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Complexity and Nonlinear Dynamics in Psychotherapy

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Human life changes with time. It seems therefore obvious that most of the phenomena that psychology and psychotherapy are concerned with are dynamic in nature. For human development processes, human change and learning processes, the dynamics and prognosis of mental disorders, problems manifesting in social systems such as couples, families, teams, or the question of how psychotherapy works, self-organization is ubiquitous. In the context of self-organization, complexity is a quality of changing patterns and patterns of change, produced by nonlinear coupled systems.

Anomalies of the linear input–output model of psychotherapy

A huge amount of empirical outcome studies and reviews (meta-analyses) supports the evidence that psychotherapy works – its efficacy is comparable to other medical treatments. The usual conception is that it works due to the applied methods of treatment. The input makes the output, and the treatment causes the effect. The specific factors producing the effect should exist within the treatment techniques; everything else is used only to fill in the blanks and is therefore non-specific. Against this background, for the purpose of proving the efficiency of psychotherapies, the execution of randomized controlled trials is regarded as the 'gold standard'. It makes use of experimental designs where treatment systematically varies and confusing variables are to be excluded (e.g. by randomization of patients to treatment modalities). The effect should be attributed to the employed treatment as clearly as possible. To describe this dominating paradigm, Wampold[1] used the term 'medical model', or – since it also dominates in the field of psychology as well and corresponds to the methodological canon of the general linear model – 'standard model'.

The model is highly plausible and seems to be confirmed anew with every effective therapy. But it has a blemish – it is falsified. Falsified in a sense that within empirical sciences where truth values of 0 or 1 basically cannot occur, but only more or less confirmed hypotheses, more or less accepted arguments, and more or less empirical 'corroboration',[2] things sometimes prove 'falsified'. After 50 years of process-outcome research, the anomalies of the standard model are considerable.

1. Treatment techniques and technique-specific factors of effectiveness explain only a small portion of the outcome variance. Estimations performed on the basis of meta-analyses lie between 15% and 1% of the explained variance for the therapy outcome.[1,3–5] If the intervention, especially if it corresponds to the diagnosis, would determine the outcome, this should not be so, and it also should not be that practically all therapeutic procedures, tested against each other in direct experimental comparisons, lead to very similar effects (the so-called *Dodo bird effect*).[5–10] This is particularly true when (i) only bona fide therapies were included, i.e. treatment procedures that are well-intentioned and realized by competent therapists as probably effective treatment methods (not only as half-hearted control conditions); and when (ii) the 'affiliation', i.e. the identification of practitioners and examiners with their methods and the consequential methodical biases controlled.[7] According to corresponding meta-analyses, comparable effects are to be presumed even when specific treatments are suitably used for specific diagnoses – e.g. IPT (Interpersonal Psychotherapy) or CBT (Cognitive-Behavioral Therapy) in case of depression.[1]
2. *Early rapid responses.* Specific effects can occur even before the specific treatment components were realized and brought into action in a treatment program.[11–16] For example: cognitive restructuring takes place before the beginning of irrational beliefs treatment in cognitive behavioral therapy, or reduction of compulsions before the flooding begins.
3. *Dismantling studies.* The components of treatment programmes can be used in various ways, in different orders and, for the most part, even omitted without essentially impairing the effects (e.g. on cognitive behavioral therapy, see Ref. 17; for reviews see Refs 1, 5 and 18).
4. *Efficacy of non-professionals and paraprofessionals.* Laymen, i.e. people with no specific expert knowledge and psychotherapy training, and paraprofessionals, i.e. people active in the field of health care, but with no specific psychotherapy training, are astonishingly successful. In direct comparisons, some meta-analyses

credit them with the same efficacy as that of professional psychotherapists.[19,20] Similar conclusions are drawn by the findings that show hardly any, or only very little, connection between training (i.e. extent of training) and treatment results (e.g. Ref. 21), although the results are not uniform.[5] While considering whether this should be interpreted as an argument for the importance of natural social competencies or other conditions, it is certain that laymen do not master specific treatment techniques.

5. *Placebo effects.* It has often been discussed whether the term placebo – apart from pharmacotherapy, where one can justifiably distinguish between verum and placebo – makes any sense within psychological treatments. If we understand it as a non-specific attentiveness offered to patients in control group conditions to distinguish between treatment and non-specific effects, it shows that bona fide psychotherapies are more effective than placebo conditions (those who equate therapy effects with placebo effect are thus simplifying), but placebo conditions also produce clearly better results than no treatment or waiting-list control groups.[22]
6. *Manualized therapies* do not show any convincing successes,[1,3] and highly structured therapies are no more effective than those designed by therapists in naturalistic settings.[23,24] The skills described and given in manuals can be learned, but do not necessarily make better therapists.[3,25] Neither compliance nor adherence (treatment integrity) correlates continuously high with outcome. On the contrary, sometimes manual integrity seems to undermine the natural social competencies of therapists.[26,27] Manuals mainly appear useful to beginners. Therapists obviously also wait for successes to appear, before actually employing the manual. In any case, the execution of manuals must leave space for therapeutic experience, competencies, and justified deviations.
7. *Non-specific factors.* Numerous studies have pointed out the importance of variables outside interventions and technical components of psychotherapy, e.g. the therapeutic relationship and working alliance, patient's expectations and attitudes concerning therapy, the fitting of patient's subjective disease theories and therapist's treatment theory, therapist's authenticity and genuineness, conditions in the social environment of the patient (partnership, family, occupation), setting variables, and so on.[28,29]
8. *Patient variables* seem to have the most important impact on the therapy outcome.[30] More than about the diagnosis and problem severity it is about the premorbid adjustment (personality disorders

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are considered an unfavourable predictor), personal and interpersonal competencies and resources, and particularly about the patient's intrinsic motivation to change, his self-relatedness, and receptivity to change.

9. *Research findings on self-organization and nonlinear dynamics*. Patient and therapist variables unfold in a dynamic and ever-changing context, i.e. interactively, and by this they take effect and produce emergent qualities (Ref. 30, p. 215). Orlinsky and Howard's generic model[31,32] can be regarded as a synopsis of the variables to create these system effects. Various studies have explicitly examined the nonlinear and non-stationary dynamics of a complex therapy system on an individual level (for psychological measurements see Ref. 33; for physiological measurements see Ref. 34), on the level of micromatching between the therapist and patient, or on the level of interpersonal processes at a hospital ward (see the following sections of this contribution). Empirical evidence suggests that therapy works in cascades of transitions between bio-psycho-social patterns at different time scales.
10. *The brain does not function as a serial input–output system.* Suitable computer metaphors of brain functioning are obsolete.[35,36] It is much more about a complex, self-organizing system, in which nonlinearities determine the functioning *within* neurons, and even more so *between* neurons and neural assemblies (e.g. mixed feedback loops, nonlinear coupled oscillators).[33,37–40] There are nonlinear resonance and coupling effects which build the basis of healthy (e.g. binding processes[41]) as well as pathological neural processes (over-synchronization[42]).

These phenomena and empirical findings can be seen as anomalies of the linear input–output model of psychological treatments. Opposing this 'standard model', they support the hypothesis of nonlinearity and self-organization in human change processes. Additionally, they suggest that psychotherapy would not represent an execution of interventions in the sense of environmental events, by which the system is to be forced to a particular reaction, but a concept of psychotherapy as the dynamical realization of conditions for the possibility of human self-organization within a certain professional context.

Nonlinear dynamics in the interaction of patient and therapist

As several research programmes revealed during the last few decades, psychological change processes show all important features of nonlinear systems – such

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as deterministic chaos, non-stationary phase transitions, and nonlinear coupling between patient 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 psycho-physiological variables). In a study by Villmann *et al.*[43] heart rate, respiratory frequency, muscular tension, and skin conductivity were measured from both therapist and patient, during 37 therapy sessions. Speech production was analysed by the Mergenthaler Model, focusing on emotional feeling and cognitive referential activity/abstraction.[44] Physiological data were analysed by an artificial neural network approach (growing self-organizing map), which used a kernel smoothing for improved data density estimation. It was possible to generate an entropy model of psycho-physiological variability detecting emotionally unstable 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 also exists 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.[45]

Taking into account the importance of the therapeutic relationship for the treatment outcome, a study of our own group focused on the interactional process between therapist and patient.[46–48] The study applied the method of Sequential Plan Analysis, which is a development of the hierarchical plan analysis proposed by Grawe and Caspar (e.g. Ref. 49). Plans in this sense are verbally or non-verbally communicated intentions of self-presentation in a social situation. The patient's and therapist's interactional behaviour was analysed on the basis of video recordings. Two complete therapies (13 and 9 therapy sessions, respectively) were encoded with a sampling rate of 10 seconds (Figure 1). The construction of an inclusive hierarchical plan-analysis leads to an idiographic 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 (vertical) configurations (on–off patterns) of plans in the scores. This distribution follows a power law ($1/f^{a}$) demonstrating a distinct order within the data. Following Bak *et al.*,[50] power law-distributions emerge from self-organized criticality of dynamic systems.

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 (Figure 2).

The time series were analysed by methods that are sensitive to the nonlinearity as well as the non-stationarity of the time series.[33,46–48] Nonlinearity was proved

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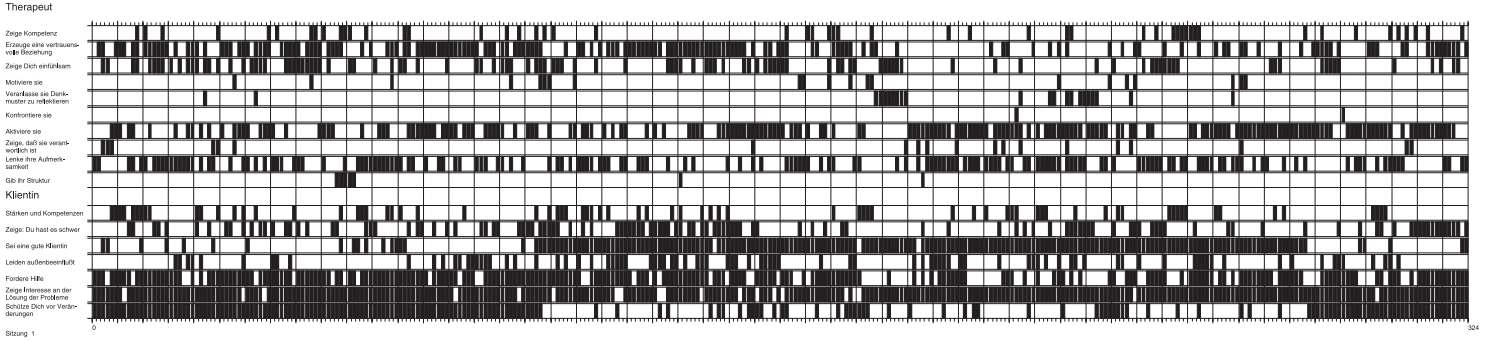

Figure 1. Nominal sequences of interactional plans of the therapist (top) and the patient (bottom) during a psychotherapy session. The sampling rate is 10s. Different plans can be realized simultaneously. The pattern looks like a music score with the plans representing the different instruments of an orchestra. A sonification of the score of plans coded from a 13-session psychotherapy is recorded on a DVD added to the textbook of Haken and Schiepek[33]

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 idiographic observation categories for the Sequential Plan Analysis

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

by surrogate data tests[51] using random surrogates as well as FFT-based phase-randomized surrogates.[52] Whereas fractal dimensionalities of the empirical time series (based on the correlation dimension D2 as well as the mean Pointwise D2 [PD2][53]) saturated at finite values (convergence to a fractal dimensionality of about 6), random and FFT-surrogates did not. The methods of PD2[53] and of the Local Largest Lyapunov Exponents (algorithm from Ref. 54) were used to identify phase-transition-like discontinuities. Following the evolution of PD2 dimensionalities, both therapies realized non-stationarities, 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

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Exponents (Figure 3), representing changes in the chaoticity of a time signal.[46] 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 can be seen as the trigger system 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[55,56] 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

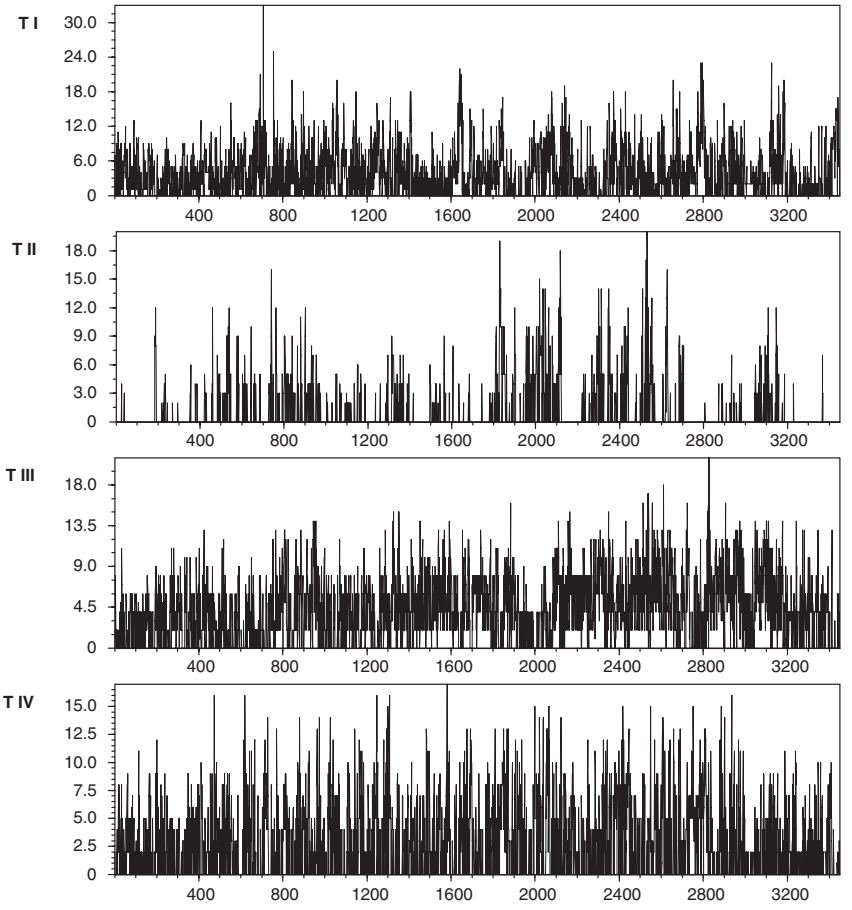

Figure 2. Time series of the categories of self-representation. From top to bottom (T = therapist; P = patient): TI encourage trust/create a secure atmosphere; TII confrontation/exposing to insecurity; TIII encourage self-responsibility of the patient; TIV activate structuring work; PI search for sympathy/appreciation/good relationship; PII externalization/demonstration of helplessness; PIII problem-oriented work (self-relatedness versus avoidance)

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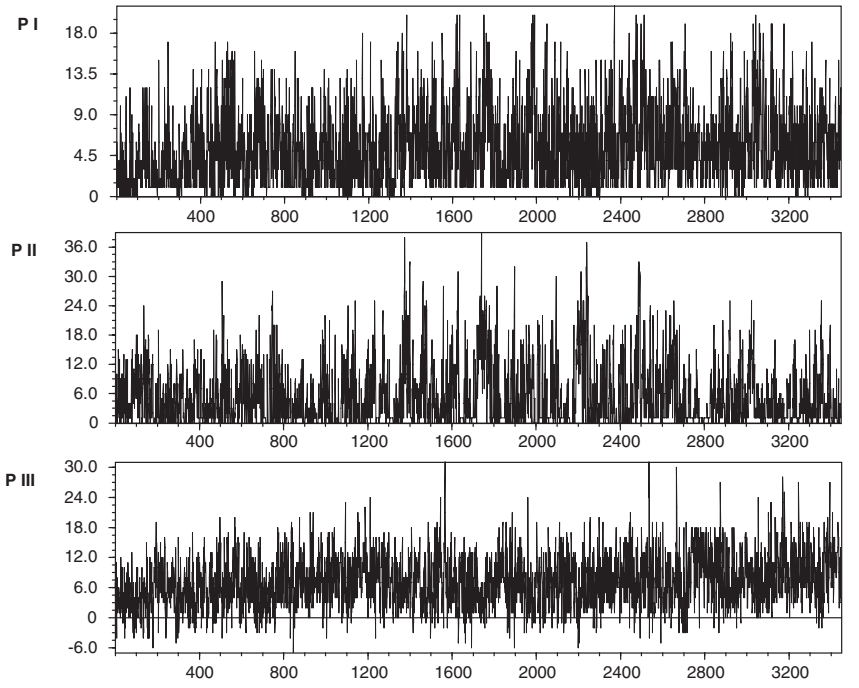

Figure 2. Continued

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.

Self-organization in human change processes

A quite different approach to human change processes focused on inpatient treatments at a hospital of psychosomatics. In a study (results in Ref. 33) 94 change processes were investigated, realized by 91 inpatients with different diagnoses (depression, anxiety disorder, post-traumatic stress disorder, eating disorder, somatoform disorder, and others). Here, the time series data were produced by patients' self-ratings given a day in the evening. For this purpose a 53-item rating sheet was developed (*Therapy Process Questionnaire [TPQ]*[33]) whose factor structure is represented in 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 different measures (questionnaires as well as ratings of the therapist).

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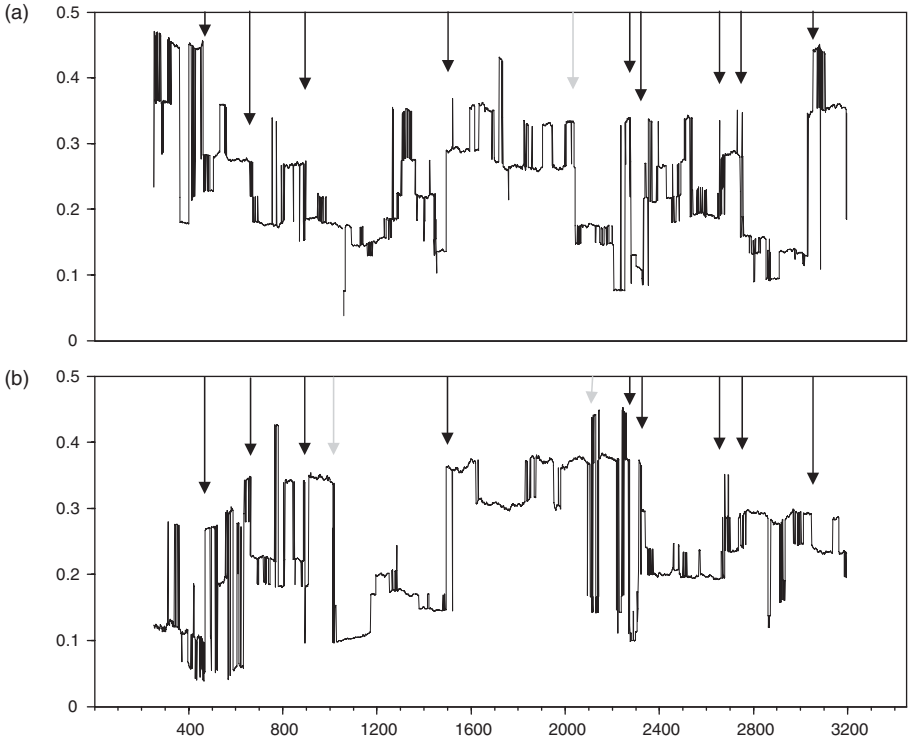

Figure 3. Synchronized jumps in the dynamics of Local Largest Lyapunov Exponents (black arrows). Grey arrows indicate not clearly synchronized changes. Top: therapist, bottom: patient

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 Ref. 33)

I(2) Change Involvement	I. Therapeutic progress/confidence in treatment effects/ self-efficacy (0.571)
	VI. Intensity of therapeutic work/motivation to change (0.596)
	V. Opening of perspectives/personal innovations (0.649)
II(2) Relationship/Social Climate	III. Quality of the therapeutic relationship/openness/ confidence in the therapist (0.705)
	II. Ward atmosphere, social relationship to other inpatients (0.692)
III(2) Emotionality	IV. Dysphoric emotions/self-relatedness (0.732)
	VII. Impairment by symptoms and problems

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Results confirmed synergetic conceptualizations of how psychotherapy works and corroborated hypotheses drawn from self-organization theory. 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 behaviour, and the 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 dynamic complexity[57] 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 that was observed during the process (data were created by daily applications of the Therapy Process Questionnaire TPQ). Correlations were -0.455 (second order factor I: 'change involvement' of the TPQ, $p = 0.002$), -0.431 (second order factor II: 'relationship/social climate', $p = 0.003$), and -0.572 (second order factor III: 'emotionality', $p = 0.000$) (compare Table 2). Negative correlations result from the fact that increased local maxima of dynamic complexity correspond to more reduced problems, symptoms, and impairment.

In order to answer the question of whether the observed intensities of dynamic complexity reach critical values, intra-item 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 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* (Figure 4).

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.[55,58,59] This method is based on the embedding of time series into a phase space constructed by time-delay coordinates, a method that is also crucial in

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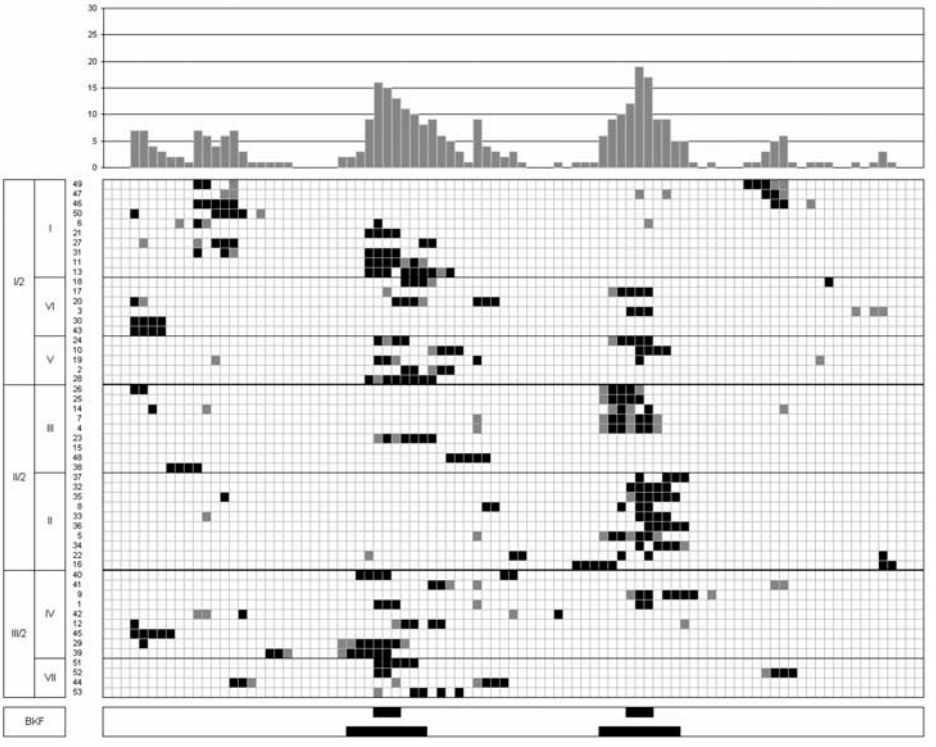

Figure 4. Complexity resonance diagram of a psychotherapy process. Such diagrams portray the threshold exceeding dynamic complexities of a process encoded by the 53 items of the Therapy Process Questionnaire (TPQ). Gray dots: 5% threshold of significance; black dots: 1% threshold of significance. *x*-axis: 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

the algorithms for the estimation of dimensional complexity or chaoticity (e.g. Kolmogorov-Sinai-Entropy, Lyapunov Exponents). Neighbours 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 (see fig. 6). The overall correlation is -0.45, if small shifts (lags of ± 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 of the time series. The TFD method uses wavelet spectra in order to scan the evolution of the frequency distributions within

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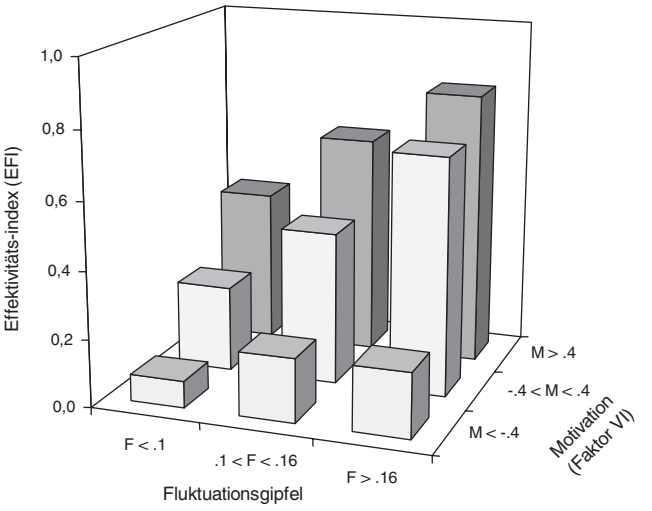

Figure 5. The effect size (ES) (mean ES of all outcome measures introduced in the study, see text) of inpatient psychotherapy is produced by an interaction between the local maximum of critical fluctuations and the intensity of the control parameter realized during the change process. The local maxima 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

a signal.[55,56] 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 & Schiepek[33]).

An overall result of the study is shown in Figure 5. 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 is that 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 intrinsic motivation to change, including his or her engagement into the therapeutic work. The second condition is 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 therapy process. The interaction of both conditions results in treatment effectiveness. A third important condition is not represented in Figure 5: it is the experienced stability of

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the boundary conditions. Boundary conditions can be the outer environment (the context in the ward or therapeutic bond) or the inner environment (intra-systemic conditions such as self-esteem, 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 – 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 that 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 reason 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 context and evolve by its own nonlinear interactions in specific systems. These factors are (i) personal features of the patient, such as 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, such as his own personality, 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[5,32]). 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 Mini-Laptop or Handy technology) of outcome and process questionnaires. Data are sent to a server, where they are stored and analysed. 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 setting) are encouraging. Lambert and co-workers (e.g. Ref. 60) were able to identify processes when getting difficult or unsuccessful ('not on track' therapies, compared with 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.[33] The *Synergetic Navigation System*, using the Therapy Process Questionnaire (see Table 2) for daily ratings, 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, which is measured by the dynamic complexity;
- Recurrence Plots indicating transitions or repeating patterns; and
- 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 6 shows a synopsis of these analysis methods applied to an individual therapeutic 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. When looking at the time shown on the computer screen, the diary text is shown within a gliding tip-tool running over the time series. By this, corresponding qualitative and quantitative information completes the picture.

Therapist and patient can use this form of feedback as a basis for repeated conversations, in which the course of treatment and patient's personal development are reflected and discussed in a form of suitable future steps. It is an 'eye-level' therapy, where patients can use and develop their self-management resources. Possible functions of such a continuous process summarization and a feedback concerning a 'tertium datur', which in this case consists of measurement results presented on the screen, are shown in Figure 7. Thus, the conditions are created for considering psychotherapy as a management of self-organization processes with an equal contribution of the therapist and the patient.

Do order transitions in psychotherapy correspond to patterns of neural activity?

Synergetic research in psychotherapy is reaching the brain. The aim of an actual fMRI-study[61,62] was the investigation of phase-transitions of brain activity and related subjective experiences of patients during their psychotherapy process. Repeated fMRI scans were related to the degree of stability or instability of the ongoing dynamics (measured by the dynamic complexity of daily TPQ-ratings)

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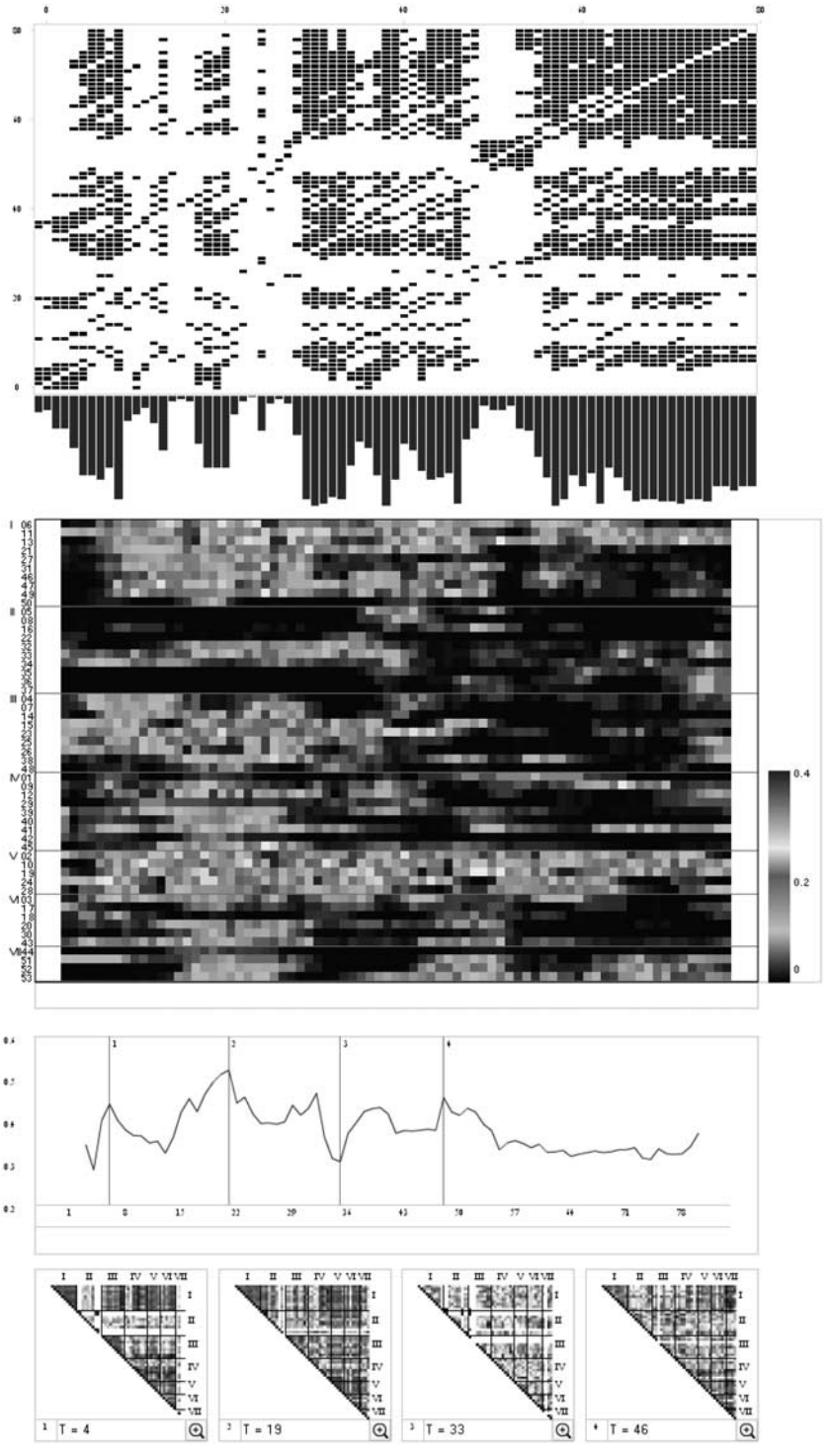

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as well as to the therapy outcome. Real-time monitoring by the Synergetic Navigation System allows for the identification of stable or unstable periods and, through this, for a decision on the appropriate moments of fMRI acquisitions. Three or Four scans were realized during each of the psychotherapy processes of 9 patients. The study included patients with obsessive-compulsive disorder (OCD) of the washing/contamination fear subtype (DSM IV: 300.3), without any medication or comorbid psychiatric or somatic diagnoses. Patients were matched to healthy controls.[63]

OCD seems to be an appropriate model system for synergetic studies in psychotherapy, 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 – are easy to be observed. OCD-specific functional neuroanatomy is partially known: Friedlander and Desrocher[64] 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 used symptom provoking, disgust provoking, and neutral pictures. The disgust and the neutral pictures were taken from the International Affective Picture System, whereas the OCD-related pictures were photographed in the home setting of the patients, showing specific and individual 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 to the patient. The second acquisition was done

Figure 6. 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 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 Figure 4, the intensities of the dynamic complexity of each item is transformed into colours. Items are arranged by the order of the first- and second-order factors of TPQ. Bottom: mean of all inter-item correlations irrespective of the sign (absolute values). This is a measure of the overall synchronization 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 ($t = 4$, $t = 19$, $t = 33$, $t = 46$). Grey to black cells of the correlation structure matrices represent high correlations, grey to white cells low correlations

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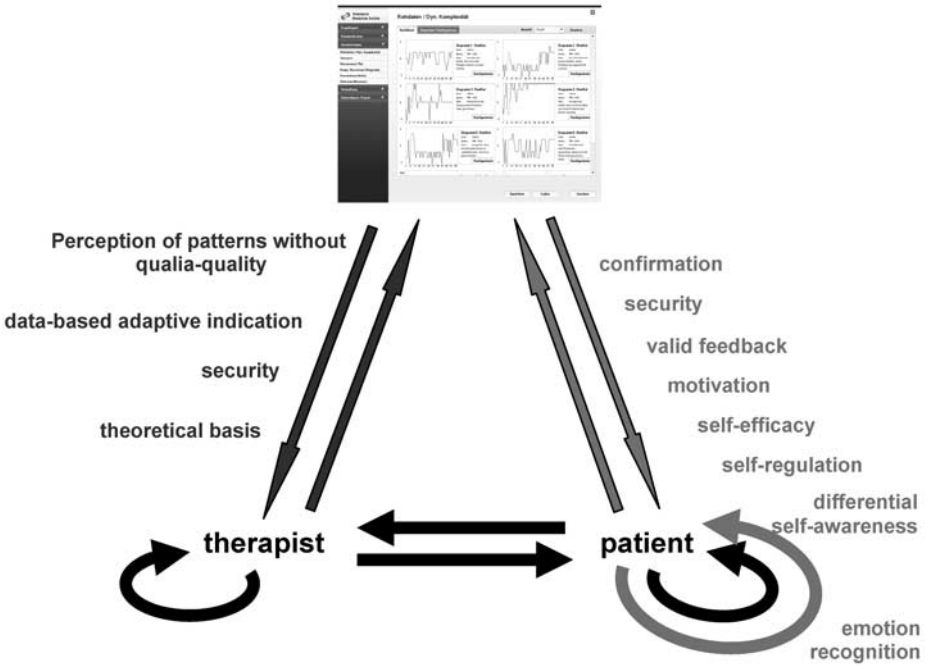

Figure 7. Functions of repeated internet-based self-evaluations (by the use of a therapy process questionnaire or other usual instruments) and of the computer based feedback for patient and therapist. The existing interactions and intra-individual feedback loops are supplemented by an external source of information, which is specialized for measuring and visualizing the characteristics of nonlinear dynamics and therapeutic self-organization

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 behavioural 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 (marital) 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.[5,13,14] Additionally, marked alternations in brain activity were to be

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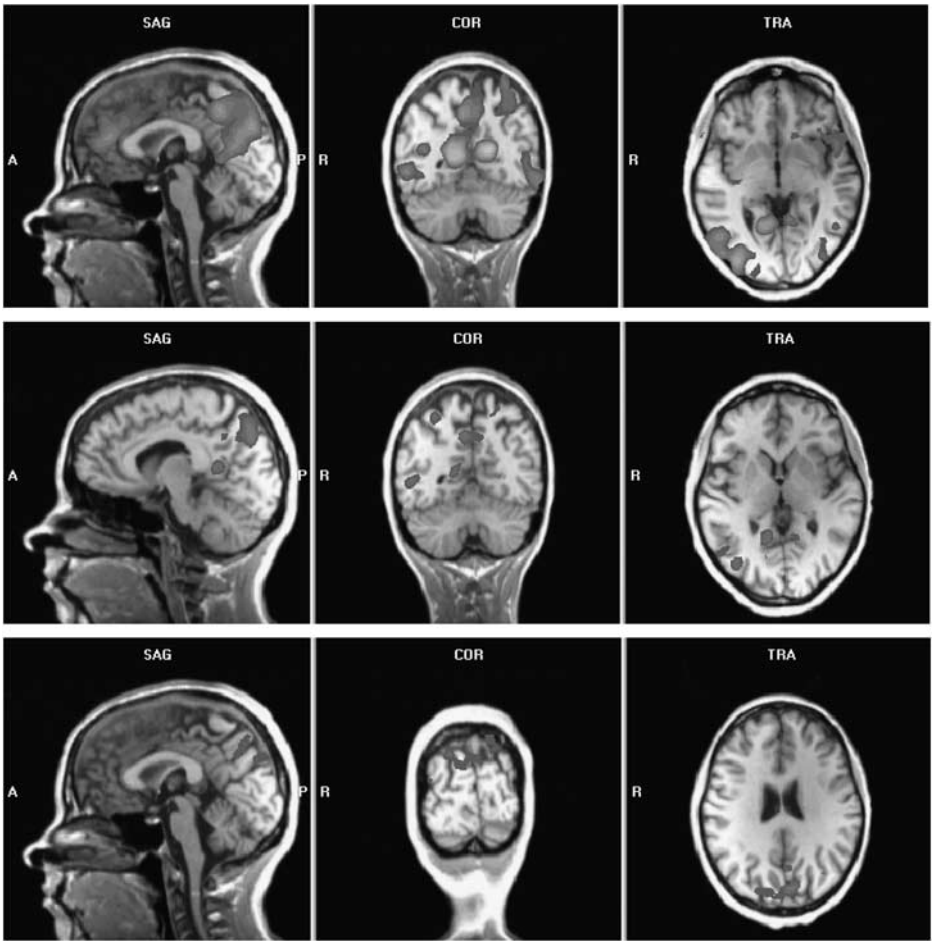

Figure 8. Brain activation patterns of a patient with OCD during psychotherapy. BOLD signals from a 1.5 Tesla fMRT scanner. Top: first scan (ninth day of hospital stay; $x = 0$, $y = –55$, $z = –2$; $p(\text{uncor}) < 0.001$). Middle: second scan (30th day of hospital stay; $x = 8$, $y = –54$, $z = 5$; $p(\text{uncor}) < 0.001$). Bottom: third scan (57th day of hospital stay; $x = 0$, $y = –85$, $z = 26$; $p(\text{uncor}) < 0.001$). Activations during the presentation of OCD-related pictures compared to activations during the presentation of neutral pictures (OCD > disgust)

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 Figure 8 for an OCD to disgust contrast). Thalamic and basal ganglia activation is part of the frontal-caudate-striatum-thalamus circuitry

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of OCD. In particular the caudate nucleus takes a role within the executive dysfunction model of compulsions, and its activity has been found to be reduced after treatment (e.g. Refs 65, 66).

The function of the anterior cingulate cortex is interesting with regard to synergetics. The cingulate cortex comprises various functions, such as somatosensoric integration, mediation of affective and cognitive processes, control of attention, and processing of painful stimuli. Additionally, it plays an important role as a conflict monitoring system: it is sensitive to ambiguous or conflicting information,[67,68] is involved in decision making,[69,70] and its activation is predictive to treatment outcome in depression.[71] This is true especially for the dorsal (cognitive) structures of the ACC. By this, it could be an indicator of symmetry states of brain functioning 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 versus 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 the present data analysis of the whole sample (nine patients)[72] and 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 of symptom severity, compared with 50% reduction in dynamic complexity – could be an argument in favour of the instability hypothesis.

The paradigm of self-organization is a very promising approach to psychotherapy as well as other fields of psychology and medicine. Its interdisciplinarity is due to the fact that the laws and principles of self-organization are true for neural, mental, and behavioural processes (and the corresponding data qualities). Interdisciplinary cooperation is underpinned by the unifying terminology as well as by the unifying formalism and modelling tools of synergetics. This opens new perspectives for basic and applied research, but also for the treatment of mental disorders.

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