Self-Organization in Clinical Psychology

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Article Outline

Definition of the Subject

Clinical psychology is a sub-discipline of psychology engaged in the description, classification, explanation, and treatment of mental disorders. The primary focus is on psychological methods, models, and topics such as behavior, cognition, emotion, and social interaction with substantial overlap with related areas in psychiatry, psychosomatics, or behavioral medicine. Yet, the main stream in clinical psychology views the etiology of mental disorders, their time courses and susceptibility to psychological treatment still through the magnification glass of linear input-output philosophy of human functions. Owing to this paradigm, linear combinations of variables (as inner conflicts, irrational cognitions, or stressors) trigger the development of psychiatric diseases or disorders in genetically predisposed individuals. Therefore, linear multivariate regression models are assumed be able to predict the probability of falling ill or suffering from disorders. As an important field in clinical psychology, psychotherapy research defines randomized controlled trials as the golden standard of outcome research. Here, patients randomly assigned to different treatment modalities are being compared with respect to the outcome of different tests. In this regard, the input (treatment) is thought to determine the outcome (treatment effects).

Contrary, or rather, supplementing this line of research is the scientific paradigm of self-organization, i. e. the functioning of complex nonlinear systems with circular causality at its center. Gestalt psychology, traditionally concerned with patterns ("Gestalts") in perception, human behavior and interaction (e. g., those prevalent in group dynamics, Lewin Koch et al. 2002) focuses on such self-organization processes. Gestalt psychologists like Wolfgang Köhler (e. g. Köhler 1947), Wolfgang Metzger, Max Wertheimer, Kurt Lewin and others can be seen as direct predecessors of modern complexity researchers in psychology (Stadler and Kruse 1990). Another root of this development is Jean Piaget's equilibration theory of action-cognition patterns (schemata) describing assimilation-accommodation-cycles of these schemata (Piaget 1976). During these processes, input from the inner and outer environment assumes the role of disturbing stimulation of individual system dynamics. A third important line of thinking in circular causality comes from anthropological medicine. The "Gestaltkreis" integrates feedback loops between sensorial and actional systems on the one side, and individual and environmental systems on the other side (ecosystemic approach) (von Uexküll and Wesiack 1996).

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Introduction

During the past decades in clinical psychology, it was particularly the transdisciplinary approach of *synergetics* (Haken 1990a) which inspired a specific nonlinear and complexity research on cognition (Haken 1990b; Tschacher and Dauwalder 1999), social interaction (Nowak and Vallacher 1998; Tschacher 1997), etiology and dynamics of mental diseases (e. g., Schiepek et al. 1992; Tschacher and Kupper 2002), and psychotherapy (for an overview see Haken and Schiepek 2006). Synergetics describes, measures, and explains the autonomous processes of pattern formation and pattern transitions in complex nonlinear systems. Founded on Haken's fundamental discovery that these processes do not depend of the matter of the systems they occur in, synergetics became one of the most important inspirations to many scientific fields and topics. Especially, Haken early transferred synergetics to brain research (e. g., Basar et al. 1983), since the brain is an outstanding example of a complex, self-organizing system. Today, it is widely accepted that the brain and a serial computer not only differ profoundly, but there is almost nothing they share: No wonder in light of the more than 10^{11} nonlinear interconnected neurons forming a dynamic mega-network of neural networks with essential features like arrays of emerging and submerging synchronizations, its flexibility and ever changing pattern formation, working at the edge of chaos, or realizing combined (activating and inhibiting) feedback mechanisms following the principles set forth by synergetics which describes the laws of self-organizing systems (Haken 1996, 2002).

Taking a closer look at most of the phenomena clinical psychology is concerned with it becomes obvious that they appear to be of dynamic nature. Human development processes, human change and learning processes, the dynamics and prognosis of mental disorders, problems mani-festing in social systems like couples, families, teams, or the question of how psychotherapy works: Self-organization is a ubiquitous entity.

Dynamic Diseases

Mental disorders are characterized by specific dynamic patterns, mirroring "endogenous" and common features of a disorder (like the repetitive phases of unipolar major depression or the bipolar phases of bipolar disorders, oscillating between mania and depression), as well as the effects of an individual life-style including individual coping and treatment efforts. Mental disorders can be conceived as highly structured and coherent states which enslave and thus impair the individual's mental and social functioning. Following the "enslaving principle", emerging order parameters reduce the degrees of freedom in the behavior of the single parts of a system. There is phenomenal evidence that this is the case in many mental disorders. Obsessive-compulsive disorder patients coerced to repeat unwished thoughts or rituals are just but one most impressive example. On the brain level, such pathological states correspond with abnormal synchronization in specific neural networks impairing brain functions. In obsessive-compulsive disorders, cortico-striato-thalamo-cortical feedback-loops are thought to be at the center of the dysfunctional network (Saxena and Rauch 2000; Schiepek et al. 2007), while abnormal synchronization in highly similar neural populations is the source of Parkinsonian resting tremor (Lenz et al. 1994; Pare et al. 1990).

At times, transitions between different pathological states or between states of health and disease are linear and balanced, at other times they are discontinuous and abrupt, such as in nonlinear phase transitions accompanied by critical fluctuations described by synergetics to occur in physical systems. Such transitions have been reported for unipolar or bipolar cyclic depression (e. g., Heiden 1992), and also for schizophrenia (Strauss 1989). The usefulness of the concept of attractors in psychopathology is best reflected by the final common pathway of different disorders with similar phenomenology and syndromal patterns. Different initial conditions and different qualities and degrees of stressors and vulnerability factors may result in similar pathological end-states on the one hand. But on the other hand, small fluctuations within the intrapsychic or environmental conditions or small differences of some boundary or threshold conditions may result quite different disorders or may decide between health and disease (for a dynamical simulation of major depression see Schaub and Schiepek 1992). The encouraging message synergetics delivers is that while the structure of a generic system may stay unchanged, small changes in control parameters, threshold conditions, and internal or external fluctuations are able to trigger dramatic changes in the behavior of the system. As a consequence, therapy exerting changes of these parameters is thus able to trigger return of the system to a healthy state.

For illustrative purposes we present results of a computer simulation of different chronic courses of schizophrenia (Schiepek et al. 1992). A qualitative network model of five macroscopic variables was transformed into a set of nonlinear difference equations, with each equation describing and determining the change rate of each variable from t to $t + 1$. The empirical references of the simulation model were empirical studies of the chronic course of schizophrenic patterns, mostly mixed psychotic episodes, healthy functioning, and chronic states. For example, (Ciompi and Müller 1976) report on eight different patterns in the long-term evolution of schizophrenia, most of them reproduced by our model. These patterns result from various combinations of slow vs. acute onset, acute episodes vs. progressive deterioration, and remission vs. chronic end-state.

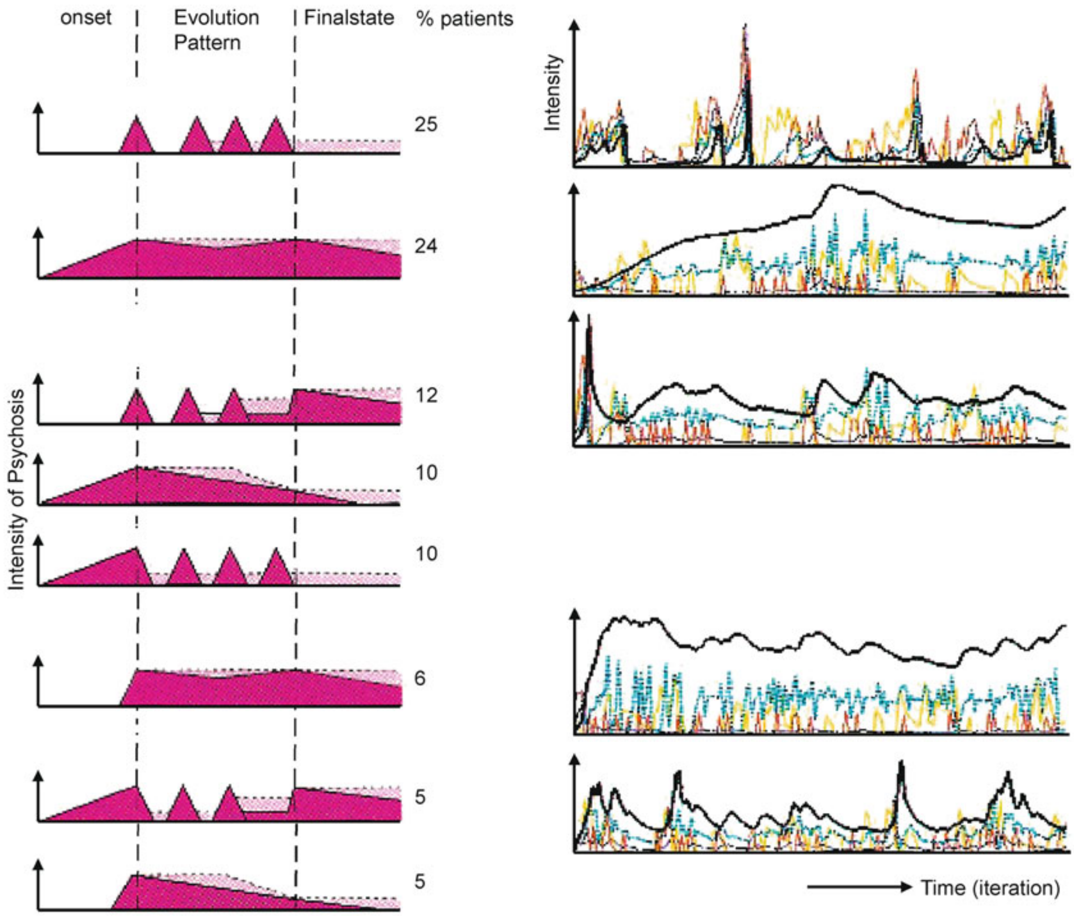
Variables taken into account were chosen from reviews in psychiatric and psychological schizophrenia research (e. g., Böker and Brenner 1996, 1989; Ciompi 1989). Selected were (1) degree of cognitive disorders, (2) emotional and interpersonal stress, (3) withdrawal and social isolation, (4) degree of expressed (negative) emotions in the social environment of the patient, and (5) positive symptoms like delusions and hallucinations. The parameters mediating the nonlinear interplay of these macroscopic variables or order parameters were (a) diffuseness of affective-cognitive schemata as a central long-term vulnerability of mental functioning, (b) dopamine and serotonin metabolism, (c) social deficits and lack of competencies, (d) genetic risk for schizophrenia, and (e) some parameters mediating mixed feedback processes, especially the negative feedback responsible for antipsychotic damping effects of the pathology. Results of the simulation runs are indicated in Fig. 1. The simulation reproduces most precisely (a) episodic patterns with prodromal symptoms and acute onset, (b) acute onset, but continuous evolution with chronic end-state, and (c) slow and smooth onset with chronic long-term course (see also Tretter and Scherer 2006).

Other simulation models are effective on the microscopic level of neural networks. Kruse et al. (Kruse et al. 1997) introduced a model focusing on the coupling dynamics between neurons processing brain correlates of social experiences. If unable to learn from cues delivered by the relevant environment, this system will fail to establish adaptive and coherent structures. When inducing fluctuations which promote re-learning and self-healing processes, the neural network causes incoherent and chaotic behavior. Most current models of schizophrenia take into account the neural circuits of relevant brain regions (cortical areas, basal ganglia like striatum and pallidum, thalamic areas, brain stem centers) and particularly the equilibria between different neurotransmitters and neuromodulators (e. g. Carlsson 2006). The complicated local balances and their (non-) equilibria states are in the focus of the strongly evolving field of computational or systems neuroscience (Friston et al. 2003; Penny et al. 2004).

Not only central neuroscience has benefitted from concepts introduced by synergetics, however, but also physiology studying the effects of the autonomic nervous system (ANS) activities on peripheral systems, such as the cardiovascular, the respiratory, or the microcirculation system. Such activities are most prominent as the ANS engages in the mediation of emotions.

Self-Organized Synchronization Patterns in Peripheral Physiological Systems

For decades, the study of the ANS involvement in emotional arousal and its impact on the cardiovascular system has attracted clinical and scientific



Self-Organization in Clinical Psychology, Fig. 1 Different patterns of the long-term evolution of schizophrenia (empirical data from a study by Ciompi and Müller 1976) *(left)* were reproduced by simulations based on a set of five coupled nonlinear difference equations with different parameter values (Schiepek et al. 1992) *(right)*

attention in psychology and psychophysiology (e. g. Sinha et al. 1992). Ever since the seminal findings of W. B. Cannon (1915) and H. Selye (1936) on the general adaptation syndrome, colloquially condensed as stress, the clinical relevance of emotional responses became ultimately clear. This obvious clinical relevance is thwarted by the fact that direct observations of ANS activity in humans are restricted not only because of ethical constraints but also because of the fear to provoke what they strive to detect. Therefore, the study of the ANS in humans had to rely for a long time preferably on indirect measures, such as the power spectral density (PSD), a linear computation method. Based on the fast Fourier transform (FFT) which extracts periodic components in the frequency domain, the PSD was favored by many researchers due to its computational ease to analyze frequencies inherent in the two branches of the ANS, the parasympathetic (PNS) and the sympathetic nervous system (SNS). This allowed to divide the effects of the PNS and SNS activity on variations of the heart rate, the so-called heart rate variability (HRV), into three major variance components, the very low frequency (VLF) band below 0.04 Hz, the low frequency (LF) band between 0.04–0.15 Hz, and the high frequency (HF) band between 0.15–0.45 Hz. While the origin of both VLF and the HF bands is not debated, controversy reigns whether the origin of the LF band is attributable to SNS activity or whether it represents a mixture of SNS and PNS activity.

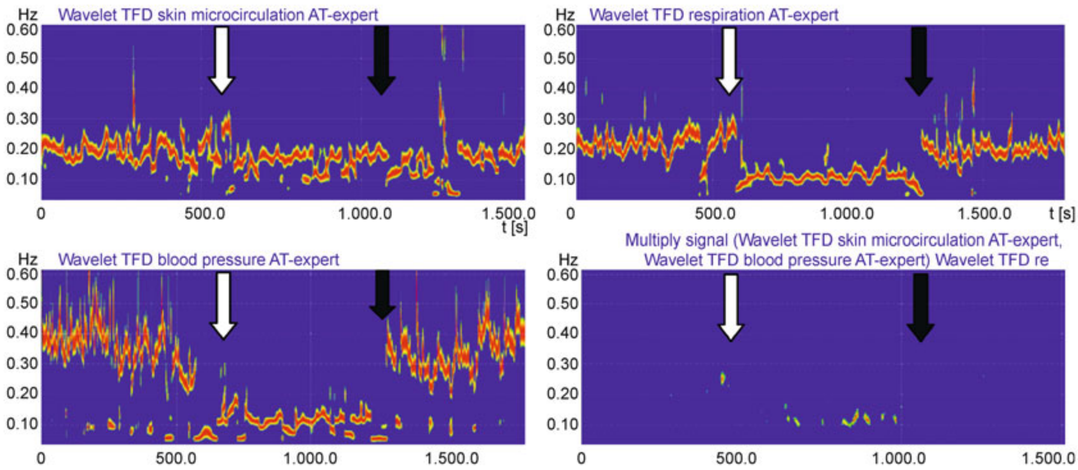
Subsequently, some authors propose calculating the LF to HF ratio assumed to reflect the sympatho-vagal balance (for an overview see Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). There has been growing discontent and criticism as to the validity of such drawer style classifications based on the consideration that the PSD, or FFT resp., as a linear routine is only able to detect linear properties, that are to some extent included in most physiological signals (Kettunen and Keltikangas-Järvinen 2001; Yuru et al. 2006). That, however, should restrict and limit its use since an increasing body of scientific evidence is demonstrating the obvious: In times of adaptation and rapid changes – a hallmark of life and its living systems – healthy ANS activity exhibits nonlinear dynamics necessary to mediate responses appropriate to those change processes. This is particularly the case for emoting as one of the most volatile change patterns.

However, this is not only true for discrete emotion transitions but also for a process crucial for the maintenance of health, namely psychophysical relaxation. Contrary to the rigid scheme depicted above, Perlitz and coworkers have introduced a relaxation model which takes into account adaptive, self-organizing characteristics of the central and peripheral subsystems involved in the psychophysical relaxation process. They scrutinized the physiological conditions and interactions observed with the emergence of a frequency at ca. 0.15 Hz, which in terms of the classical scheme is attributed to the transition between parasympathetic and sympathetic nervous activity. This frequency prevailed at different amplitudes in HRV, blood pressure and respiration, but foremost in the microcirculation of the forehead skin. Using several nonlinear methods, such as wavelet time frequency distributions (TFD) or post-event-scan (PES) analysis, this 0.15 Hz frequency band (range 0.12–0.18 Hz) emerged or erupted with amplified oscillations and periods of 6–7 s in all time series of subsystems under study. The emergence clearly depended on psychomotor drive reduction which can be either reduced by taking naive relaxation maneuvers (such as closing the eyes), or be enhanced using auto-suggestive means, such as autogenic training. Their zest to elaborate the origin of this frequency was supported by invasive observations with anesthetized dogs made by Lambertz and colleagues who had presented their findings earlier. They found a rhythm at a similar frequency which originated in reticular brainstem neurons of freely breathing dogs when administering narcotics to reduce drive. Followed by the emergence in those unspecific reticular neurons, this frequency also emerged in arterial blood pressure, HRV, and respiration (Lambertz et al. 2000; Perlitz et al. 2004b, c). This reticular rhythm, termed retR, was unaffected by changes in the frequency of respiration or arterial blood pressure which could both be presumed to exert distinct influences owing to linear models. Rather, in these experiments respiration and HRV were entrained to the 0.15 Hz band at 1:1, 2:1 and 1:2 integer number ratios which are, according to Bethe (Bethe 1940), an outflow of central-peripheral order–to–order transitions. With regard to parallels in frequency and dynamics observed in man and dog, Perlitz and coworkers suggested that also in humans the 0.15 Hz band most likely originates from reticular neurons of the lower brainstem network (Perlitz et al. 2004a, b, c).

In summary, the findings presented in Fig. 2 underpin the theory of synergetics, since there is reason to regard the ca. 0.15 Hz frequency as an order parameter and the level of mental drive as control parameter. The ca. 0.15 Hz frequency is a prominent example of biological pattern formation lacking external or macroscopic control.

Nonlinear Dynamics in the Communication of Patient and Therapist

As mentioned above, psychotherapy is usually conceptualized as the application of psychological treatments to patients in order to change their problem states and diseases. However, as different research programs revealed during the last decades, psychological change processes show all important features of nonlinear systems – like deterministic chaos, nonstationary phase transitions, and nonlinear coupling between patient

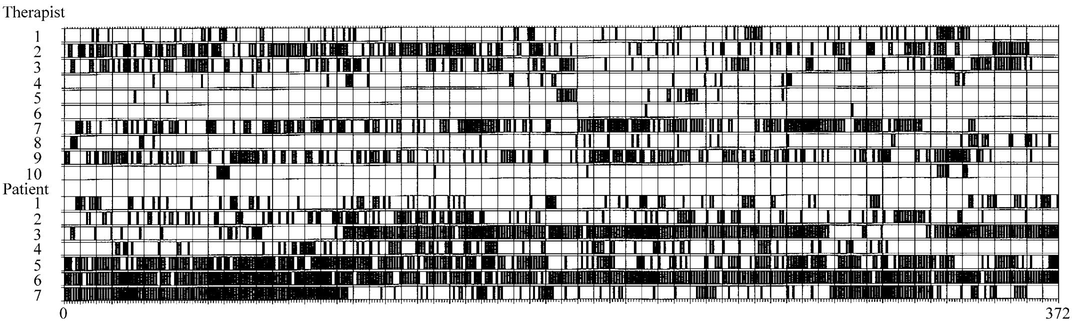


Self-Organization in Clinical Psychology, Fig. 2 Wavelet time frequency distributions (TFD) of peripheral noninvasively obtained recordings of a female expert in autogenic training (AT, 56 yrs., healthy, non-smoker, 15 yrs practice AT). *Top left:* TFD of glabella skin microcirculation photoplethysmography; *top right:* TFD of chest respiration related movements; *bottom left:* TFD of peripheral systemic arterial blood pressure; *bottom right:* So-called "joined TFD" of PPG-, respiration-and blood pressure-TFD, a novel method by Besting and colleagues (2005) (multiplying TFDs yielding only frequencies prominent at identical times and identical frequencies, used to compute the intersection of TFD time series. *White arrows* mark the start of AT, *black arrows* mark the end of AT. In the TFD of PPG, the main frequency is at ca. 0.21 Hz prior to the onset of AT and is clearly stabilized at ca. 0.18 Hz with the start of AT, with signs of dissociation when terminating AT. The TFD of respiration supplies ample evidence of an order-order transition triggered by the practice of AT: The main frequency plummets from ca. 0.25 to 0.15 and 0.07 Hz to be maintained at ca. 0.12 Hz. With termination of AT, the main frequency skips back to frequencies shown beforehand. The TFD of systemic arterial blood pressure exhibits an intersection of approx. 90% during the AT section, but also few minor intersections before and after AT (data not shown); the joined TFD intersection shows merely few frequency "spots" at ca. 0.12 Hz during AT

and therapist. Physiological synchronization appears to be realized at an interpersonal level (between therapist and patient) as well as between different phenomenological levels of the interpersonal system (speech qualities and psychophysiological variables). In a study of Villmann et al. (2008) heart rate, respiratory frequency, muscular tension, and skin conductivity were measured from both, therapist and patient, during 37 therapy sessions. Speech production was analyzed by the Mergenthaler model focusing on emotional feeling and cognitive referential activity/abstraction (Mergenthaler 1998). Physiological data were analyzed by an artificial neural network approach (growing self-organizing map), which uses a kernel smoothing for improved data density estimation. It was possible to generate an entropy model of psychophysiological variability detecting emotionally instable phases during the therapy process. The entropy reflecting psycho-physiological and emotional variability was related to the dramatic value of speech analysis according to the cycle model of Mergenthaler.

Empirical evidence exists also for synchronized chaoto-chaotic phase transitions in the brains of therapist and patient during a therapeutic interview, measured by local largest Lyapunov exponents in the EEGs of both interaction partners (Rockstroh et al. 1997).

Taking into account the importance of the therapeutic relationship for the treatment outcome the attention of a study realized by Schiepek and co-workers focused on the interactional process between therapist and patient (Kowalik et al. 1997; Schiepek et al. 1997). The authors used the method of sequential plan analysis, which is a development of the hierarchical plan analysis proposed by Grawe and Caspar (e. g. 1996). Plans in this sense are verbally or non-verbally



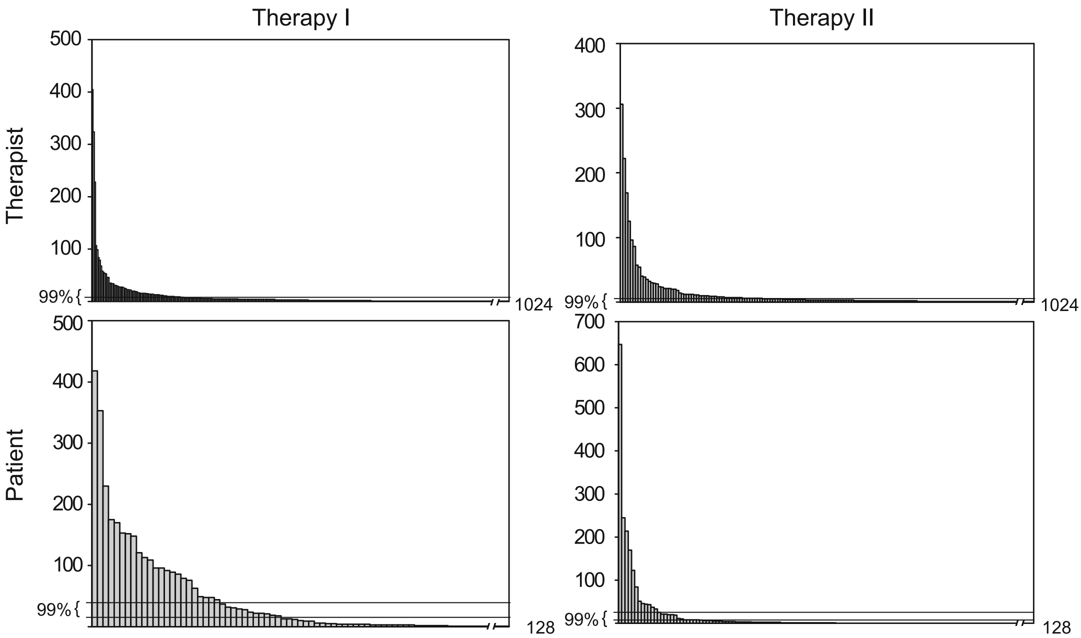
Self-Organization in Clinical Psychology, Fig. 3 Nominal sequences of interactional plans of the therapist *(top)* and the patient *(bottom)* during a psychotherapy session. The sampling rate is 10 s. Different plans can be realized simultaneously. The pattern looks like a music score with the plans representing the different instruments of an orchestra. A sonification of the score of plans coded from a 13-session psychotherapy is recorded on a DVD added to the textbook of Hakenand Schiepek 2006

Self-Organization in Clinical Psychology, Table 1 Second-order plans and categories of self-presentations as identified by the hierarchical plan analysis of a complete 13-session psychotherapy. Encoding of therapist and patient. Plans and categories are used as ideographic observation categories for the sequential plan analysis

	Second-order plans	Categories of self-presentation
Therapist	1 show competence 2 encourage a trusting relationship 3 show understanding 4 motivate her	I encourage trust/create a secure atmosphere
	5 encourage her to reflect on her patterns of thinking 6 confront her with her avoidance and problem behavior	II confrontation/exposing to insecurity
	7 activate her 8 show her that she is responsible	III encourage self-responsibility of the patient
	9 guide her focus of attention 10 give her structure	IV activate structuring work
Patient	1 demonstrate strength and competence 2 make it clear that things are or have been difficult 3 be a good patient/create a good relationship to the therapist	I search for sympathy/appreciation/good relationship
	4 show that your suffering is strongly influenced by external causes 5 ask for help from the therapist	II externalization/demonstration of helplessness
	6 show interest and willingness in solving your problems 7 protect yourself from threatening changes	III problem-oriented work (self-relatedness vs. avoidance)

communicated intentions of self-presentation in a social situation. Patient's and therapist's interactional behavior was analyzed on the basis of video recordings. Two complete therapies (13 and 9 therapy sessions, resp.) were encoded with a sampling rate of 10 s (Fig. 3). The construction of an inclusive hierarchical plan-analysis leads to an ideographic categorical system for the observation of the client–therapist interaction (Table 1).

The first hints of order in the dynamics came from the distribution of simultaneous configurations (on-off-patterns) of plans in the scores. This distribution follows a power law ($1/f^{\alpha}$) demonstrating a distinct structure order within the data (Fig. 4). Following Bak et al. (1989), power law-distributions as demonstrated in Fig. 4 emerge from self-organized criticality within dynamic systems.



Self-Organization in Clinical Psychology, Fig. 4 Empirical frequencies of constellations of interactional plans realized by therapists (10 plans) and patients (7 plans) within two psychotherapies (therapy I: 13 sessions, therapy II: 9 sessions). *X*-axis: Number of all possible configurations of plans (therapist: $2^{10} = 1024$, patient: $2^7 = 128$) ordered by the frequency of their realization. *Y*-axis: Frequencies of plan configurations. The distributions follow a power-law (**1/*f*^α^**) distribution

Further data analysis was based on the time series of the highest-level categories, the so-called categories of self-presentation (see Table 1). Since in the hierarchical system of the plan analysis the operators at the lowest observation level were quantified by intensity ratings, the plans and the self-presentation categories at the top level integrating the lower level categories were also quantified. The time series were analyzed by methods which are sensitive to the nonlinearity as well as the nonstationarity of the time series (Haken and Schiepek 2006; Kowalik et al. 1997; Schiepek et al. 1997; Strunk and Schiepek 2006). Nonlinearity was proofed by surrogate data tests (Rapp et al. 1994) using random surrogates and FFT-based phase-randomized surrogates (Strunk 2004). Whereas fractal dimensionalities of the empirical time series (based on the correlation dimension D2 as well as mean Pointwise D2 (Skinner et al. 1994)) saturated at finite values (convergence to a fractal dimensionality of about 6), random and FFT-surrogates did not. The methods of PD2 (Skinner et al. 1994) and of the local largest Lyapunov exponents (algorithm from Rosenstein et al. 1993) were used to identify phase-transition like discontinuities. Following the evolution of PD2 dimensionalities, both therapies realized nonstationarities, and both therapies showed periods of strongly synchronized (with correlations from 0.80 to 1.00) and anti-synchronized PD2-processes (with correlations from –0.80 to –1.00) between patient and therapist. Quite similar and even more pronounced dynamical jumps were to be seen in the development of the local largest Lyapunov exponents (Fig. 6), representing changes in the chaoticity of a time signal (Kowalik et al. 1997). An important part of the discontinuities of the LLLE were exactly synchronized between patient and therapist. Obviously both persons create a dynamic self-organizing communication system, which allows for the individual change processes of the patient.

These results get support from nonlinear coupling measures between the time series of the interaction partners. Pointwise transinformation as well as pointwise coupling conditional divergence (Lambertz et al. 2003; Vandenhouten 1998) were applied to the data, and both indicate changing and time-dependent coupling strengths between the time series of the interaction partners. There is no priority to the therapist's influence on the patient, which contradicts the classical idea that input from the therapist should determine the client's output. The other way round is also true and both constitute the circular causality of psychotherapeutic self-organization.

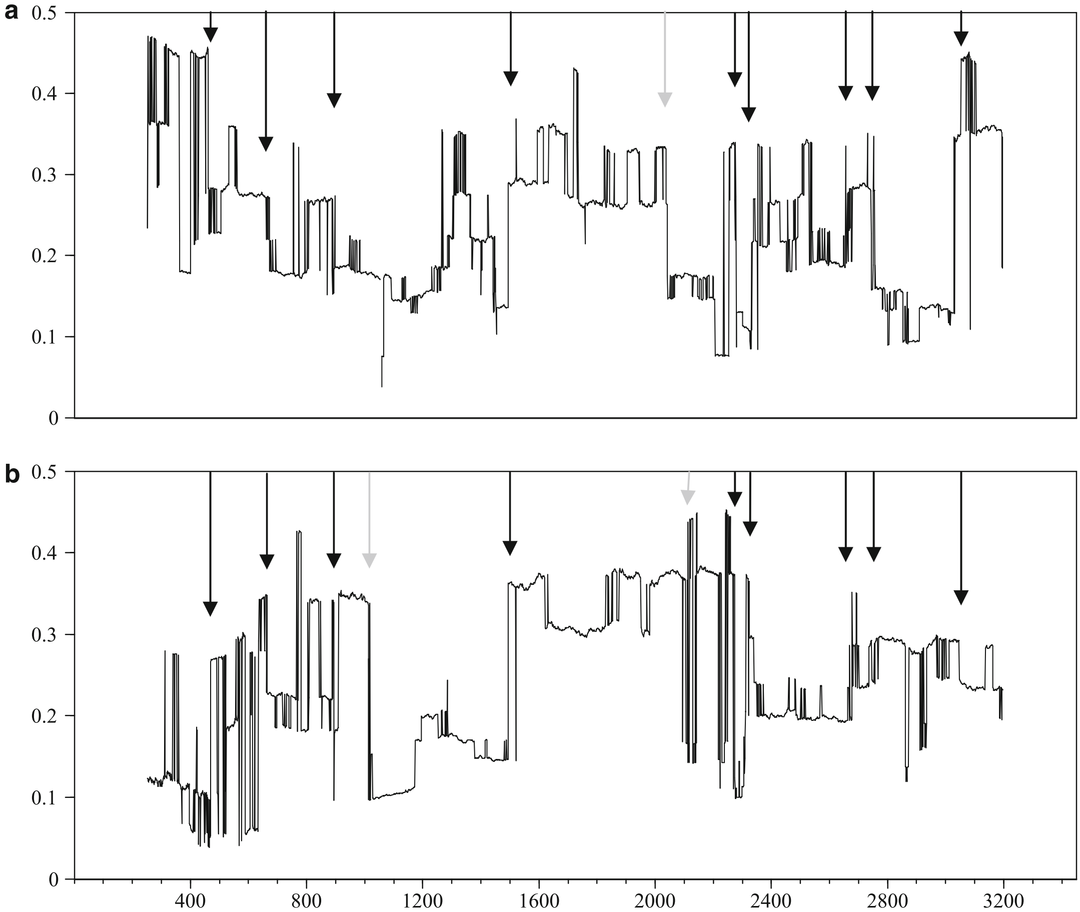
In other studies, sequential plan analysis was applied to the microdynamics of group interaction (Haken and Schiepek 2006). In a group of five persons a creativity and problem solving task was to be solved within 2,5 h (creation of ideas, rules, and physical handicraft realization of a prototype board game from different materials). Similar to the psychotherapy study the sampling rate was 10 s. The superordinate plans which could be identified for all five persons were (1) spontaneity and emotional engagement vs shyness, restricted behavior, and orientation to social norms, (2) engagement in the group interaction and in positive social climate, (3) task orientation. Length of time series was about 810 coding points (= intervals). D2 as well as mean PD2 estimates saturated at a fractal dimensionality of about 5 for all categories. The embedding of the time series was realized by two ways: (1) The phase space was constituted by the three dimensions of superordinated plans with five trajectories representing the five group members, or (2) the phase space was constituted by the five persons with three trajectories representing the time course of the three plans (additional embedding dimensions result from time delay coordinates). In both cases PD2 results show an evolving pattern of quasi-attractors with changing complexity and LLLEs (algorithm from Rosenstein et al. 1993) portray chaoto-chaotic phase transitions with clear-cut and interpersonally synchronized jumps – similar to the dyadic interaction of the psychotherapy study.

Self-Organization in Human Change Processes

A quite different approach to human change processes focuses on inpatient treatments at a hospital of psychosomatics. In a study by Schiepek and coworkers (results in Haken and Schiepek 2006) 94 change processes were investigated, realized by 91 inpatients with different diagnoses (depression, anxiety disorders, posttraumatic stress disorders, eating disorders, somatoform disorders, and others). The time series data was produced by patients' self-ratings which were completed once a day in the evening. For this purpose a 53-item rating sheet was developed (*Therapy Process Questionnaire [TPQ],* Haken and Schiepek 2006) whose factor analysis resulted in a solution of seven factors defining the subscales of the questionnaire (Table 2). The ratings combined seven-step Likert scales and visual analogue scales especially for ratings of emotions. TPQ measurements reflect important aspects of the patient's experience of progress and goal attainment, emotional involvement, self-efficacy, therapeutic relationship, social relations with other inpatients, and the ward atmosphere.

The inclusive outcome criterion integrated the following measures: Inventory of Interpersonal Problems (IIP), Gießener Beschwerdebogen (GBB), Hospital Anxiety and Depression Scale (HADS), Questionnaire for Social Support (F-SOZU), a life-quality questionnaire (Münchener Lebensqualitäts-Dimensionenliste), a self-efficacy questionnaire (Fragebogen zur Generalisierten Kompetenzerwartung), the Sense-of-Coherence Questionnaire, and an interview-based assessment of personal resources. Additionally, therapists and patients scored the overall treatment effectiveness and treatment quality.

Results confirmed synergetic conceptualizations of how psychotherapy works and corroborated hypotheses drawn from this model. Here therapy is supposed to provide support for the patient's own self-organization processes, which should be characterized by cascades of order-to-order transitions accompanied by critical instabilities of the process. Pathological and restrictive order should be transformed into more flexible and adaptive patterns of behavior, and the

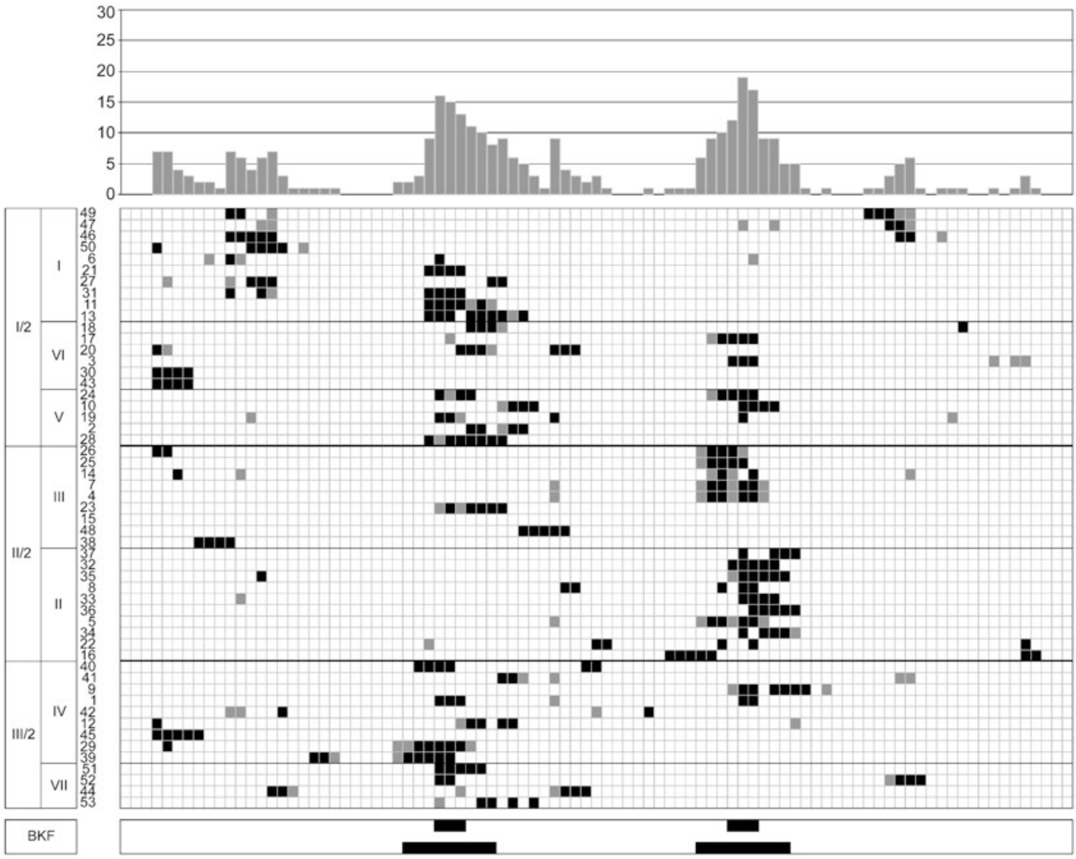


Self-Organization in Clinical Psychology, Fig. 5 Synchronized jumps in the dynamics of local largest Lyapunov exponents *(black arrows). Grey arrows* indicate not clearly synchronized changes. (**a**) Therapist, (**b**) Patient

synchronization of the different aspects of the patient's experience should undergo some transformations. Exactly this could be observed.

Significant correlations exist between the local maxima of critical fluctuations and the outcome of psychotherapy. The local maxima were defined by the difference between the mean dynamic complexity of the whole psychotherapy process and the maximum of the complexity which was observed during the process. Correlations were –0.455 (second-order factor I: "Change involvement" of the TPQ, $p = 0.002$), –0.431 (second-order factor 2: "Relationship/social climate", $p = 0.003$), and –0.572 (second-order factor 3: "Emotionality", $p = 0.000$) (compare Table 2). Negative correlations result from the fact that increased local maxima of dynamic complexity correspond to reduced problems, symptoms, and impairment.

The *dynamic complexity* combines a fluctuation index with a distribution index. The fluctuation index measures the frequency and amplitude of the change rates of a time series between the reversals of the development within a scanning window gliding over the whole time series. For analysis purpose a window width of seven measurement points (= days) was introduced. The distribution index measures the scattering of realized values within a given scanning window. The more scores are restricted to only narrow intervals of the available scale range, the smaller the distribution index becomes. The score of this index



Self-Organization in Clinical Psychology, Fig. 6 Complexity resonance diagram of a psychotherapy process. Such diagrams portray the threshold exceeding dynamic complexities of a process encoded by the 53 items of the Therapy Process Questionnaire (TPQ). *Gray dots:* 5% threshold of significance; *black dots:* 1% threshold of significance. *X*-axis: Days of hospital stay, *Y*-axis: Items of the TPQ arranged by the order of the factors as reported in Table 2. Window width for the calculation of dynamic complexities is 7. Column-like structures indicate phases of critical instabilities during the process

Self-Organization in Clinical Psychology, Table 2 Factors (principal component analysis) of the Therapy Process Questionnaire (TPQ). Factor analysis was based on 94 therapy processes (mean stay = 66 days, daily ratings). Seven first-order factors *(right)* are related to three second-order factors *(left)*. Numbers behind the first-order factors indicate factor loadings on second-order factors (for details see Haken and Schiepek 2006)

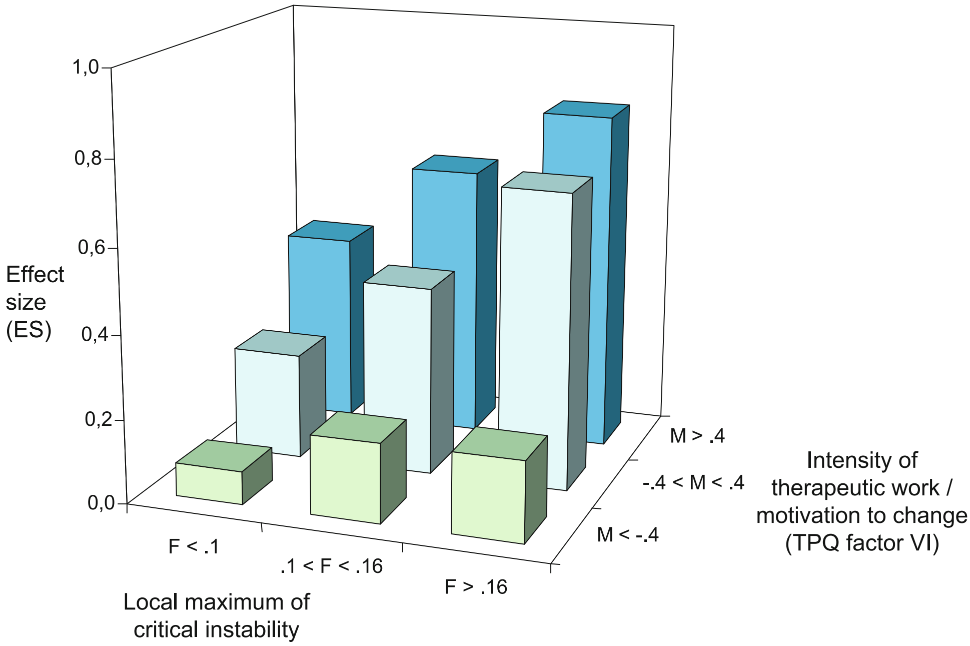
I(2) Change involvement	I Therapeutic progress/confidence in treatment effects/self-efficacy (.571) VI Intensity of therapeutic work/motivation to change (.596) V Opening of perspectives/personal innovations (.649)
II(2) Relationship/Social climate	III Quality of the therapeutic relationship/openness/confidence in the therapist (.705) II Ward atmosphere, social relationship to other inpatients (.692)
III(2) Emotionality	IV Dysphoric emotions/self-relatedness (.732) VII Impairment by symptoms and problems

increases as the interval filled by the realized values grows. The algorithm solves the problem of value distribution independently of the scale resolution, the width of the scanning window, and of any combination of these parameters.

In order to answer the question if the observed intensities of dynamic complexity reach critical values, intraitem calibration procedures were used in order to define adequate thresholds fitting to the actual dynamics. The time series of dynamic complexity were standardized by z-transformations, providing significance thresholds of 5% or 1%. Applying this threshold method to all items of the TPQ reduces the quantitative complexity signals of each time series to a three-step signal (not significant, complexity exceeds a 5% threshold, complexity exceeds a 1% threshold). A synopsis of these qualitative signals referring to all items of the TPQ gives an impression of the localization of critical fluctuations during the whole process. Dynamic complexities seem to be synchronized over many items and factors of the TPQ, resulting in the structure of columns of grey (< 5%) or black (< 1%) dots. In a large part of the investigated therapies such column-like structures could be identified. In an item-by-time synopsis they indicate phases of intensified as well as synchronized fluctuations and entropies of quite different aspects of the process. Consequently, these item-by-time synopses are called *complexity resonance diagrams* (Fig. 6).

In order to confirm the structures found within the complexity-resonance-diagrams, surrogate tests were realized based on random as well as on FFT-based surrogates of the time series. The empirical patterns are impressively different from the surrogate-based patterns (all realized comparisons with $p = 0.000$). Further support for phase-transition like phenomena in the change processes came from recurrence plots representing similarities and dissimilarities of dynamic segments of a whole time series (Eckmann et al. 1987; Vandenhouten 1998; Webber and Zbilut 1994). This method is based on the embedding of time series into a phase space constructed by timedelay coordinates, a method which is also crucial in the algorithms for the estimation of dimensional complexity or chaoticity (e. g., Kolmogorov–Sinai-Entropy, Lyapunov Exponents). Neighbors in the time-delay phase space represent similar dynamic segments and are plotted by a dot in the recurrence plot. Dissimilarities are represented by empty columns in the recurrence plots, which in many cases exactly correspond to the columns of dots in the complexity-resonance diagrams. The overall correlation is –0.45, if small shifts (lags of + or –3 measurement points at maximum) will be allowed. This means that periods of critical instability correspond to transient dynamics outside of the quasi-attractors established by the self-organizing system under consideration. These different ways to identify critical phase transitions are further validated by the time frequency distribution (TFD) of the time series. The TFD method uses wavelet spectra in order to scan the evolution of the frequency distributions within a signal (Lambertz et al. 2003; Vandenhouten 1998). It is a dynamic counterpart to the static fast Fourier transformation and allows for the identification of pronounced frequency amplitudes or changes in the frequency distributions. In the data set of the referred study these often appear exactly during the phase transitions which can be identified by other methods (see the synoptical representations of different time series analysis methods on the DVD in the textbook of Haken and Schiepek 2006).

An overall result of the study is shown in Fig. 7. It portrays the evidence that in order to bring forth change processes within self-organizing systems at least two conditions should be realized. The first condition: The degree of the control parameter energizing the system and pushing it away from its actual equilibrium state should exceed a certain intensity level. With respect to psychotherapies this control parameter could be the patient's motivation to change including his engagement into the therapeutic work. Second condition: The degree of instability the system attains during its change process. This instability during emerging symmetries and symmetry breaking transitions is given by the local maximum of dynamic complexity during the hospital stay. The interaction of both conditions results in treatment effectiveness. A third important condition is not represented in Fig. 7: It is the experienced stability of the outer environment (context at the ward or therapeutic bond) or of the inner environment (as self-esteem,



Self-Organization in Clinical Psychology, Fig. 7 The effect size (ES) (mean ES of all outcome measures introduced in the study, see text) of inpatient psychotherapy is produced by an interaction between the local maximum of critical fluctuations and the intensity of the control parameter realized during the change process. The local maxima of fluctuations were defined by the difference between the mean dynamic complexity of the whole therapy process and the maximum of the complexity observed during the process. The diagram is based on the mean of the local maxima of all items. The control parameter was defined by the overall mean of the TPQ factor VI: Intensity of therapeutic work/motivation to change

self-confidence, or activated resources). This context of stability is a prerequisite for a system to undergo critical instabilities.

The Concept of Self-Organization Promotes New Information Technologies in Clinical Psychology – The Synergetic Navigation System

Since self-organization and nonlinear dynamics seem to be ubiquitous in human change processes, it should be helpful to go beyond the diagnostics of steady states to an assessment of dynamics. Practitioners should get information on the therapy and its features *during* the ongoing process in order to use this information for an adequate placement of interventions and a control of the dynamics. “Controlling” self-organization processes in psychotherapies means the generation and co-creation (together with the patient) of adequate boundary conditions, the decision to do or to retain certain interventions, and to support the dynamics which the system is creating by itself. The patient takes an active and cooperative role in this understanding of data-based and co-creative change processes. Another important motivation for the development of real-time assessment comes from the evidence that most of the empirically identified specific and non-specific factors driving therapeutic change processes are connected with specific persons (the concrete therapist who meets a concrete patient in a concrete setting) and evolve by its nonlinear interactions in specific systems. These factors are (i) personal features of the patient like his motivation to change, his premorbid adaptation and degree of social functioning, personality integration, ego-strength, or comorbidities, (ii) personal and professional features of the therapist like his own personality integration, social and professional competencies, allegiance to his approach of doing therapy, stress-resistance, and so on, and (iii) factors of the professional and social context (see the so-called generic model of psychotherapy

Lambert and Ogles 2004; Orlinsky et al. 2004). In consequence, *evidence-based treatments* should be based on the evidence of concrete data mirroring the ongoing change process and on the professional decisions reflecting this insight.

Real-time monitoring actually uses internet-based presentations (including PDA or cell phone technology) of outcome and process questionnaires. Data are sent to a server, where they are stored and analyzed. Professionals and patients can inspect the results whenever they want. Experiences with real-time feedback to therapists (based on an outcome questionnaire the patient fills out during the therapy sessions in an ambulatory or outpatient context) are encouraging. Lambert and co-workers (e. g., Lambert et al. 2002) were able to identify processes on the way of getting difficult or unsuccessful ("not on track" therapies, compared to more promising "on track" therapies), and helped therapists to correct these not-on-track dynamics by specific interventions. By this, threatening drop-outs could be avoided, bad results could be corrected, and on-track processes could be optimized and even shortened.

More sophisticated than the distinction between "on-track" and "not-on-track" courses is the feedback on self-organization features realized by a system based on synergetics (Haken and Schiepek 2006). The *Synergetic Navigation System* uses the therapy process questionnaire for daily ratings and applies methods from nonlinear time series analysis in order to identify important qualities of the change process. This are:

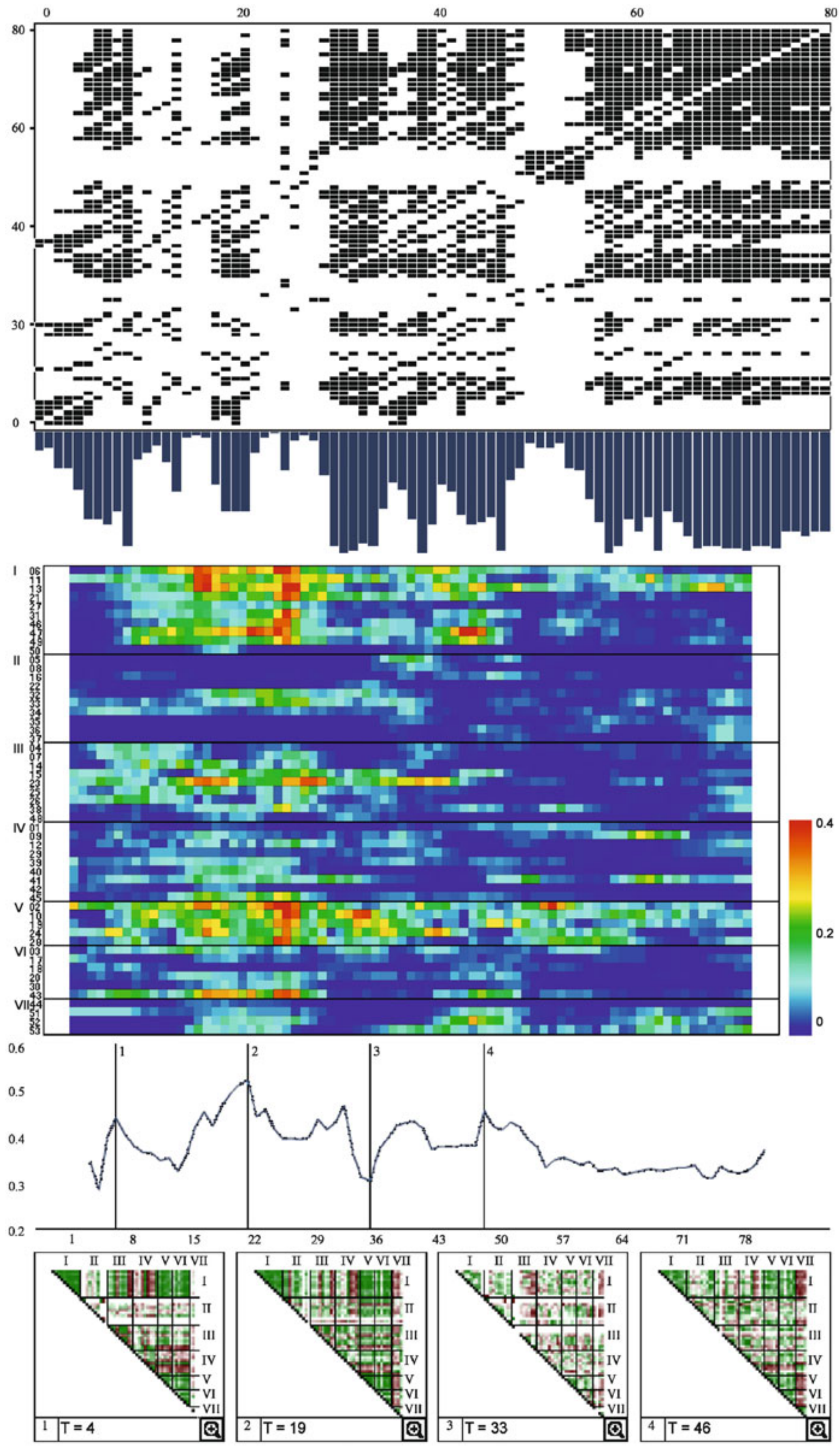
- Stability or instability of the dynamics as represented by the subscales (factors) of the TPQ (see Table 2), which is measured by the dynamic complexity
- Recurrence plots indicating transitions or repeating patterns
- Intensity of synchronization and time-dependent synchronization patterns between the items and the factors of the TPQ (realized by the cross-correlations of all items of the TPQ, calculated within a running window).

Figure 8 shows a synopsis of these analysis methods applied to a specific change process. Preceding the inspection of all analysis results the raw data series of the items and the time courses of the factors (z-transformed values) are available. Additionally patients can write an electronic diary after filling out the questionnaire. The diary entries can be presented within a gliding tiptool running over the time series. By this, corresponding qualitative and quantitative information completes the picture.

The Self-Organizing Brain

The human brain is one of the most outstanding examples of a complex nonlinear system producing self-organized patterns of functioning. Since function corresponds to structure and vice versa, structural changes (changes of intersynaptic coupling strengths and network configurations, (re-) wiring patterns following the synchronized coactivity of neurons) can be explained by functional self-organization of neural populations. Perception, action and transition of action patterns, decision making, and cognitive, behavioral, as well as emotional learning are psychological functions following the principles of self-organization (Haken and Schiepek 2006). At a neural level they correspond to and are based on nonlinear brain dynamics. The emergence of order parameters and the occurrence of phase transitions can be described and measured on a psychological as well as on a neural level.

One of the phenomena modeled by synergetics is Gestalt perception – the construction of percepts and the switching of ambiguous visual patterns (e. g., Necker cube or stroboscopic alternative motion). These processes of Gestalt perception constitute the link between Gestalt psychology and actual mathematical modeling in synergetics (Haken 1990b). The binding of different perceptual features or components to coherent structures or "qualia" seems to be due to synchronization processes of extended brain regions and converging integrative areas (Singer and Gray 1995). Pattern perception corresponds to pattern formation – as H. Haken puts it into pointed words. Tallon-Baudry et al. (Tallon-Baudry and Bertrand 1999; Tallon-Baudry et al. 1997) measured enhanced gamma-band activity (30–50 Hz) in the EEG of the primary and secondary visual



Self-Organization in Clinical Psychology, Fig. 8 Synopsis of a psychotherapy process as monitored by the Synergetic Navigation System. The time course of the inpatient treatment of a patient with eating disorders cortex while subjects identified a triangle within the offered stimulus material. This could be a fingerprint of corresponding neural synchronization processes. This activity occurred when subjects saw a real object (triangle) as well as a figural illusion of the object (Kanizsa triangle), but not if geometrical components could not be composed to a true Gestalt. The research group of Basar–Eroglu and Stadler (Basar-Eroglu et al. 1996) measured significant gamma-band activity in EEG during states of perceptual switching triggered by stroboscopic alternative motions. In summary: Perception of multistability is one of the multifold cognitive processes giving rise to 40 Hz enhancement in the cortex, and coherent oscillations reflect an important mechanism of feature linking in the visual cortex which corresponds to the emergence of a neural order parameter. Changing order parameter dynamics during different cognitive activities was shown by Schupp et al. (Schupp et al. 1994). Mental imagery of an object could be differentiated from its concrete perception. The dimensional complexity of prefrontal EEG was increased during sensory imagery compared to the real perception of the same object (compare Lutzenberger et al. 1992).

The well-known movement coordination paradigm modeled by Haken et al. (Haken et al. 1985) was used to demonstrate neural correlates of instability and symmetry breaking processes in the motor brain. The order parameter in this finger movement experiment is the relative phase of the index fingers of both hands. Metronome-pacing – with movement frequency as the control parameter – triggers the system from parallel (out-of-phase) to mirror (inphase) movement. Meyer-Lindenberg et al. (2002) showed that the emergence of patterns in open, nonequilibrium systems like the brain is governed by their stability in response to small disturbances. Transitions could be elicited by interference at the neural level. Functional neuroimaging (PET) identified premotor (PMA) and supplementary motor (SMA) cortices as having neural activity linked to the degree of behavioral instability, induced by increasing frequency of the finger movement. These regions then were transiently disturbed with graded transcranial magnetic stimulation (TMS), which caused sustained and macroscopic behavioral transitions from the less stable out-of-phase to the stable in-phase movement, whereas the stable pattern could not be affected. Moreover, the strength of the disturbance needed (a measure of neural stability) was linked to the degree of the control parameter (movement frequency) and thereby to the behavioral stability of the system.

Synergetic research in clinical psychology is now reaching the brain level. The aim of an actual fMRI-study (Schiepek et al. 2008) is the investigation of phase transitions of brain activity and related subjective experiences of patients during their psychotherapy process. Repeated fMRI scans are related to the degree of stability or instability of the ongoing dynamics (measured by the dynamic complexity of daily TPQ-ratings) as well as to the therapy outcome. Realtime monitoring by the *Synergetic Navigation System* allows for the identification of stable or unstable periods and by this for a decision on the appropriate moments of fMRI acquisitions. Three or four scans are realized during each of the psychotherapy processes of 15 patients. The study includes only patients with obsessive-compulsive disorder (OCD) of the washing/contamination fear subtype (DSM IV: 300.3), without any

Self-Organization in Clinical Psychology, Fig. 8 (continued) portrays a clear cut phase-transition associated with critical instabilities. *Top:* Recurrence plot of the item "Today I was successful to do steps towards my personal goals". *Dots* represent recurrent segments of the time series, empty spaces represent transitions. *Middle:* Complexity resonance diagram of all items of the TPQ. Different from Fig. 6, the intensities of the dynamic complexity of each item is transformed into colors. Items are arranged by the order of the first-and second-order factors of TPQ. *Bottom:* Mean of all interitem correlations irrespective of the sign (absolute values). This is a measure of the overall synchronisation of the patient's experiences as represented by the items of the TPQ. The correlation structure is shown at four measurement points (days) of the psychotherapy process ($t = 4$, $t = 19$, $t = 33$, $t = 46$). Intensity of green represents positive correlations, intensities of red represents negative correlations medication or comorbid psychiatric or somatic diagnoses. Patients are matched to healthy controls. (This research is a multi-center study of the Ludwig-Maximilians-University Munich, Institute of Psychology (Prof. Dr. Günter Schiepek, head of the project), and Clinic of Psychiatry (PD Dr. Oliver Pogarell, Dipl. Psych. Susanne Karch, Dr. Christoph Mulert), Hospital of Psychosomatic Medicine Windach/Ammersee and Day Treatment Centre Munich/Westend (Dr. Igor Tominschek, cand. Psych. Stephan Heinzel, Prof. Dr. Michael Zaudig), University Hospital Vienna/Astria, Clinic of Psychiatry (Prof. Dr. Martin Aigner, Prof. Dr. Gerhard Lenz, cand. med. Markus Dold, Dr. Annemarie Unger), MR Centre of Excellence, Medical University Vienna/Austria (Prof. Dr. Ewald Moser, Dr. Christian Windischberger).

OCD seems to be an appropriate model system for synergetic studies in clinical psychology, since the pathological order parameter is phenomenologically quite evident, the disease has an obvious and quite stable time course, and therapeutic phase transitions – if they do occur at all – are easy to be observed. OCD-specific functional neuroanatomy is partially known: Friedlander and Desrocher (Friedlander and Desrocher 2006) report on an executive dysfunction model corresponding to the cortico-striato-thalamo-cortical feedback-loops involved in perseverations and compulsions, and on a modulatory control model involved in the pathological mechanisms of anxiety and distress provoking obsessions.

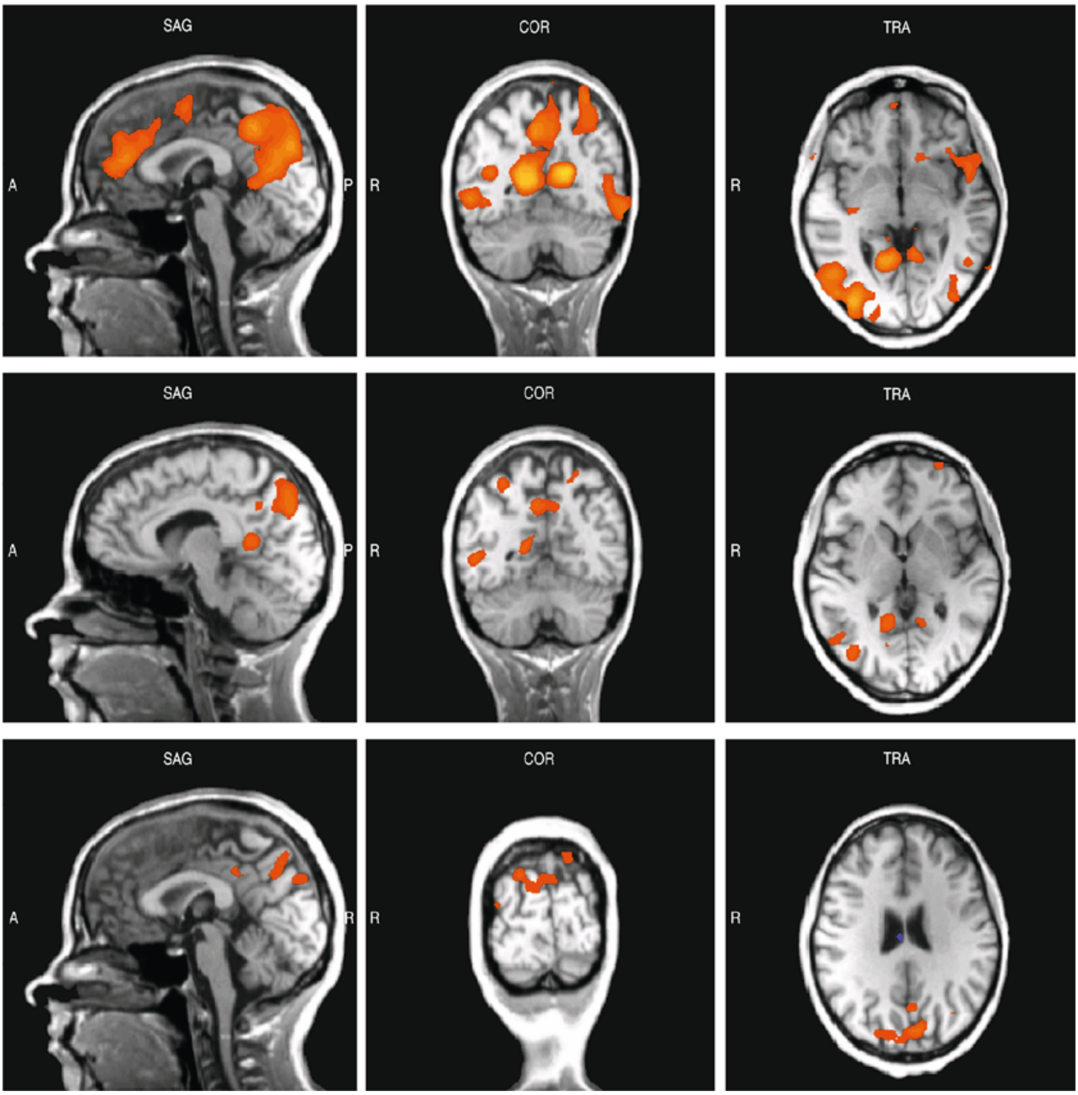
The visual stimulation paradigm of the study uses symptom provoking, disgust provoking, and neutral pictures. The disgust and the neutral pictures are taken from the International Affective Picture System, whereas the OCD-related pictures are photographed in the home setting of the patients, showing specific and individualized symptom provoking stimuli.

For illustrative purposes we report on the results of a single case. It is a female patient, whose fMRI scans were taken three times during the 59 days of their hospital stay at days 9, 30, and 57. The healthy control was also scanned three times at identical time intervals as the patient. The second acquisition was done after an intensive period of critical instability of the TPQ-based time series, but just before the flooding was started. (Flooding or response prevention is an essential therapy technique in the treatment of OCD, where patients are confronted with symptom provoking stimuli but abstain from performing compulsive rituals.) The instability of the patient's process was the precursor of an important personal decision to divorce from her husband. (It should be noted that the development of her OCD symptoms was in the context of a long-lasting marital conflict.) This decision was the essential phase transition of the therapy.

Indeed, the most pronounced changes in brain activity occurred from the first to the second fMRI scan, whereas BOLD response differences from the second to the third session were only slight. They perhaps represent the neural correlates of an important personal phase transition related to the resolution of a severe personal conflict. Because these changes occurred before the flooding procedure was started, this can be seen as indicator of an early rapid response in the therapy (Lambert and Ogles 2004). Additionally, marked alternations in brain activity were to be observed before or during symptom reduction took place (measured by the Y-BOCS), not afterwards.

Alternations in brain activity involved widespread areas, e. g. the medial frontal brain regions including anterior cingulate cortex, superior and middle frontal gyrus, inferior frontal and precentral gyrus, superior temporal gyrus, superior parietal lobe, cuneus, thalamus and caudate nucleus in both hemispheres, as well as the right fusiform gyrus (see Fig. 9 for a OCD to disgust contrast). Thalamic and basal ganglia activation is part of the dorsolateral-caudate-striatum-thalamus circuitry of OCD. Especially the caudate nucleus takes a role within the executive dysfunction model of compulsions, and its activity has been found to be reduced after treatment (Nakao et al. 2005).

The function of the anterior cingulate cortex is interesting with regard to synergetics. The cingulate cortex comprises various functions like somatosensoric integration, mediation of affective and cognitive processes, control of attention, and processing of painful stimuli. Additionally, it plays an important role as conflict monitoring system: It is sensitive to ambiguous or conflicting



Self-Organization in Clinical Psychology, Fig. 9 Brain activation patterns of a patient with OCD during psychotherapy. BOLD signals from a 1.5 Tesla fMRI scanner. *Top:* First scan (9th day of hospital stay; $x = 0, y = -55, z = -2$; p(uncor) < 0.001). *Middle:* Second scan (30th day of hospital stay; $x = 8$, $y = -54$, $z = 5$; p (uncor) < 0.001). *Bottom:* The third scan (57th day of hospital stay; $x = 0$, $y = -85$, $z = 26$; p(uncor) < 0.001). Activations during the presentation of OCD-related pictures compared to activations during the presentation of neutral pictures (OCD > disgust)

information (van Veen and Carter 2002a, b), is involved in decision making (King-Casas et al. 2005; Sanfey et al. 2003), and its activation is predictive to treatment outcome in depression (e. g. Mayberg et al. 1997). This is true especially for the dorsal (cognitive) structures of the ACC. It could be an indicator of symmetry states of brain functioning, which is characterized by two or more dynamic patterns or attractors in competition. In the present case, the ACC activation at the beginning of the therapy could be either part of the pathology or could be indicative for the critical instability of the cognitive-affective system of the patient, preparing her important decision. The second fMRI measure was conducted during a local minimum of critical fluctuations. If the impressive change in cingulate activation could be attributed to a changed critical symmetry state of the neural self-organization before vs. after the phase-transition or to changes in symptom severity cannot be decided within a single case study, but seems to be an interesting question to further research. Perhaps the fact that during the second fMRI measure the Y-BOCS score was nearly on the same level as during the first measure – only 14% reduction, compared to 50% reduction in dynamic complexity – could be a first argument in favor of the instability hypothesis.

The paradigm of self-organization is a very promising approach to clinical as well as other fields of psychology. Its interdisciplinary is due to the fact that the laws and principles of self-organization are true for neural, mental, and behavioral processes (and the corresponding data qualities). Interdisciplinary cooperation is underpinned by the unifying terminology as well as by the unifying formalism and modeling tools of synergetics. This opens new perspectives for basic and applied research, but also for the treatment of mental disorders. New developments in the real-time monitoring of human change processes based on synergetics and nonlinear science have been mentioned. Another field of encouraging developments is deep brain stimulation (DBS), which apply to neurological diseases as Parkinsonian or essential tremor, but also to psychiatric disorders as OCD or mayor depression (Tass et al. 2003). The difference between new technologies (applying the mathematical instruments and concepts of synergetics as well as methods from stochastic phase resetting) and classical electrical deep brain stimulation is that normal DBS at high frequencies has a blocking effect on the stimulated target and mimics the effect of tissue lesioning. New technologies are demand-controlled, working with low stimulation frequencies, and avoid the suppression of neurons' firing. Its effect is a desynchronization of pathologically synchronized populations of neurons, using multi-site coordinated reset stimulation (Tass and Hauptmann 2007) or nonlinear delayed feedback stimulation (Popovych et al. 2006). Both methods counteract abnormal interactions and detune the macroscopic frequency of the collective oscillators – that is the abnormally established order parameters of neural synchronization. Thereby they restore the natural frequencies of the individual oscillatory units. Neurons get in the range of physiological functioning and can engage in changing and varying synchronization patterns. If altered synchronization patterns also change the coupling strength connecting synapses, a rewiring of neural nets could be reached. Changed function triggers the emergence of healthy attractors and by this changes the structure of neural networks. Perhaps in the future technologies of DBS or even non-invasive brain stimulation could be combined with psychotherapy and psychological navigation instruments developed to optimize self-organizing change processes.

Future Directions

The future developments of self-organization and complexity research in clinical psychology and psychotherapy will be interconnected to its acceptance in practice and training. Perhaps this sounds paradoxically, since in most other scientific fields the future depends on the investigations to basic research and to new technologies. Of course this holds also for synergetics and its applications to clinical psychology. However, it should be noted that complexity research and nonlinear dynamics are done since more than two decades in European academic psychology with poor impact to mainstream science. So, the future will depend on a greater number of new arriving and highly qualified students in this topic who do not avoid the touch with mathematics. Self-organization and complexity research including its mathematical backgrounds should become part of the training curricula in psychology and psychotherapy. Since the Synergetic Navigation System waits for its broad application in clinical and psychotherapeutic practice, a new decade of practice-based research can be started. But these developments depend on its acceptance by practitioners because of the competencies required for the widespread use of sophisticated methods. This integration of science with practice will open huge sources and new dimensions of data gathering on dynamic systems. An important database for outcome and time series data (including biomarkers) of human change processes is actually prepared.

Another stream of development is concerning the integration of psychological and biological/physiological data. Since human self-organization takes place on synchronized mental, social, and biological system levels, all of them should be taken into account in further research. One research paradigm was suggested in this chapter: The investigation of individual and social processes by the Synergetic Navigation System, and in parallel repeated brain scans using fMRI technology or other methods to get insight into brain dynamics (EEG, gene expression markers Koch et al. 2002, immune or endocrine markers Schubert and Schiepek 2003, or others). Two final remarks: First, future developments of synergetic-based minimal invasive DBS could be combined with psychotherapy and psychological interventions – as pharmacological and psychological treatments are combined nowadays. Second, the nonlinear networks underlying psychological as well as neural self-organization will not be understood without applying appropriate mathematical tools, giving raise to a new systemic psychology and neuroscience.

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