning theory). The linear causal thinking of interventionist theories has nevertheless survived. The same applies to established organizational theories in industrial economics: companies are above all seen as hierarchical systems; here also interventionist thinking is still effective in the shape of action theory and decision theory (Ochsenbauer, 1989).

In our view, both of the above positions become untenable when the results of self-organization research are considered (Tschacher & Brunner, 1992). The non-trivial machine cannot be described analytically as only its unpredictable behavior is given; one is reminded of a deterministic but chaotic dynamics (Bergé et al., 1984). But chaos is not necessarily predominant or typical in complex systems. Therefore von Foerster's implicit argument (if simple variable systems can be chaotic, complex systems should even be more likely to show irregular behavior) is appealing but invalid. Synergetics and self-organization theory have shown that in very complex recursive systems, the opposite phenomenon – an enormous reduction of degrees of freedom – arises. The stunning result of this type of research is rather: the more complex the system, the simpler its behavior. On the other hand interventionist ideas are contradicted by self-organization theory as well: the spontaneous activity of systems is obviously contrary to a primitive can-do! approach as in early behavior therapy.

When tackling the problem of intervention and planning along these lines one is forced to differentiate. The question is not: Can we plan and intervene purposively at all? but rather: What restrictions and options are inherent in interventions into systems that show self-organization?

a) **Restrictions.** We have to consider the irreversibility of self-organized systems. Therapeutic or managerial influences and communications cannot be undone in psycho-social systems. The theory of dissipative structures leads to conclusions that are well-known in systemic therapy: one cannot *not* communicate (Watzlawick et al., 1969), nor can communications be "taken back" by selecting some kind of inverse communication. All the same the system differentiates itself via bifurcations into new behavior patterns, while the same route back is barred. This applies to management decisions too (cf. Ulrich & Probst, 1990). In sum, there are connections between the second law of thermodynamics and axioms of intervention pragmatics.

Secondly, long term planning will be possible only in rare cases. The evolution of a system may undergo surprising branchings since close to instability points chance fluctuations can decide in which way the system evolves further. The problem of prognosis is obviously most acute in the case of chaos because the sensitivity to small perturbations becomes permanent then.

Finally, attractors (equilibria) cannot be influenced directly and at will. Within a certain range of boundary conditions (control parameters) and under the permanent influence of fluctuations the system states fall into the equilibrium again and again (Fig. 8). One of many examples would be the following observation: single employees are often delegated to attend training seminars; back in their groups or departments employees usually "forget" whatever new skills and procedures they had just acquired. Thus, trying to influence behavior directly may
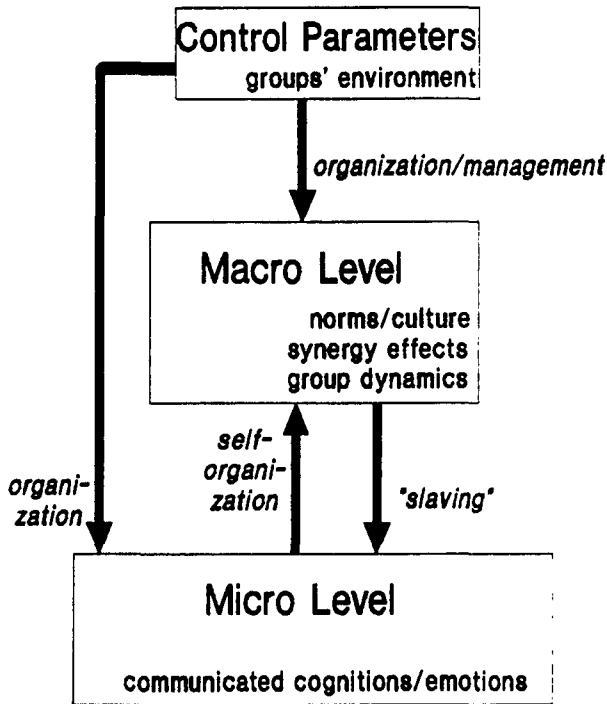
Fig. 8. Scheme of self-organization and organization in a social system

turn out to be a futile fight against the dynamics of an unchanged system; instead of "breaking the resistance" the method of choice will rather consist of indirect action (like intervention on the "meta-level", cf. Malik, 1984). But additionally, there is still self-reference: a manager who sets out to change the culture of an organization is herself or himself culturally biased to an unknown degree (Schein, 1985).

b) Options. On the other hand, the systemic view can give some clues to better achievement that rests in self-organized dynamics; these options may be annihilated by linear advances.

One advantage can unfold when the adaptability and creativity of evolving systems is utilized. The trust in Tayloristic specialization and increasing division of labor as a principle of success has been overturned in the last years. In his review of type Z organizations, Ouchi (1981) describes such companies as promoting a coherent culture of egalitarian rather than rigidly hierarchical interaction. Ouchi points to the Japanese ritual of *ringi*, i.e. collective decision making.

If one tolerates solutions that are useless at first sight, unforeseen solutions to problems may open up. From a self-organization perspective it makes sense to follow the present trend towards participative models of leadership and organizational development. The creative potential that is embedded in the dynamics of the constitutive small groups is to be utilized rather than fought as an

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disturbing "shadow organization". Autonomous work teams and quality circles are well-known examples for promising approaches towards new ways of delegation (Weinert, 1987). In order to utilize synergy effects flat organizational structure and decentralization seem adequate. Less hierarchy has the additional advantage of requiring less interfaces in an organization's information flow.

Especially in the design of groups that are supposed to develop new products or projects, evolutionary aspects should be considered. Here it is important to preserve a broad spectrum of alternatives for some time at the start of the project; immediately aspiring to a fixed (and necessarily fictitious) goal often turns out to be dysfunctional.

Leadership should be understood as an indirect and, at most, strategic intervention. In interventions of a small range we advise use of the sequence of pacing→leading which is a related principle in systemic therapy and hypnotherapy: it is not very effective to try to control the system right from the start – rather one should follow the system's own dynamics first (pacing), and only later get hold of some control out of the impact gathered until then (in the field of management, cf. the "jiu-jitsu principle", Gomez, 1981).

How can we investigate indirect management further? Influencing the attractors of self-organized systems can be achieved primarily by shifting control parameters, i.e. the conditions in the system's environment. Control parameters change the potential landscape, and thereby indirectly change the path that the system will follow. According to our theory, interesting control parameters of groups in organizations will be those variables that establish the distance from thermodynamical equilibrium; this distance is realized by flows of matter, energy and information through the system's permeable boundaries. Correspondingly (as a proposal for further research) pattern formation and pattern change should be studied in parameter spaces spanned by variables that measure the flow of energy (resources, budget, money?) and especially information (which is not easy to operationalize, but say social or political environment, setting of goals, pressure for efficiency and the like). As a result of a research enterprise of this kind we would learn about the bifurcation scenarios of psycho-social systems in organizations and also learn how to manage (and adapt to) the nonlinear life of groups.

Acknowledgments

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