Contributions of Systemic Research to the Development of Psychotherapy

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Challenges of Contemporary Psychotherapy

Compared with its early decades at the beginning of the twenty-first century, psychotherapy has less urgent needs to legitimate its effectiveness in general but is confronted with other challenges concerning the development of the profession, the question of how research should be realized and how the effectiveness of treatments can be optimized. Other challenges concern the development and dissemination of psychotherapy in health-care systems and the understanding of the mechanisms of change. The points I will bring up for discussion refer to our knowledge on the field as represented in contemporary conferences and textbooks (e.g., Duncan, Miller, Wampold, & Hubble, 2010; Lambert, 2013; Wampold & Imel, 2015):

1. Psychotherapy works on the average, but not for every client. There is a considerable number of nonresponders, deteriorations, or not sustainable effects. One of the consequences could be optimized and tailored treatments for the individual.
2. Psychotherapy works, but we do not know how, or in other words, we have many concepts on this (each therapeutic confession has its own), but no approved and generalizable models, may it be on the level of neurobiological or psychological mechanisms (Kazdin, 2009).

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3. We have acquired an accumulated knowledge on the ingredients or factors (e.g., common factors) contributing to the effects of psychotherapy, but not on how they interact. The development of models which could explain change dynamics is at its very beginning.
4. We cannot predict the trajectories of change, and we cannot predict if and when therapeutic crises will appear.
5. Interventions or treatment techniques have only a small impact on the outcome. This may have consequences for how we conceptualize psychotherapy.
6. Discontinuous jumps to the better or to the worse appear, but the jumps often are independent of interventions. Existing linear models cannot explain this; the phenomenon has the status of empirical "anomalies."
7. There are many approaches in psychotherapy (maybe several hundreds), but no unifying paradigm.
8. Research data often are not produced in real-world practice but are collected in artificial settings (e.g., RCTs in the setting of university hospitals). Practice-based research in realistic settings of health care should create ecologically valid and generalizable results.

Systemic research has to be judged by if and how it contributes to meet these challenges. Independent on how we may define systemic research, any step on this way requires that the term "systemic" will not be reduced to research on a psychotherapeutic school (e.g., systemic therapy) or on a specific setting (e.g., family therapy). We define *systemic research* as a *theoretical and methodological approach to measure, analyze, and model the structures and functioning of complex dynamic systems at a biological, mental, and/or social level*. Examples of complex systems may be brains, physiological systems (e.g., endocrine or immune networks), cognitions and emotions, communication and social interaction, health-care systems, and others. The methods to be applied should cover a wide range of approaches, qualitative and quantitative, idiographic (focused on the individual) and nomothetic ones (focused on generalizable models and theories) (see Schiepek, 2012 in Schweitzer & Ochs, 2012).

Principles of self-organization and basic features of nonlinear dynamics are independent of contexts and of the substrate of the concrete system we are concerned with. Self-organization and nonlinear dynamics are ubiquitous phenomena occurring at different spatial and time scales. One example is the relationship between the connectome of the brain (neural network structures) and its functional connectivity dynamics (Hansen, Battaglia, Spiegler, Deco, & Jirsa, 2015; Ritter, Schirner, McIntosh, & Jirsa, 2013); another is the mental or behavioral change dynamics during psychotherapy. In this general sense, the systemic approach is a meta-theoretical or paradigmatic framework for multi-methods research. Systemic research and complexity science are characterized by transdisciplinarity and by a structuralistic view on theories (Haken & Schiepek, 2006; Stegmüller, 1973). However, in clinical contexts (psychotherapy), in counseling, and in organizational development, systemic research often adopts the criteria of practice-based and participative procedures and of ecological validity. Data should be produced in real-world settings by active cooperation with subjects, may it be practitioners, clients, or members of social networks (see Seikkula, this volume). One approach fulfilling these criteria is Internet-based real-time monitoring of change dynamics in everyday routine practice.

Combining Practice and Research by Monitoring Change Dynamics

Since many years and in diversified clinical contexts, practitioners have used therapy feedback for continuous cooperative process control of change processes (Schiepek, Eckert, Aas, Wallot, & Wallot, 2015; Tilden & Wampold, 2017). The technical device for realizing real-time monitoring and feedback procedures is the Synergetic Navigation System (SNS), an Internet-based tool for the continuous assessment of change processes by self-related or interpersonal ratings of the included subjects (e.g., clients, coaches, family, or team members). Continuous assessments create time series data which is the raw material for any further analysis.

Systems like human or social networks are characterized by their ever-changing dynamics – pattern formation and pattern transitions (Haken & Schiepek, 2006). In consequence, feedback systems have to mirror these dynamics by the option of performing frequent (e.g., daily) assessments and by applying methods of nonlinear time series analysis on the data. Given the fact that nonlinear and chaotic processes are complex, unpredictable, and specific in each case, these features have to be represented by feedback systems. Individual dynamics do not follow any standard track or expected response curve (Schiepek, Gelo, Viol, Kratzer, Orsucci, et al. 2020).

The Synergetic Navigation System

The Synergetic Navigation System (SNS) is a highly flexible and generic Internet-based service for data acquisition, time series analysis, and visualization of outcome and process data as well as analysis of results. It allows for the implementation of various questionnaires or coding systems. Data can be entered and results can be checked by most web-compatible devices, including PCs, notebooks, tablets, or smartphones (ubiquitous computing). Also an SNS app is available.

The sampling rate of the data acquisition (time sampling, event sampling) is up to free choice (e.g., pre-post, weekly, session-related, once per day, higher frequencies). Using the questionnaire editor of the SNS, outcome or personal process questionnaires can be created. Comment fields for text entry and scales for quantitative measures can be combined. Global indicators of change processes can be defined by a “traffic lights” editor. The system does not expect standard tracks.

Outcomes are visualized by histograms, and processes are visualized by time series graphs. Different sizes and alignments of the diagrams can be chosen. If necessary, all diagram fields can be configured independently. The selected item configurations can be saved. When selected again subsequently, the changes automatically are activated and show the current stage of a client's development. When the cursor is moved over the graph of a time series, it displays the value, the entry date, and the diary entry of each data point.

The available analysis and visualization tools:

- Visualization of time series
- Superposition of time series (even if the time series are only partially overlapping or were recorded with different sampling rates, e.g., once per day and once per session)
- Color-coded visualization of the values of one or many time series in a diagram
- Calculation of the dynamic complexity in a running window
- Color-coded visualization of the synchronized dynamic complexities of many time series (complexity resonance diagram)
- Dynamic correlation pattern analysis
- Colored Recurrence Plots

A further option is to assess interpersonal relations by a dynamic interaction matrix tool for dyads (e.g., in couples therapy), families, groups, teams, or organizations.

Interested users can get into contact with the Center of Complex Systems for using this web service. License fees are 780 Euro/year for an outpatient psychotherapy office; see www.ccsys.de. There is an international and transdisciplinary SNS network/community of users and also a professional user group at the German Society of Systemic Therapy and Family Therapy (DGSF).

Hospitals and institutions using the SNS (selection):

- University Hospital of Psychiatry, Psychotherapy, and Psychosomatics, Salzburg, Austria (Dept. of Psychotherapy, Dept. for Crisis Intervention and Suicide Prevention, Day Treatment Centre of Psychosomatics, Institute of Clinical Psychology)
- University Hospital of Child and Adolescent Psychiatry/Psychotherapy, Salzburg, Austria
- Klinikum Grieskirchen-Wels, Dept. of Psychotherapy, Dept. of Adolescent Psychosomatics, Grieskirchen, Austria
- University Hospital of Lower Austria, Psychiatric Day Treatment Centre, Tulln, Austria
- Psychosomatic Clinic St. Irmingard, Prien am Chiemsee, Germany
- Clinic for Psychosomatics (Chiemseewinkel), Seebruck am Chiemsee, Germany

- Psychosomatic Clinic Bad Zwischenahn, Germany
- Rottal-Inn-Kliniken, Simbach am Inn, Germany
- Health Center sysTelios, Siedelsbrunn, Germany
- Christophsbad Hospital, Dept. of Psychiatry and Psychotherapy, Göppingen, Germany
- Marienhospital, Papenburg, Germany
- Center for Training in Psychotherapy, Bielefeld, Germany
- Erzbischöfliches Jugendamt Munich, Germany
- Johanna Kirchner Haus, AWO, Marktbreit, Germany
- Universität Heidelberg, Institute of Counseling Research, Heidelberg, Germany
- MEDIAN Klinik Odenwald, Breuberg, Germany
- Psychiatric Hospital Münsterlingen, Thurgau, Switzerland
- Behavioural Science Institute, Radboud University Nijmegen, Netherlands
- Interacting Minds Centre, Aarhus University, Denmark
- South Denmark University, Center for Human Interactivity, Odense, Denmark
- Psychiatric Hospital Bronderslev, Denmark
- Others

The Identification of Order Transitions: Converging Evidence from Different Methods

From the perspective of self-organization and nonlinear dynamics, an important aim of doing feedback on change processes is to get early warning signals on upcoming order transitions. Periods of critical instability preceding such transitions are often sensitive to minor interventions, personal decisions, or new and encouraging activities. These periods are critical moments which in the ancient Greek mythology were called “kairos” (see the *generic principles* of Synergetics; Schiepek et al., 2015). Critical instabilities can be decisive for developments to the better, e.g., sudden gains, or to the worse, e.g., sudden losses or even suicidal states (Fartacek, Schiepek, Kunrath, Fartacek, & Plöderl, 2016).

The simplest way to identify precursors of order transitions is the inspection of raw data time series by the naked eye. Given some experience in pattern recognition, this provides a first visual impression, which can be consensually validated by the oral reports and the electronic diaries of the client. Figure 1 shows some examples of order transitions as presented by the diagrams shown in the SNS. In many cases critical instabilities can be identified before an order transition occurs (Fig. 1a); in other cases, a transient deterioration may be a precursor (Fig. 1b,c).

A next step is the presentation of the factor dynamics. Factors are subscales of a process questionnaire combining information from several items. In the SNS, the

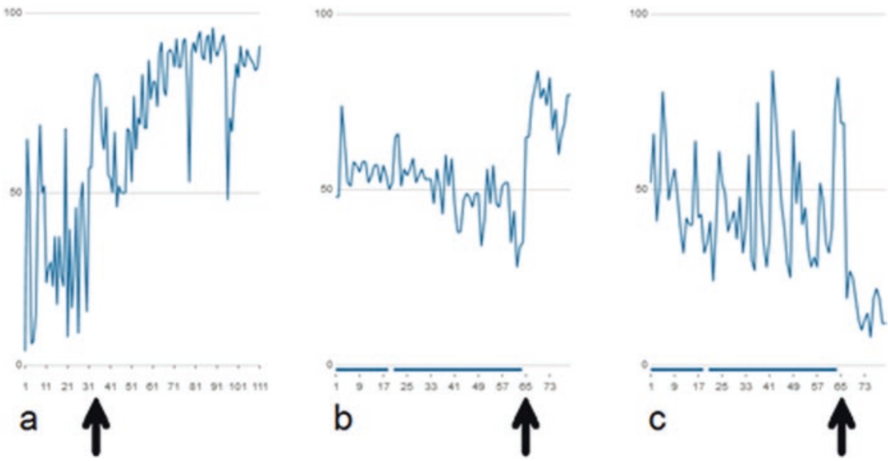

Fig. 1 Time series of items (raw data) of the Therapy Process Questionnaire (TPQ, Schiepek, Stöger-Schmidinger, Kronberger, Aichhorn, Kratzer, Heinz, Viol, Lichtwarck-Aschoff, & Schöller, 2019a). (**a**) "Today I felt joy," (**b**) "Today I felt intended to change my problems," (**c**) "Experienced intensity of problems and symptoms" (time series (**b**) and (**c**) are taken from the same client, see also Figs. 2b,c, 4a, 8, and 12). (**a**) shows a critical instability before the transition (comp. Figs. 2a, 4b, and 6), (**b**) and (**c**) show a transition after a short period of deterioration. The arrows indicate significant order transitions

items which contribute to a factor are averaged and z-transformed (Fig. 2). In many cases, the z-transformed factor dynamics gives a more pronounced picture on the processual Gestalt than the time series of each particular item. Figure 3 shows an example of a client diagnosed with "dissociative identity disorder" (for a detailed description of this case, see Schiepek, Stöger-Schmidinger, Aichhorn, Schöller, & Aas, 2016a). The time series of the raw data are quite noisy and fluctuating (Fig. 3a), whereas the factor dynamics shows a much clearer Gestalt with one dominating order transition (Fig. 3b) (see the "short case illustration" below). The SNS also allows for the superposition of several time series in a diagram, which creates an optimized picture of critical instabilities and order transitions (Fig. 2a).

Colored raw data diagrams transform the values of all included time series as given by the items of a process questionnaire into rainbow colors. These diagrams create a synopsis of the evolutionary pattern of multiple time series (Fig. 4).

Short Case Illustration

The case of Mrs. A. diagnosed with "dissociative identity disorder" and "Borderline Personality Disorder" was before therapy and through the first half of the therapy marked by a pattern of roughly daily interchanging ego states. At a certain point of the therapy (marked as time point number 1 in Figs. 5 and 9), this alternating pattern disappeared. Then, the client had abolished her previous goal to soon enter the first labor market again, which she

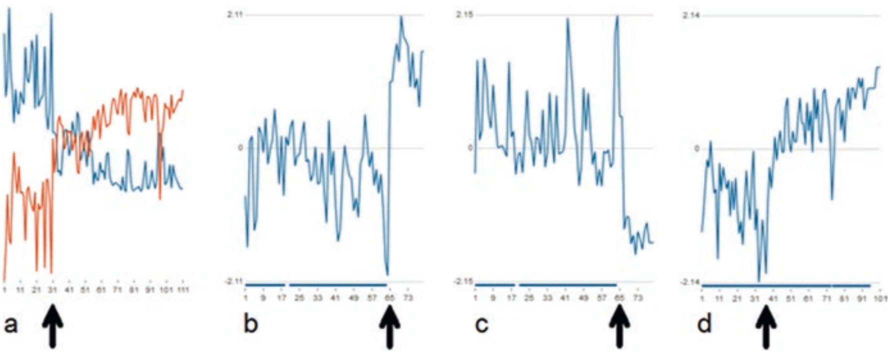

Fig. 2 Time series of factors of the TPQ. (**a**) Two factors superimposed: "Problem and symptom severity" (blue) and "self-awareness/body experience" (red; same client as in Figs. 1a and 4b). (**b**) "Therapeutic progress/confidence/self-efficacy," (c) "problem and symptom severity." (**b**) and (**c**) refer to the same client as Figs. 1b,c, 4a, 8, 10, and 12, (**d**) "therapeutic progress/confidence/self-efficacy" (another client). The arrows indicate significant order transitions

described as a great relief. An attractive job offer by a friend had triggered days of ambivalent feelings, ambiguity, and inner conflicts (critical fluctuations before the order transition). Instead of her earlier behavior of allowing others to "whip her into" new situations, she was capable to allow herself of turning down the offer. She experienced this decision as big liberation, listening to her inner voice. A process enabled by previous work on traumata and states, in which the creation of an idiographic system model and thereby the better understanding of mechanics of her state dynamics played a major role (e.g., understanding the relation between as disturbing experienced voices and incidences of traumatizing violence in earlier relationships).

Mrs. A's record in her SNS-based electronic diary at this order transition said: "…I have the feeling of being myself again (…) the last couple of days were unpleasant and painful. (…) Decisions for the time after the hospital stay have been made, that are better for me. I want to make peace with myself, which not always works out, but is so important!! Because the last years I always tried and worked on myself to find work again, but always felt so much stress and pressure (…) and that is not how things work!! My switches are set differently (…), in order to have some room for peace and let the stress go and to think about, what I really want to do and what I could work. (…) I will not surrender, to nothing and nobody!!"

This pattern transition can be seen in the item's and factor's time series (comp. Fig. 3 and 5). Also the mutually exclusive correlation pattern of the personality states (items of factors I and II, see Fig. 5a and 11a) disappeared almost immediately after the order transition (Fig. 5a and 11b). All this information was integrated to the ongoing therapy, clarifying the change in terms of state dynamics and related cognitions and emotions, for both therapist and client.

Accompanied was this crisis and the resolution thereof by an increase of depression and stress scores (assessed by the weekly administered DASS-21), followed by a drop to low scores on these attributes just at the order transition (Fig. 9a). Figure 9b shows an increased inter-item-synchronization during the state-driven pattern before the first order transition (pathological oversynchronization), which disappeared after the order transition (flag 1) (this case is presented in detail in Schiepek, Stöger-Schmidinger, Aichhorn, Schöller, & Aas, 2016a).

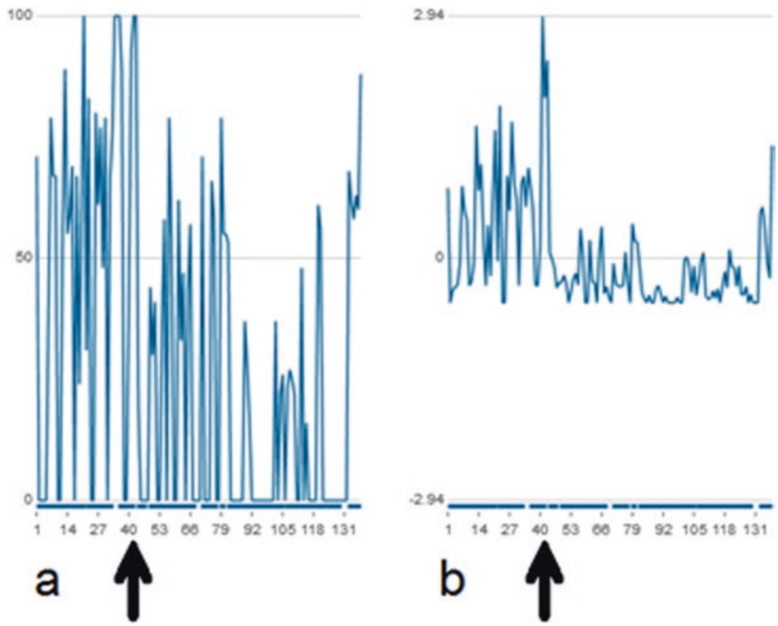

Fig. 3 (**a**) Time series of the item "Today I experienced stress." (**b**) Time series of the factor "stress and coping with stress" (individualized questionnaire). The items of this factor correspond to a child-related ego state of a client diagnosed with "dissociative identity disorder" (see also Figs. 5, 9, and 11, which refer to the same client). The arrows indicate the dominating order transition

Pattern transitions appear not only in changed mean levels of a time series but also in their variability, rhythms, frequency distribution, complexity, or other dynamic features. The option of a superposition of time series in a diagram (Fig. 2a) or the visualization of colored raw data diagrams can show such synchronized or anti-synchronized rhythms in multiple time series (Fig. 5a). In some cases, order transitions are characterized by the emergence or submergence of synchronized rhythms.

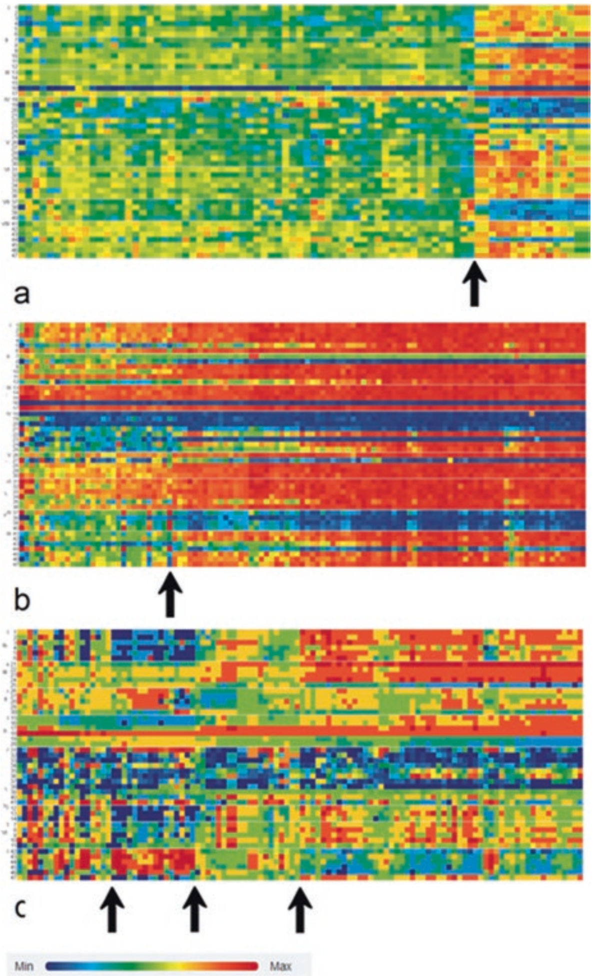

Fig. 4 Color-coded raw data diagrams. The arrows indicate significant transitions. (**a**) Same client as in Figs. 1b,c, 2b,c, 8, 10, and 12; (**b**) same client as in Figs. 1a, 2a, and 6. X-axis: time (days)

A common precursor of order transitions is critical instability (Haken, 2004; Haken & Schiepek, 2006). In the SNS this is represented by the measure of dynamic complexity, which combines the amplitude, the frequency, and the distribution of the values of a signal over the available range of a scale. All three features (amplitude, frequency, and distribution) are calculated within a gliding window which runs over the time series (given daily measures the usual window width is 7 days) (Haken & Schiepek, 2006; Schiepek & Strunk, 2010). The evolution of dynamic complexity can be presented as time series (Fig. 6) or as colored complexity resonance diagrams (Fig. 7). In the resonance diagrams, vertical columns or sudden changes of complexity over many items indicate order transitions. Another way of

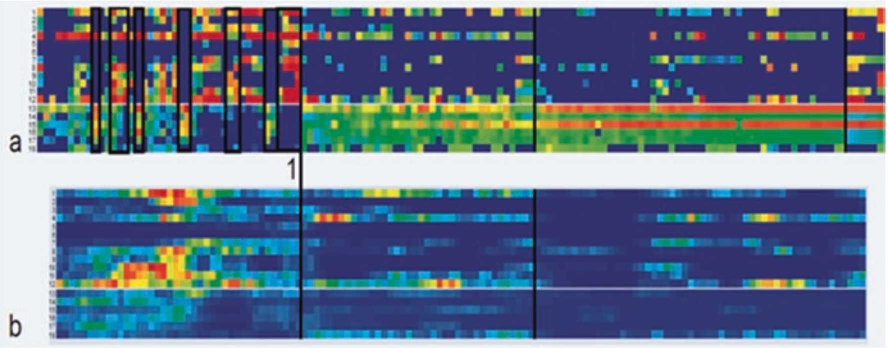

Fig. 5 (**a**) Color-coded raw data diagram of a client diagnosed with "dissociative identity disorder" (individualized questionnaire). X-axis: time (days). Blue colors represent low intensities, yellow to red colors represent high intensities of the ratings. The vertical line (1) indicates the most significant order transition of this therapy. Before the first transition, an alternating pattern between the items corresponding to two ego states can be identified. Black frames underline periods of alternating item scores and manifestations of states. Items 1 to 12 correspond to a "child state", shown above the thin white line in the diagram; items 13 to 18 correspond to an "adult state", shown under the thin white line. (**b**) Complexity resonance diagram of this client's change process. The cluster of high dynamic complexity occurs especially in the items of the "child state" before the order transition occurs (at 1), corresponding to the intensely fluctuating and mutually exclusive states. The x-axis is time (days) or, to be more precise, the number of overlapping running windows (window width: 7 days)

representing dynamic complexity is not to include all complexity values from all items and to transform them into colors, but to calibrate the complexity values within each time series. The ten highest complexity values of an item's time series are transformed into gray steps (from black corresponding to the highest to a bright gray as the lowest complexity value, all others are white). This procedure is more sensitive to low complexity values and shows the synchronization of intra-item calibrated complexity in a gray-step diagram (Fig. 8).

In some cases, the weekly assessed symptom or stress intensity may indicate an upcoming order transition. In the example presented in Fig. 9a, the intensities of depression and stress are increased just before the order transition takes place. After this transition, the values are significantly reduced. In routine practice, depression, anxiety, and stress are assessed once per week by the short form of the Depression Anxiety Stress Scales (DASS-21; Lovibond & Lovibond, 1995).

Another precursor of order transitions is increased synchronization of emotions and cognitions, as represented by the items of a process questionnaire. In the SNS, the absolute (sign-independent) values of inter-item correlations of a questionnaire are averaged within a moving window and presented as averaged correlation strengths over time. This is a measure of coherence (in terms of Synergetics: "enslaving") of the dynamics (Figs. 9b and 10). The changes of all inter-item correlations are presented in a sequence of correlation matrices with color-coded correlations (from −1 [dark red] over 0 [white] to +1 [dark green]). The correlation

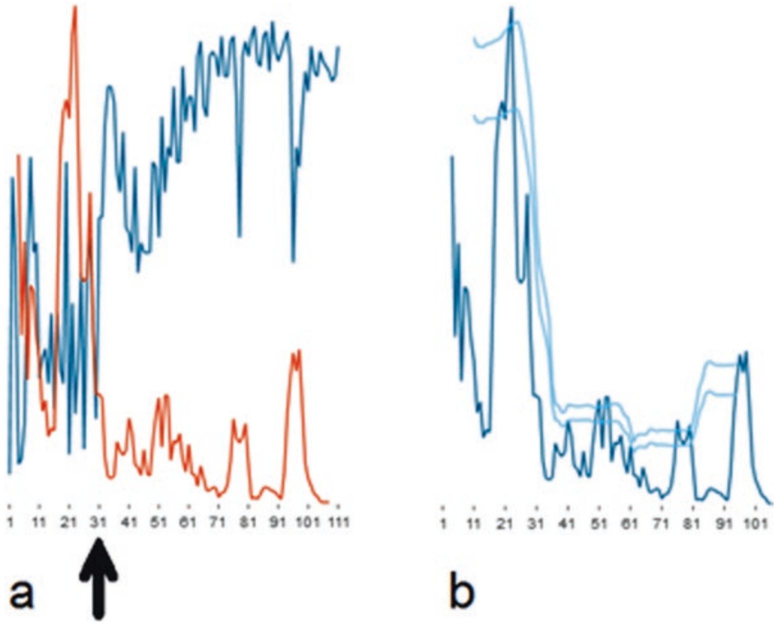

Fig. 6 (**a**) Dynamic complexity (red) of the time series "Today I felt joy" (blue, see Fig. 1a). In the SNS diagrams, the dynamic complexity curve (red) can be superimposed onto the time series of raw data or factors. The complexity peak precedes the order transition. (**b**) Over the dynamic complexity (blue line), dynamic confidence intervals are calculated in a running window (95% and 99%, bright blue lines). The width of the running window for the calculation is 21

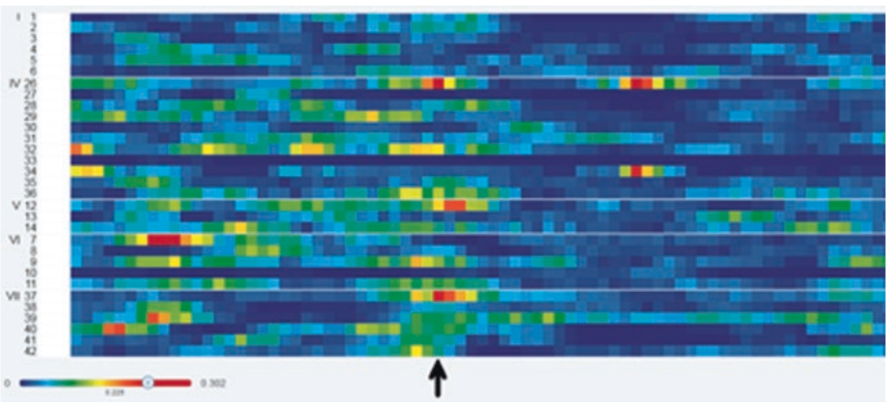

Fig. 7 Complexity resonance diagram. The dynamic complexity is calculated in overlapping running windows (window width = 7 days). Each line corresponds to an item of the process questionnaire (TPQ, factors II, III, VIII not shown). The maximum score of the dynamic complexity is depicted by a full red pixel, while all other values are graded according to that maximum (red = high, yellow = medium, blue = low complexity). The order transition is marked by the arrow. The x-axis is time (days) or, to be more precise, the number of overlapping running windows

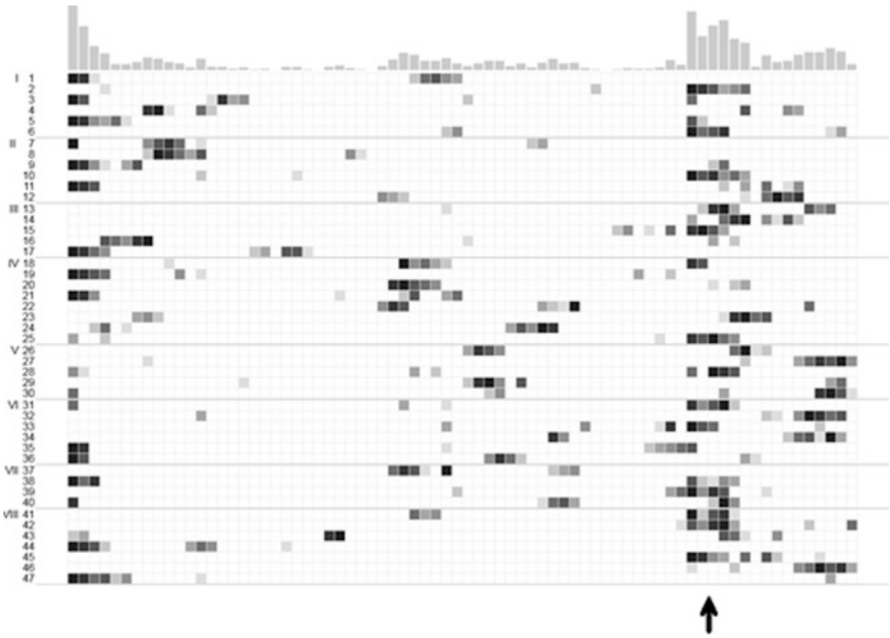

Fig. 8 Complexity resonance diagram, based on an intra-item calibration of the dynamic complexity. Each line corresponds to an item of the TPQ. The ten highest complexity values of each item are coded by gray steps. The arrow indicates the order transition (same client as in Figs. 1b,c, 2b,c, 4a, 10, 12). The x-axis is time (days) or, to be more precise, the number of overlapping running windows (window width: 7 days)

matrices are calculated within a running window (the window width is up to free choice, here: 7). A marker can be dragged along the time points to display the change of synchronization patterns over time. The local increase of the absolute inter-item synchronization together with a more pronounced correlation pattern of the matrices in many cases corresponds to a qualitative change of the correlation pattern. Figure 11 illustrates this pattern transition in the case of the client diagnosed with “dissociative identity disorder.” Before the first-order transition, the correlation matrix represents the alternating ego states (high positive *intra*-state correlations of cognitions and emotions [green], high negative *inter*-state correlations [red]) which is dissolved after the order transition.

A method which identifies recurrent patterns within a time series in a time×time diagram is Recurrence Plots (Eckmann, Oliffson Kamphorst, & Ruelle, 1987; Webber & Zbilut, 1994). Snippets of a longer time series are embedded in a phase space with time-delay coordinates. Each snippet represents a vector point in the phase space (with each measurement point represented on an axis). The Euclidean distances between the vector points can be binary coded according to a selected threshold or, alternatively, the distances can be directly color-coded. By this means, recurrent patterns and their transients (e.g., periods of critical instability) become apparent. Usually, Recurrence Plots and CRDs show complementary patterns:

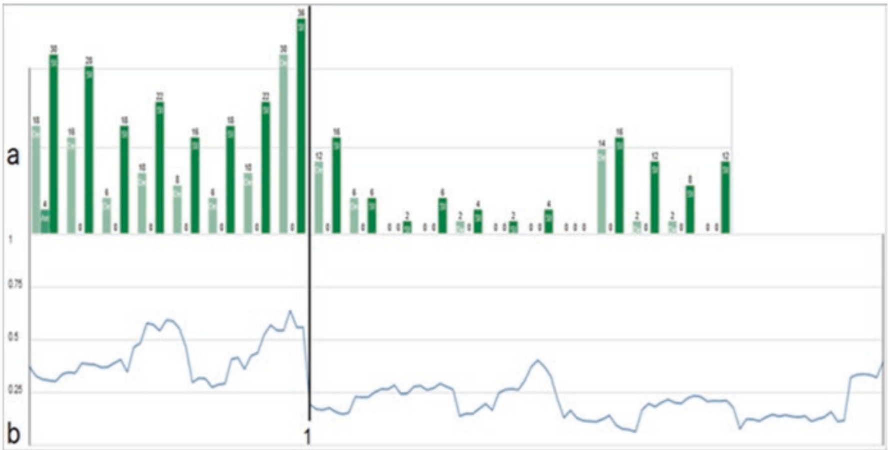

Fig. 9 (**a**) Intensity of depression (light green columns), anxiety (except for the first week always at 0), and stress (dark green columns), assessed once per week by the DASS-21 (Lovibond & Lovibond, 1995). Just before the order transition (vertical line), the values are increased; after it the values decrease immediately to a lower level. (**b**) Averaged inter-item correlation calculated in a running window of 7 measurement points. The first part of the process is characterized by a pathological oversynchronization with the maximum just before the order transition (vertical line, same client as in Figs. 3, 5, and 11)

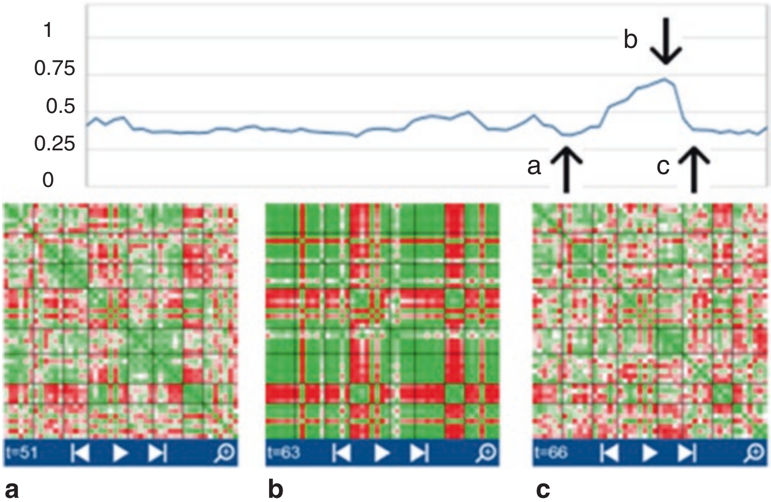

Fig. 10 Locally increased inter-item synchronization during the period of an order transition (arrow at **b**). The inter-item correlation matrices show an intensified and more pronounced pattern during the order transition compared to the matrices before and after the transition (**a** before, **b** during, **c** after). Each cell of the matrices depicts the correlation of a respective item with another item on a gradual green (positive correlation values, $0 < r < 1$) or red (negative correlation values, $-1 < r < 0$) scale (white cells correspond to a correlation of 0) (same client as in Figs. 1b,c, 2b,c, 4a, 8)

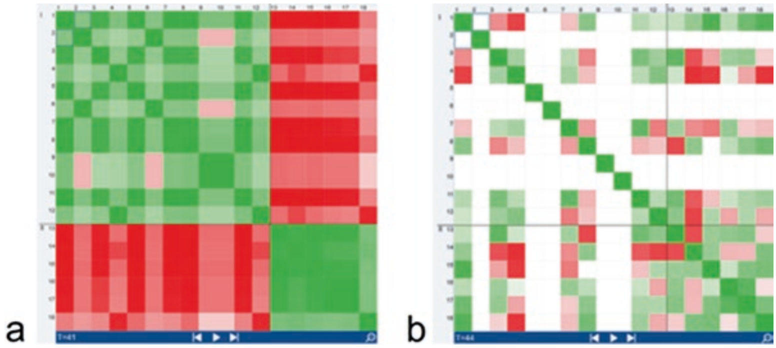

Fig. 11 (**a**) Color-coded inter-item correlation pattern characterizing the first third of the monitoring period (before the vertical line in Figs. 5 and 9). The black lines differentiate the items of factor I ("child state") and factor II ("adult state"). The left matrix ($t = 41–47$) is characterized by high positive within-factor item correlations (green colors) and negative between-factor item correlations (red colors). (**b**) Only some days later ($t = 49–56$), but after the main transition of the therapy (occurring at the vertical line in Figs. 5 and 9), this pattern dissolved. The change of correlation patterns concurs with the client's reports of increasing integration of her separate ego states throughout the therapeutic process

transient periods (yellow to red colors; out-of-attractor dynamics) correspond to periods of critical instabilities and, hence, increased dynamic complexity, whereas recurrent periods (turquoise to blue) represent more or less stable quasi-attractors. Figure 12 illustrates the transition from one stable pattern to another (blue rectangles), with a short transient period in between (yellow to orange pixels).

Besides the transition markers which are technically implemented in the SNS, there are others, like increased local frequencies, as identified by the wavelet-based method of time-frequency distributions (Cohen, 1989; see Haken & Schiepek, 2006, pp. 402ff.) or change points which can be identified by the method of change point analysis (James & Matteson, 2014). It should be noted that the coincidence of more than one transition marker or precursor is needed to identify an order transition (Schiepek et al., in review).

Dynamic Patterns of Interpersonal Systems

In order to assess interpersonal dynamics as they are realized in couple therapy, family therapy, or team development projects, the SNS offers two options: The first is to superimpose the time series of several persons (e.g., family or team members) in one and the same diagram. By this the processes of more than one person can directly be compared. For example, the experienced well-being or stress of the family members can be shown in superimposed time series. The other option is based on the assessment of sent or received communications by all involved members of a social system – a method which is called *dynamic interaction matrices* (Schiepek et al., 2015). In a first step, the dimensions on which this "sending" and "receiving" is experienced

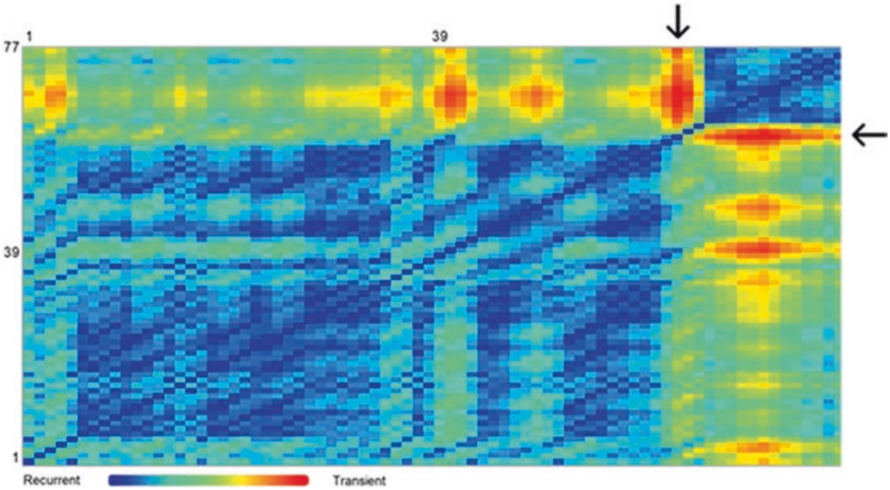

Fig. 12 Recurrence Plot. The arrows show a short transient period (coded by yellow to red colors) between two more stable quasi-attractors (compare Figs. 1b,c, 2b,c, 4a, and 8)

have to be defined, e.g., support, information flow, or stress. The questionnaire asks for the intensity of sending the defined quality (e.g., support) from one person to all others (arrows) and also for the intensity of receiving this quality from all other persons (counter-arrows, i.e., the space around the arrows in the cells). When all persons involved in the communication process during a defined period (e.g., a family therapy session) have rated their exchange, the results are presented by an interaction matrix, with the persons as senders arranged in lines and the persons as receivers arranged in columns (Fig. 13). The numbers in the lines at the right border of the matrices and under the columns at the bottom of the matrices represent the sum or the average of all arrows in a line (sent by one person) or the sum or average of all arrows in a column (sent to a person). The second number represents the perceived intensity of received communication (counter-arrows from one person as perceived by all others in lines, counter-arrows from all others as perceived by one person in columns).

Usually interaction matrices are assessed repeatedly, e.g., after every therapy session, every week, or every month (e.g., in a longer process of organizational dynamics). The sequence of such matrices can be visualized in the diagram wizard of the SNS by dragging a flag along a time series which represents the relation of sending (intensity of all arrows) and receiving (intensity of all counter-arrows). Methods like the interaction matrix which can be scaled up to 100 or more persons or the option of comparing the dynamics of many persons by time series diagrams can be used for the monitoring of change processes in organizations, interconnected teams, or other interpersonal networks. Current developments of the SNS concern the option of introducing not only time series from one and the same process questionnaire (intra-individual assessment) into raw data diagrams or complexity resonance diagrams but from different persons (inter-individual assessment). Here the lines would represent persons corresponding to different teams or departments of an organization. The SNS is on the way to get a powerful monitoring tool for change dynamics in organizations.

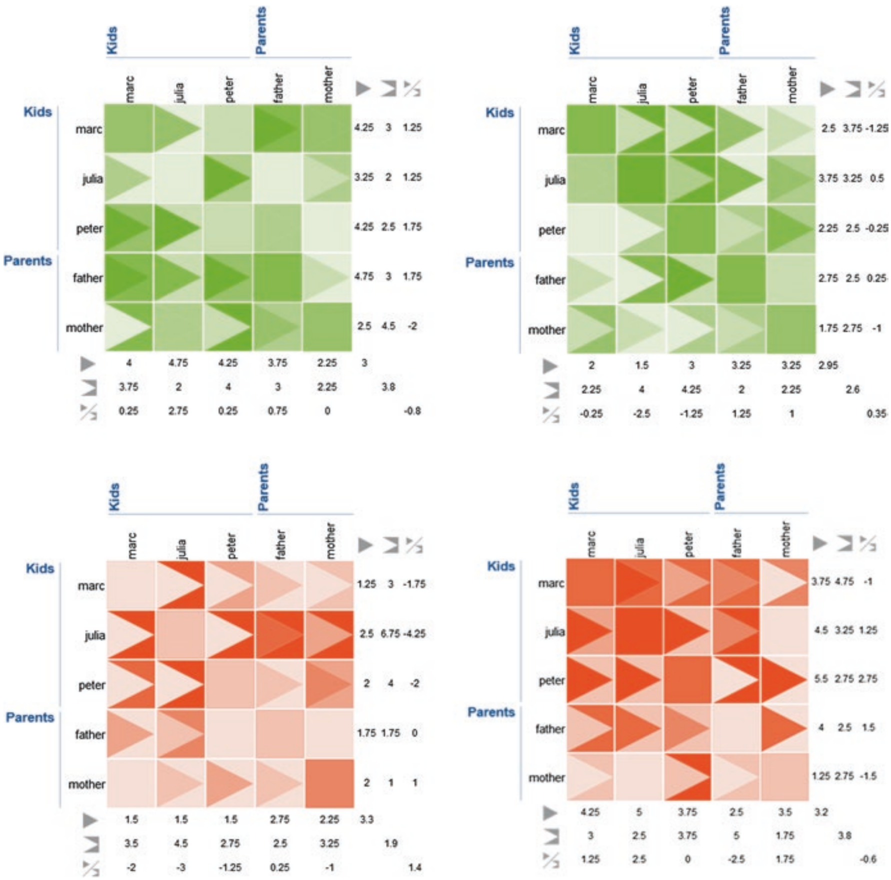

Fig. 13 Snapshots from a sequence of interaction matrices taken from 20 family therapy sessions. The matrices refer to session 8 (left) and session 17 (right). Upper part (green colors): The family members (father, mother, and the kids Marc, Julia and Peter) rated the intensities of sending (arrows) and receiving (counter-arrows in the cells) "support" to and from each other. Lower part (red colors): sending and receiving "stress"

Criteria of a Systemic Monitoring and Feedback Approach on Change Dynamics

Feedback procedures are able to capture the nonlinear features of human dynamics. Ten years of experience with the Synergetic Navigation System allowed for a deep insight into these features in many cases (e.g., Heinzel, Tominschek, & Schiepek, 2014; Schiepek, Tominschek, & Heinzel, 2014; Schiepek et al. 2016b). Actually, a data set of about 1.100 valid cases is available from different treatment centers. This continuously increasing data base opens the door to the investigation of many research questions and to a further validation of the mostly used process questionnaire (Therapy Process Questionnaire, TPQ; Schiepek et al., 2019a). In times of upcoming doubts on research results based on smaller (RCT) samples, it is important for quantitative and qualitative psychotherapy science to enter the world of big data. Perhaps more important is the option to combine big data with the individualization of measures and treatment procedures (e.g., Fisher, 2015; Fisher & Bosley, 2015; Schiepek et al., 2015).

Compared to other approaches in psychotherapy feedback, systemic concepts make a difference in practice as well as in technology. Most of the existing approaches focus on outcome and are far from any high-frequency assessment of change dynamics. Usually data are taken only at therapy sessions. In consequence, they cannot identify nonlinear features of change processes (e.g., order transitions, critical instabilities) and expect linear standard tracks of change dynamics. In contrast to this, the following criteria should be respected within a systemic monitoring approach:

- The theoretical framework is given by systemic theories like Synergetics, chaos theory, and complexity science.
- In order to identify the core concepts of systemic theories, e.g., dynamic patterns and pattern transitions, critical instabilities, or synchronization, it is necessary to assess processes and to visualize the processes by time series.
- The implemented linear and nonlinear methods of time series analysis should be able to identify important features of complex, nonlinear dynamics and self-organization.
- Sampling rates should be up to free choice, may it be event sampling or time sampling. In clinical practice, the preferred sampling rate is once per day. This is not imposed by the system, but is a decision of clinicians.
- Flexibility should exist concerning the applied questionnaires. In the SNS, standardized or individualized questionnaires – which are developed together with the client – can be used and combined. Of course, also process and outcome measures can be used and combined.
- Assessment of therapy outcome can be done in different ways: At rare time points – e.g., pre, post, follow-up – primary and secondary outcomes can be assessed. Based on high-frequency measurements, changing dynamic patterns of behavior, cognitions, and emotions can be identified. An example would be the transition of emotional instability of a borderline personality disorder to a more stable pattern of emotion processing.
- It should be possible to assess interpersonal patterns. In the SNS, this can be realized by dynamic interaction matrices or by superimposed time series from different persons.
- Individualized and client-specific procedures in psychotherapy and counseling should be facilitated by monitoring systems. Personalized procedures are based on the option of using individualized questionnaires and by mirroring individual dynamic patterns.

Understanding the Mechanisms of Change

The Investigation of Order Transitions

High-frequency monitoring of change dynamics provides the data base for understanding the mechanisms of change in psychotherapy and counseling. Especially from Synergetics and chaos theory hypotheses can be derived which are up for empirical proof. One hypothesis is that phase-transition-like phenomena (order transitions) characterize the short-term as well as the long-term evolution of cognitive, affective, and social networks. In order to investigate these phenomena in psychotherapy, we used the data from daily self-assessments of 18 clients diagnosed with obsessive-compulsive disorder (OCD; ICD diagnosis, F42; average age, 32.2 years, SD = 9.6; 9 female, 9 male) (Heinzel et al., 2014; Schiepek et al., 2014). The therapies were realized in a day-treatment center in Munich. Mean duration of treatment was 61 days (SD = 12.5, range from 37 to 88 days). Exposure with response prevention (ERP) was the most important intervention of the therapy. ERP is a therapeutic procedure where clients are confronted with symptom-provoking stimuli but abstain from performing compulsive rituals (e.g., cleaning). Every day, clients completed the Therapy Process Questionnaire (TPQ) and two times per week the Yale-Brown Obsessive Compulsive Scale (Y-BOCS), a self-assessment scale for obsessions and compulsions (Goodman et al., 1989). In order to compare individual change dynamics to ERP, we related the individual symptom severity trajectories to the onset of ERP.

The measure of dynamic complexity was calculated for the items of the TPQ in a running window (window width: 7 days). The time series of each client reveals increased dynamic complexity of the subscales and most of the items of the TPQ just before or during sudden changes, which were characterized by the steepest decrease gradient of the Y-BOCS scores. Significant decrease of symptom severity takes place before (!) the most important therapeutic intervention (ERP) has started. Figure 14 illustrates the mean z-transformed complexity signal of the change processes of all clients. Besides a complexity peak at the beginning of the treatment, which may be interpreted as an initial instability period representing individual ambiguity and varying degrees of working intensity, the most important peak occurred 3 days before the steepest gradient of symptom reduction was realized and about 7 days before ERP (flooding) onset ($T(17) = 2.48$, $p = 0.026$). In terms of Synergetics, this corresponds to the assumed critical instabilities accompanying order transitions of a self-organizing process.

Another study investigated order transitions of brain activity related to subjective experiences of clients during their psychotherapy process (Schiepek et al., 2013). 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). The time series of dynamic complexity were averaged over the items of the TPQ, and the maxima of these dynamics were used as an indicator of the most intensive fluctuation periods and the discontinuous transition(s) during the therapies. Three or four fMRI scans were realized during each of the psychotherapy processes of nine clients and

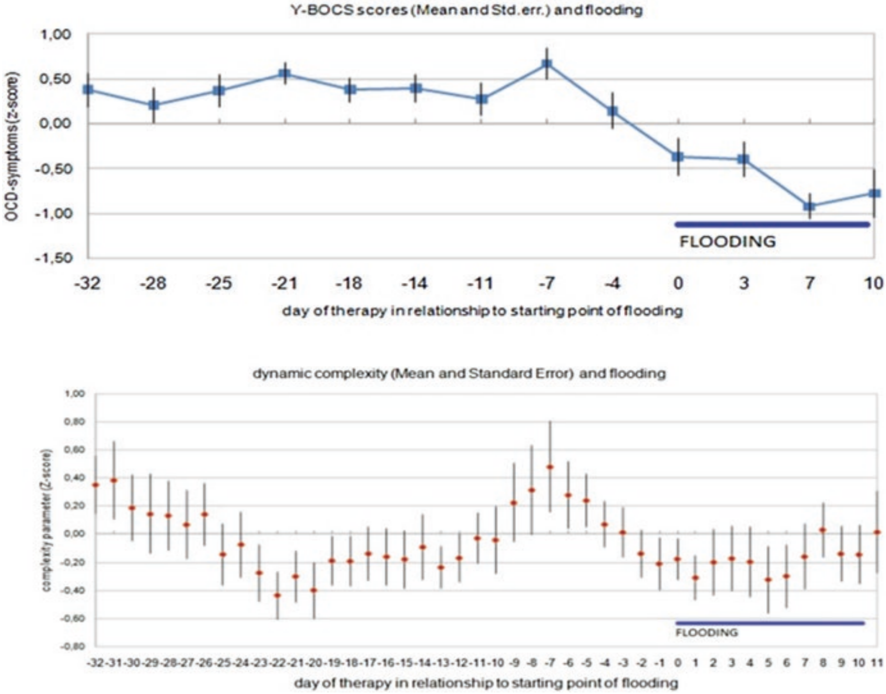

Fig. 14 Mean course of symptom severity (Y-BOCS, z-transformed) (upper part of the Figure), and mean course of the dynamic complexity of the TPQ (z-transformed) (lower part of the Figure), normalized in relation to the beginning of ERP. Vertical bars: standard error. The figure aggregates the dynamics of all 18 clients. For each client, the individual ERP onset was defined at $t = 0$, and the trajectories of the total Y-BOCS scores were related to this event. In 72% of the 18 cases, the steepest gradient of symptom change was located before ERP onset. The figure illustrates that the mean trajectory of the z-transformed individual total scores of the Y-BOCS has its steepest change gradient before ERP starts ($t = -4$ days), and symptom severity reaches a significantly reduced level at the day of ERP onset at $t = 0$ ($T(17) = 3.07$; $p = 0.007$). The averaged dynamic complexity reaches a maximum value at about 7 days before ERP (flooding) starts

compared to the scans of nine healthy controls. The study included clients with obsessive-compulsive disorder (OCD) of the washing/contamination fear subtype (DSM IV, 300.3), without comorbid psychiatric or somatic diagnoses. All clients except of one were drug naïve. Clients were matched to healthy controls. The visual stimulation paradigm of the fMRI scans used individualized symptom provoking, disgust provoking, and neutral pictures. The disgust and the neutral pictures were taken from the International Affective Picture System, whereas the client-specific OCD-related pictures were photographed in the home setting of the clients. Here we refer on the contrast of individualized symptom-provoking pictures vs. neutral pictures.

Eight brain regions (ROIs) were identified that are important in OCD-related neuronal processing: the anterior and the medial cingulate cortex as well as the supplementary motor area (CC/SMA), the dorsolateral prefrontal cortex (DLPFC) right and left, the insular cortex right and left, the parietal cortex right and left, and the cuneus.

When interscan intervals including order transitions (OT) were compared to intervals without (no) order transitions (NOT), the changes of the number of significant voxels for the contrast between individualized symptom-provoking pictures and neutral pictures show increased BOLD responses during OT in all relevant brain regions. The healthy controls received no therapy so that any distinction between intervals with and without order transitions has no importance. In healthy subjects functional changes were averaged across all interscan intervals (ISI). Figure 15 illustrates the changes in significant voxels averaged for each of the eight brain areas of OT and NOT of the clients and of interstimulus intervals (ISI) of the controls. Activation rates and change rates were significantly higher for clients compared to controls.

The differences between order transition intervals (OT) of the clients (mean voxel number difference: 7480, SD: 6835) and non-order-transition intervals (NOT) of clients (mean voxel number difference: 1900, SD: 1968) reached significance. In addition, the number of activated voxels differenced significantly between order transition intervals of clients and the interscan intervals (ISI) of the controls, whereas the differences between the NOT intervals of clients and the ISI intervals of the controls were quite similar. For each of the eight brain regions, pronounced differences occurred between OT and NOT and even more clearly for OT vs. ISI, but not for NOT vs. ISI. The most pronounced differences were realized in the CC/SMA, the DLPFC left, the DLPFC right, and the insula right. The differences in the area of the cuneus and the left parietal cortex did not reach significance because of large confidence intervals of the NOT number voxel differences. The high individual variability is partly the result of distinctly differing change patterns in clients as well as therapy processes.

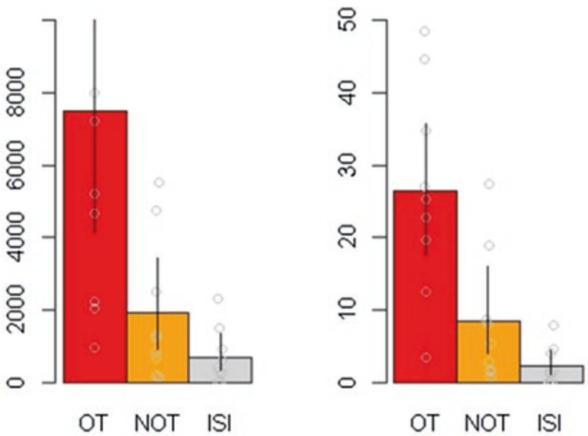

Fig. 15 Differences of significant voxels (averaged over subjects) between fMRI scans. OT (red): Differences between scans before and after an order transition occurred; NOT (yellow): Differences between scans where no order transition occurred (non-order transitions); ISI (gray): interscan intervals of fMRI scans of healthy controls. 95% confidence intervals of the means (vertical lines) were bootstrapped with R's boot.ci function using 10,000 resamples and the "bca" type of confidence intervals

An additional result concerned the intercorrelations of the involved brain areas. When comparing correlations before and after order transitions, the difference is striking, independent of where the order transitions were located in the course of therapy. The mean intercorrelation of the brain areas changed from 0.73 (SD: 0.09) to 0.33 (SD: 0.33) (p of the difference < 0.001). In addition to the decline in correlation, a differentiation of intercorrelations occurred which is reflected in an increase in variation (standard deviation of the intercorrelations increased from 0.09 to 0.33). This could be taken as an indicator of a decreased (pathological) network synchronization of OCD-specific brain areas.

To conclude: Most clients showed clearly recognizable order transitions in different brain areas. Changes in the activity of brain areas outside of order transitions were considerably weaker, similar to the differences between fMRI scans of the healthy controls which did not undergo psychotherapy and by this did not experience any significant dynamic changes. The strong connection between cognitive-affective order transitions and BOLD responses reversely validate the operationalization of order transitions by the maximum of dynamic complexity of the time series gained from daily self-assessments by the Synergetic Navigation System.

Modeling the Mechanisms and Dynamics of Psychotherapeutic Change

Like all other fields of research, systemic research tries to combine empirical studies with theoretical modeling. Conjectures and hypotheses are based on theoretical models of the systems under investigation. Because of its focus on complexity and dynamics, modeling plays an outstanding role in systemic research. The *explanandum* not only is the outcome of change processes but the process itself. We have to explain the mechanisms behind the dynamics of nonlinear systems, what needs for a qualitative modeling of the involved variables and parameters *and* for mathematical formalizations. In a next step, computer-based simulations of the processes can be realized (“experimentum in silico”). One example for theoretical systems research (*computational systems psychology*) is the modeling of client-related mechanisms of change. We developed a model which is based on profound knowledge in cognitive, emotional, and motivational psychology, psychopathology, and research on common factors of psychotherapy (described elsewhere, see Schiepek et al., 2017; Schöller et al., 2018). It includes five variables which are connected by 16 functions (Fig. 16a, b). The functions are represented in mathematical terms, which are integrated into five coupled nonlinear equations (one for each variable). The graphs in the coordinate planes of Fig. 16b (x-axis, input variable; y-axis, output variable) illustrate how the shape of each respective function depends on the parameter values. The full range of the variables is covered by the functions defining the influence of other variables, that is, there are no arbitrary segmentations or thresholds, which would have been introduced from the beginning. Thresholds and discontinuous jumps of the dynamics are emerging from the dynamics and not forced by specific predefined assumptions.

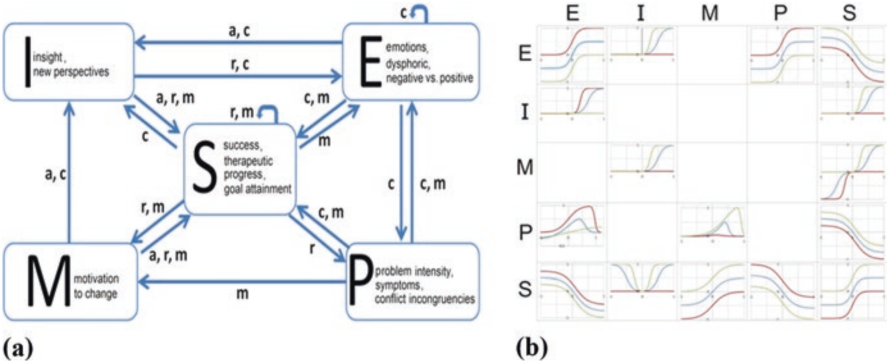

Fig. 16 A client-centered theoretical model of psychotherapeutic change. (**a**) The structure of the model illustrates the dependencies between the variables and the parameters of the system. (**b**) The matrix represents the 16 functions of the model (for a detailed description, see Schiepek et al., 2017). The variables noted on the left of the matrix (lines) represent the input; the variables noted at the top (columns) represent the output. Each function is represented by a graph in a coordinate system (x-axis, input; y-axis: output). Green function graphs correspond to the maximum of the respective control parameter(s) (= 1), red graphs to the minimum of the parameter(s) (= 0). Blue graphs represent an in-between state (0 < parameter value <1)

The model includes the following variables and parameters:

(E) Emotions. This bidimensional variable represents dysphoric emotions (e.g., anxiety, grief, shame, guilt, and anger) at the upper end of the dimension (positive values of E) and positive emotional experiences (e.g., joy, self-esteem, happiness) at the lower end (negative values of E). This definition of polarity is based upon the results of a factor analysis of the TPQ (factor "dysphoric affectivity")

(P) Problem and stress intensity, symptom severity, experienced conflicts, or incongruence

(M) Motivation for change, readiness for the engagement in therapy-related activities and experiences

(I) Insight, getting new perspectives on personal problems, motivation, cognition, or behavior (clarification perspective in terms of Grawe.)

(S) Success, therapeutic progress, goal attainment, and confidece in a successful therapy course.

The parameters of the model mediate the interactions between variables. Depending on their values, the effect of one variable on another is intensified or reduced, activated, or inhibited. Formally, parameters modify the functions which define the relationship of the variables to each other:

(*a*) Working alliance, capability to enter a trustful cooperation with the therapist, quality of the therapeutic relationship, and interpersonal trust. This parameter signifies the disposition to engage in a trustful relationship (attachment disposition) and also resembles the realized quality of the therapeutic alliance.

(*c*) Cognitive competencies, capacities for mentalization and emotion regulation, and mental skills in self-reflection.

(*r*) Behavioral resources and skills for problem-solving.

(*m*) Motivation for change as a trait, self-efficacy, hopefulness, and reward expectation.

The model reproduces some basic features of human change dynamics, as chaoticity (Fig. 17), sensitive dependency of the dynamics on initial conditions, minor interventions, and parameter values, order transitions (sudden changes), time sensitivity of interventions, impact of dispositions and competencies on the course of psychotherapy, and others (Schiepek et al., 2017). One important development of the model is the evolution of parameters (competencies or traits of a client) depending on the variables (state dynamics). The model realizes a circular causality of the parameters (traits) on the variables (states) and of the variables on the parameters (Schöller et al., 2018). Parameters are changing at a slower time scale, but in principle, a co-evolutive loop is realized between variables and parameters. Figures 18 and 19 illustrate the dependency of the processes on interventions. Figure 18 shows how dynamic noise can trigger order transitions if a self-organized threshold is reached or fails to create an order transition below this threshold. Figure 19 illustrates some long-term dynamics after intensive continuous interventions on all variables (e.g., a hospital stay for inpatient psychotherapy), including a rebound effect after release from treatment and a long-term evolution to stable effects when external emotion regulation (e.g., anxiety-reducing drugs) is stopped.

Further steps are model testing by using empirical data from the SNS (Schöller, Viol, Goditsch, Aichhorn, Hütt, & Schiepek, 2019) and the integration of data-driven computer simulations of individual processes into therapy feedback and treatment control.

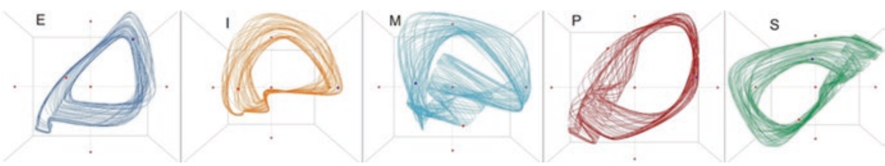

Fig. 17 The attractors of the variables E, P, M, I, S in a chaotic regime. *a*: 0.400; *c*: 0.675; *r*: 0.740; *m*: 0.475. Initial conditions of the simulation run: E: 0.99; P: 0.57; M: −0.34; I: 0.01; S: −0.32. Three-dimensional time delay embedding with $\tau = 1$. The attractors are based on 413 valid iterations (the last iterations from a simulation run of 5000 iterations) splined by the Excel standard spline function

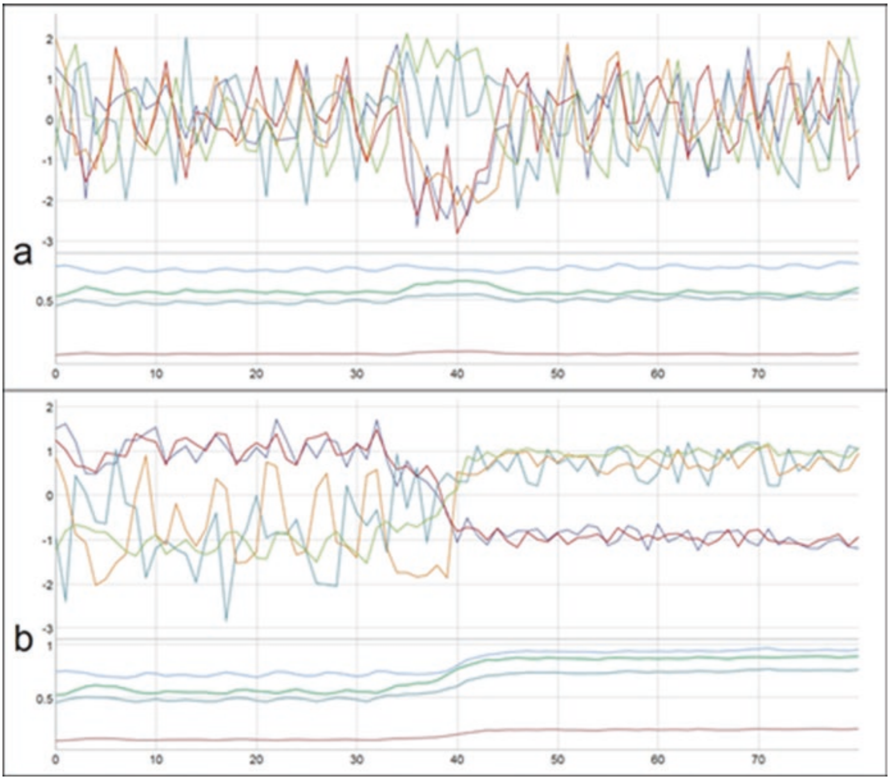

Fig. 18 Two realizations of dynamic noise (same amplitude and distribution of random numbers) applied on two realizations of simulation runs (**a** and **b**). Parameters: *a*: red; *m*: green; *c*: bright blue; *r*: dark blue. In both cases, the initial values of variables and parameters are identical: E: 97.6; P: 61.5; M: 7.5; I: 100; S: – 40.7. *a*: 0.10; *c*: 0.75; *r*: 0.46; *m*: 0.53. Dynamic noise 10% on E and P, 5% on M, I, and S, continuously. Data: (**a**) Direct access to simulation, Download CSV-file, (**b**) Direct access to simulation, Download CSV-file

Can Systemic Research Meet the Challenges of the Profession?

Coming back to the beginning, we refer to the challenges which were outlined in the introductory paragraph of this article. After presenting some ways of doing systemic research, it may be evident that at least some of the challenges can be met by the available methods and practice-related research strategies:

1. Deteriorations or precursors of dropouts can be identified in time by the process-related data and the analysis methods implemented in the SNS. Systemic methods of case formulation (Schiepek et al., 2015, 2016a) – which are beyond the scope of this article – provide the background for client-specific, tailored therapy concepts and for individualized questionnaires by which the monitoring of change processes can be optimized.

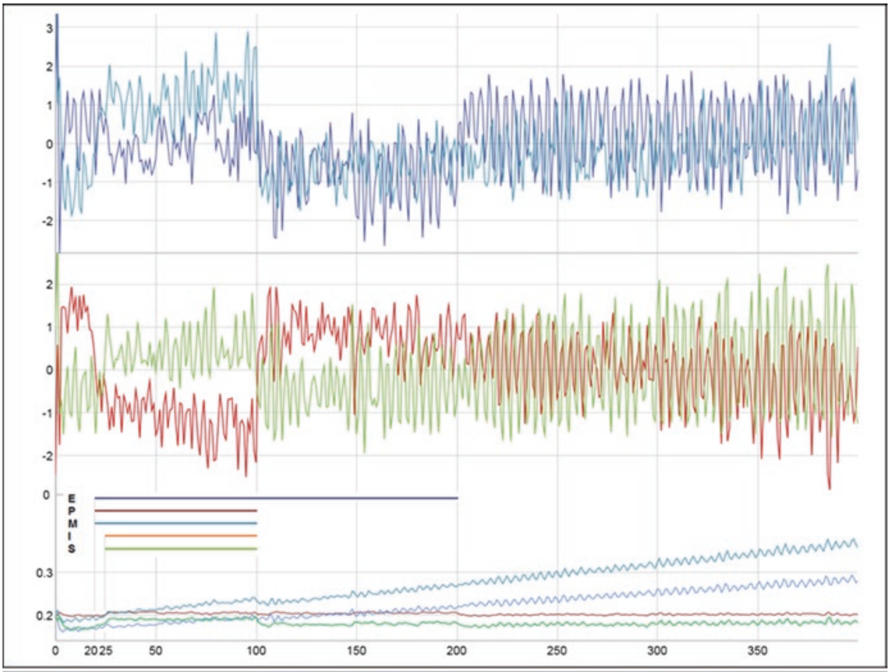

Fig. 19 Simulation run from $t = 1$ to $t = 400$. Assumed that one iteration corresponds to one measurement per day, 400 iterations represent a period of about 1 year and 1 month. Interventions on E, P, and M start at $t = 20$, interventions on I and S at $t = 25$ (+5% on M, + 10% on S and I, −10% on E and P). Except for E, all interventions end at $t = 100$, the intervention on E continues to $t = 200$. Effects of the interventions on all variables are to be seen but also a distinct rebound effect in S and M (decreases) and P (increase). The continued intervention (−10%) until $t = 200$ on E reduces stressful emotions but also the motivation to change (M) (upper part of the figure). After this period, M and S increase, and P decreases. It seems that a long-term recovery and self-healing process can only start if negative emotions no longer are suppressed, that is, the self-organizing effect onto another stable attractor can only take place if the system can follow its own unrestricted dynamics. Initial values of variables and parameters: E: 97.6; P: 61.5; M: 7.5; I: 100; S: −40.7; *a, c, r, m*: 0.20. Dynamic noise, 2%, continuously. (Data: Direct access to simulation, Download CSV-file)

2. Internet-based e-MentalHealth technologies like the SNS create a guiding thread across different segments of health care, like outpatient and inpatient psychotherapy. Clients can be monitored before, during, and after hospital stay and different professional health-care providers can use one and the same monitoring procedure, independent of the setting. This will contribute to the sustainability of treatment effects.
3. Complexity science, especially Synergetics and chaos theory, helps to understand the functioning of complex, self-organizing systems like brains, cognitive-emotional dynamics, and social networks. Beyond the meta-theoretical and paradigmatic framework for systemic research and practice, the development of concrete theories and models on the mechanisms of psychotherapy has started. These models integrate the knowledge of the ingredients and factors contributing

to the effects of psychotherapy (Schiepek et al., 2017; Schöller et al., 2018). The new transdisciplinary field of computational systems psychology opens the way to data-driven computer simulations of human change processes, which can be linked with real-time monitoring for the optimization and control of professional work.

4. The fact that we can neither predict the long-range trajectories of change nor the points in time when therapeutic crises will appear is an essential quality of nonlinear systems. Another consequence of nonlinearity is that interventions only have a small impact on the outcome. Indeed, this has consequences for how we have to conceptualize human change processes. Psychotherapy or counseling is not the manualized administration of treatment techniques but the support of self-organizing processes, which are conceptualized by the generic principles and driven by feedback on the processes.
5. Indeed, the fact that discontinuous jumps to the better or to the worse usually are independent of specific interventions cannot be explained by linear models, but by nonlinear models. These models including computer simulations based on such models gave rise to quite sophisticated concepts of "interventions" which are far beyond the idea of simply "disturbing" systems or "disrupting" patterns (Schiepek, Schöller, Carl, Aichhorn, & Lichtwarck-Aschoff, 2019b).
6. The meta-theoretical framework of nonlinear complex systems and computational systems psychology together with specific concretizations in theory development, empirical research, and feedback-driven practice create a new unifying paradigm in psychotherapy. As we know, paradigms are not exclusive in psychology, but a useful general frame for understanding and optimizing the profession.
7. Computer-assisted and Internet-based monitoring of human change processes has opened the way for practice-based research in realistic settings of health care and creates more ecologically valid and generalizable results than RCTs in research settings ever can provide.

Summary: Systemic research – as outlined in this article – can meet some important challenges of psychotherapy and hopefully will contribute to the development of our profession.

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