# PSYCHOSOCIAL DEVELOPMENT IN ADOLESCENCE

## Insights from the Dynamic Systems Approach



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# A NONLINEAR DYNAMIC SYSTEMS APPROACH TO PSYCHOLOGICAL INTERVENTIONS[1]

*Günter Schiepek, Helmut Schöller, Roswitha Carl, Wolfgang Aichhorn, and Anna Lichtwark-Aschoff*

## The common view on interventions: a linear input–output model

The common view on intervention effects, which dominates the field of intervention science but also teaching and training in practice, is that therapeutic effects are caused by applying certain interventions or treatments. From this point of view the goal is to optimize and to control interventions. Manualized treatment programs are developed to guarantee the quality of interventions and to avoid unintended variability of effects caused by client or therapist factors, or arbitrary environmental inputs. Within this tradition, randomized controlled trials are seen as the golden standard to test the effectiveness of interventions, because it is thought that through randomization and experimental or statistical control of error variance, the influence of unintended factors is eliminated. Based on this type of methodology, researchers and practitioners expect that clients' trajectories of change will follow specific pre-defined tracks. Given a certain set of initial conditions (e.g., diagnosis) a client's change profile is predicted (i.e., estimated treatment response) based on averaging the trajectories of similar types of clients (Lambert et al., 2005). This type of reasoning can be described as *intervention causality* (see also Van Geert & Steenbeek, 2014); a linear perspective on intervention effects following an input–output mechanism – the better the intervention, the better the outcome will be.



Recently, this traditional view on intervention effects has come under serious attack, not least by advocates of common or non-specific factor (e.g., alliance between client and therapist, client's expectations) research. Various meta-analyses have shown that the effect of treatment-specific elements and intervention protocols

1 This article is dedicated to Professor Isa Sammet for her 60th birthday. We appreciate her important work in nonlinear dynamics and process research on psychotherapy.

is actually smaller compared to non-specific factors like working alliance, treatment expectation or allegiance, and resources or stressors in the client's everyday environment (Wampold, 2015; Wampold & Imel, 2015). Additionally, several studies have demonstrated that clinical improvement is not necessarily "triggered" by certain specific interventions. For instance, it has been shown that clients realized cognitive restructuring of irrational beliefs before the actual cognitive interventions took place (Kelly et al., 2005, 2007). Likewise, reductions of compulsions happened before clients underwent exposure with response prevention (Heinzel et al., 2014). Moreover, adherence to treatment protocols does not seem to matter much and in fact produces only small effect sizes (Owen & Hilsenroth, 2014; Wampold, 2015). Similarly, so-called component studies (dismantling or additive studies) show that components of treatment programs can be rearranged or even eliminated without affecting the overall effectiveness of the treatment (Ahn & Wampold, 2001; Bell et al., 2013; Wampold, 2015; Wampold & Imel, 2015).

From a linear input–output perspective these findings are difficult to understand, because from an intervention causality perspective one would for instance expect that significant changes in symptoms are triggered by specific interventions, provided in a specific order, and that adherence to protocols matters. Theories of self-organization and nonlinear dynamic systems provide an alternative view on mechanisms of change, which are able to explain these "anomalies" and generate new hypotheses.



## Chaos and self-organization in human change dynamics

Decades ago psychotherapists encountered chaos theory. Basically, chaos[2] is a deterministic process that can be fully calculated but not predicted in the long term (Schuster, 1989; Strunk & Schiepek, 2006). One of the reasons for the fundamental unpredictability is the sensitive dependency of the dynamics on its initial conditions and on small fluctuations during the process (the so-called "butterfly effect"[3]). Consequently, applying interventions with expectable outcomes and controlling treatment processes becomes impossible. This (long-term) uncontrollability and unpredictability of treatment processes actually resonates well with the rather small impact of specific interventions on therapeutic outcomes. Maybe Sigmund Freud was right after all, in that psychotherapy is an "impossible profession."

Some might feel that this is a rather pessimistic view on interventions and psychotherapy. Indeed, we do believe that control and manipulation of chaos in a goal-directed manner is an illusion, and hence, an attitude of modesty and humility

2 (Deterministic) chaos can be seen as irregular dynamics, which is characterized by a complex order. Although chaotic dynamics may be created by nonlinear deterministic mechanisms (e.g., coupled nonlinear equations), their (long-term) predictability is limited.

3 The butterfly effect is the sensitive dependency of the system dynamics ("trajectory") on its initial conditions or on small aberrations of the dynamics, e.g., by intrinsic fluctuations or by any kind of input from the environment. This kind of sensitivity limits any long-term predictability of the system dynamics and it is a basic characteristic of nonlinear "chaotic" systems.

towards the feasibility of goal-directed change is warranted. But chaos theory and theories of self-organization[4] and nonlinear dynamic systems do provide us with concepts (e.g., attractor states, phase transitions, critical fluctuations) as well as tools (e.g., time-series analyses) to study and navigate clients' therapeutic processes under these "foggy" and fuzzy conditions. In particular, the concept of phase or order transitions[5] has been useful to conceptualize clinical change (e.g., a qualitative shift from a bad, psychopathological state to a good, healthy state) and based on those theories we can identify generic markers of order transitions that will enable us to identify "sensitive periods" in the change process of clients (i.e., periods in which clients are potentially most susceptible to intervention efforts) that can inform practice of how to adapt and personalize treatments.

It is important to note that we focus on sensitive periods and order transitions within therapeutic processes. But critical transitions also occur on a developmental timescale. Adolescence is a prime candidate of a phase transition on a developmental timescale (e.g., Granic et al., 2003; Lichtwarck-Aschoff et al., 2009). The increased sensitivity to external and internal perturbations during this developmental period can explain the increased prevalence of certain disorders (e.g., conduct problems, schizophrenia, depression). At the same time, it may also provide a window of opportunity to alter developmental trajectories because the instability and flux, characteristic of the adolescent period, means that deviations and perturbations (e.g., treatment efforts) are expected to have a much larger effect compared to more stable developmental periods (see Granic & Patterson, 2006, for similar argument).



## Critical instabilities and order transitions

A number of studies have identified discontinuous jumps or shifts within clinical change trajectories, such as sudden gains or losses, depression spikes and relapse (Haken & Schiepek, 2006; Hayes et al., 2015; Kelly et al., 2005, 2007; Lutz et al., 2013; Schiepek et al., 2013, 2014; Stiles et al., 2003). These sudden qualitative changes can be described formally using the theory of Synergetics[6] (Haken, 2004; Haken & Schiepek, 2006). In the field of quantum optics, Hermann Haken has shown that dissipative thermodynamically open systems undergo non-equilibrium phase transitions that emerge when system-specific control parameters (energy input, e.g., electric current) are gradually changing.

4 Self-organization is the spontaneous emergence of order or discontinuous jumps between modes of order in complex systems.

5 An order transition is a spontaneous emergence of a pattern or discontinuous jump between patterns in a complex system. Because we usually do not have access to the control parameters in psychological systems and phase transitions require particular (manipulated) changes in control parameters we prefer to use the softer term "order transition," when we refer to clinical change phenomena.

6 Synergetics is the transdisciplinary science of self-organization (pattern formation and pattern transition) in complex systems. It is a general theory and methodology that can be applied to many systems, e.g., in physics, chemistry, biology, psychology, or the social sciences.

Through this mechanism Haken was able to explain the discontinuous transition from broad-spectrum light to LASER light. These qualitative jumps (i.e., phase transitions) are preceded by critical instabilities or fluctuations, which signify that system dynamics are breaking down, searching for a new equilibrium (see also Thelen & Ulrich, 1991).

The occurrence of critical fluctuations and order transitions have also been found in psychotherapy processes (Haken & Schiepek, 2006; Schiepek, Heinzel et al., 2016; Lichtwarck-Aschoff et al., 2012), even at the level of brain dynamics (Schiepek et al., 2013). For example, Heinzel and colleagues (2014) investigated change dynamics during psychotherapy of clients diagnosed with an obsessive-compulsive disorder (see Figure 4.1). Results showed that significant sudden decreases of symptoms (Figure 4.1a) co-occurred with locally increased dynamic complexity (a marker of critical instability) (Figure 4.1b). Moreover and interestingly, these discontinuous jumps in symptoms and critical fluctuations appeared in all cases *before* exposure with response prevention (i.e., flooding) as the main treatment component was introduced, again showing that significant changes in clients' functioning are not (necessarily) triggered by specific treatment elements. This latter finding is in line with a number of case studies, in which reported significant order transitions were *not* a response to planned therapeutic interventions but were triggered by unintended but personally meaningful events in the social environment or within the internal mental processes of the client (Haken & Schiepek, 2006; Schiepek et al., 2015; Schiepek, Stöger-Schmidinger et al., 2016; Schiepek et al., 2009).



Order transitions occur in systems if there are: (a) nonlinear relations and mixed (activating and inhibiting) feedback between system components or subsystems (both can be assumed in biological systems), (b) changing control parameters,[7] and (c) more or less stable boundary conditions.[8] Order transitions do *not* necessarily emerge in response to specific interventions or triggers. Triggers can occur but triggers alone are neither necessary nor sufficient. On the contrary, whether inputs or triggers will elicit change or not depends on the stability of the system. When the system is in a state of critical instability,[9] minor triggers or fluctuations from outside or inside the system will be intensified ("deviation amplifying feedback") and will create symmetry-breaking transitions; when the system is in a stable state, fluctuations or triggers will be damped away.

7 The control parameter(s) of a dynamic system determine the dynamic pattern that is realized by the system. In thermodynamically open (dissipative) systems these parameters refer to the energy flow through the system. In a more general sense control parameters modulate the interaction between the components of a system and once critical thresholds are passed can change the qualitative state of the system.

8 Boundary conditions are environmental conditions of a dynamic system, e.g., weather or energy supply. For psychological systems, the experimental setup of a psychological experiment, treatment condition, alliance with therapist may be examples of boundary conditions.

9 Critical instability can be seen as fluctuations that are precursors of an order transition in self-organizing processes.

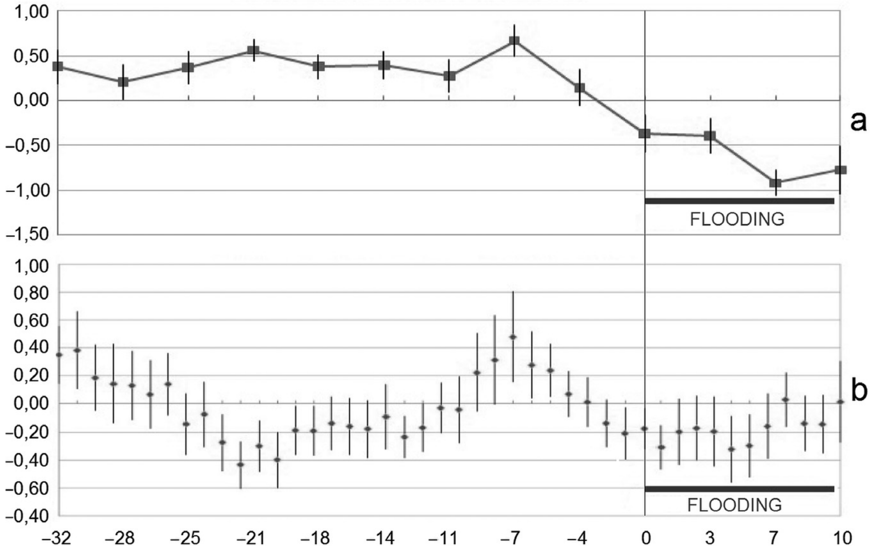


**FIGURE 4.1** Therapy process of 18 clients diagnosed with obsessive-compulsive disorder, treated with cognitive behavioral therapy. The graphs were re-normalized to the beginning of the exposure with response prevention (ERP) at t = 0 on the x-axis. The black horizontal bar indicates the ERP period (flooding). The graphs represent 35 days before ERP onset and 10 days after ERP onset. (a) Group mean trajectory of the z-transformed total score of the Yale-Brown Obsessive Compulsive Scale (Y-BOCS), completed twice per week. Vertical lines indicate ± 1 standard error. (b) The process was assessed by daily self-ratings, with the Therapy Process Questionnaire. In a running window the dynamic complexity of each item's time series was calculated. The line shows the arithmetic mean of the z-transformed dynamic complexity of all 18 clients and all items of the process questionnaire. Vertical lines indicate the standard error of the averaged dynamic complexity. Figures (a) and (b) show that Y-BOCS scores decrease and dynamic complexity increases before ERP starts.



*Source*: Adapted from Heinzel et al. (2014).

This view on clinical change and treatment effects is fundamentally different from the linear input–output model, described above. Clinical improvement is not caused by some sort of independent variable (e.g., properties of a particular intervention), which is the basic assumption in intervention causality, but it is the result of a system-wide reorganization. In that sense, causality is placed within the system (i.e., *internally driven causality*, Van Geert, 1998, p. 144; Haken & Schiepek, 2006, p. 285). It is important to note that "internally" does not mean that there are not also external factors influencing the process, but causality cannot be considered without a system's own dynamics. In other words, treatment is not a separate causal factor producing linear relationships between input (e.g., dosage, technique) and output (e.g., improvements in symptoms), but a factor whose functional role is dynamically embedded in an idiosyncratic network of multiple components.

## Psychotherapy as dynamic support of clients' self-organizing processes

Following this perspective, psychotherapy should be conceptualized as providing the conditions for self-organization to occur (Gelo & Salvatore, 2016; Haken & Schiepek, 2006; Pincus, 2009), rather than pushing interventions on clients. Therapists are responsible for the client-centered and process-sensitive realization of these conditions, not so much for the application of treatment protocols on disorders. What exactly these conditions are is inferred from the theory of Synergetics, and they have become known as *generic principles*[10] (Haken & Schiepek, 2006; see also Hayes et al., 2015). These principles serve to organize and justify the choice of therapeutic techniques (see the concept of "relative rational justification" of therapy-related decisions; Westmeyer, 1984). Therapeutic techniques can be evaluated according to whether they assist in realizing one or several of the generic principles. In this regard, therapeutic techniques are *functionally equivalent*, i.e., therapists can choose a technique depending on the client and his/her individual change process but also depending on the therapist's own experience, personal preferences, and style. This functional equivalence of techniques in the realization of conditions for self-organization is in line with the so-called "Dodo-bird effect" (Wampold & Imel, 2015), which holds that various treatment approaches produce similar effects.



The relationship between therapeutic techniques and generic principles is doubly ambiguous: a certain technique can implement several principles, and a certain principle can be realized by several techniques. For example, the principle of "activation of control parameters" can be realized by clarifying goals, by activating personal resources, and by enabling a sense of achievement. On the other hand, a therapeutic technique such as building a positive therapeutic alliance, can be important for realizing the principle of "stable boundary conditions" but also for the "activation of control parameters" or "kairos, resonance, and synchronization."

Importantly, the generic principles should not be understood as a sort of "protocol," forcing a normative sequence of things that a therapist should do in a particular order. In contrast, the generic principles are relevant throughout the entire therapeutic process and their relevance changes depending on the stage a client is in. The principles can thus be used to (a) create a theoretical foundation of the clinical work, (b) organize the therapeutic process according to an explicit description and understanding of a client's underlying change process, and (c) reduce the

10 These generic principles are derived from Synergetics and are based on principles of self-organization. The principles describe conditions that should be realized in order for self-organization in human change processes to take place.

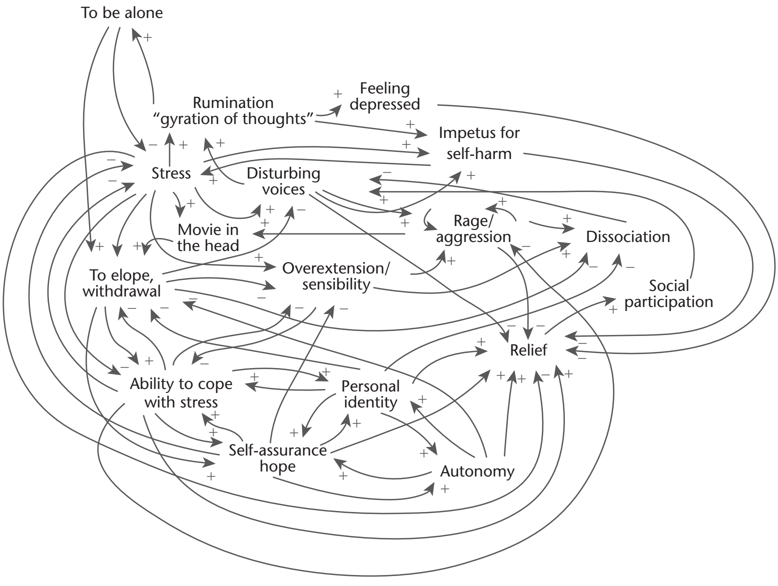


**FIGURE 4.2** An idiographic system model is a synopsis of psycho- and socio-dynamic aspects of the client's experiences.

*Source*: Adapted from Schiepek, Stöger-Schmidinger et al. (2016).



complexity in practice created by the large client-specific and situation-specific variability, according to a limited set of general criteria. In that sense, the generic principles function as a means to understand the therapeutic process, and should provide the clinician guidelines to make decisions within the treatment process. How the process is shaped is at the heart of the therapeutic art and expertise. In the following we will provide a short description of the eight generic principles:

1. *System definition*. It is necessary to determine which system the intended processes of self-organization should relate to. The structure of the system has to be modeled by methods of clinical case formulation (Eells, 2006). One method is idiographic system modeling (Schiepek et al., 2015; Schiepek, Stöger-Schmidinger et al., 2016) in which client and therapist co-create a representation of the system as a network of interconnected elements (cognitions, emotions, behavior, factors of the social and physical environment; see Figure 4.2). The case conceptions retrieved by this and other methods provide a frame of reference for the therapeutic process – not the least to assess changes – and for the decisions on therapeutic interventions (Fisher, 2015; Fisher & Boswell, 2016).
2. *Stable boundary conditions*. Order transitions occur within stable boundary conditions. Supporting self-organized order transitions means to *destabilize within the context of stability*. Stabilization includes interventions that create certainty

about the structure (setting, transparency of the procedure), the quality of the therapeutic relationship and confidence in the therapist (concerning his/her competence, credibility, emotional stability), and activities that support the client's internal growth (experiencing self-efficacy, sense of control and manageability, access to personal resources, experience of congruence towards central life goals and schemata). Also continuous self-assessments contribute to stability and structure.

3. *Sense of significance*. It is important that clients perceive their personal change process as meaningful and in congruence with their own personal life goals. This may be particularly relevant for adolescents who are in the midst of developing their sense of autonomy and own personal life goals. In cases of crisis (e.g., trauma), when the personal sense of internal coherence and goal-oriented behavior are severely threatened it may even be more important that the therapeutic process – at least in the beginning – is compatible with the client's schemata and basic beliefs (Caspar, 1996). This corresponds to the dimension of "meaningfulness" in Antonovsky's "sense of coherence" (Antonovsky, 1987). Only significant and meaningful projects warrant investment of resources and effort.
4. *Activation of control parameters and motivation for change*. Self-organization requires, in the broadest sense, the energetic activation of a system. Specifically, order transitions require a certain activity level of relevant control parameters that drives the system from its thermodynamic equilibrium. In many physical systems, these control parameters relate to an energy flow, such as increases of the electric current in the case of the LASER (see above). Likewise, providing hope and motivational conditions (e.g., goals and wishes), activating resources (e.g., social support), and intensifying emotional involvement of clients may be the "energy" required in psychological treatments. These factors might thus be the driving parameters of change in therapeutic processes (control parameter equivalents).
5. *Destabilization and amplification of fluctuations*. Psychotherapy provides new opportunities for experiences. Consequently, existing cognitive, emotional, and behavioral patterns are destabilized during psychotherapy, which, in the beginning, can feel unsettling. The client experiences new and emotionally relevant states for an increasing length of time and in increasing magnitude (deviation amplifying feedback[11]). In practice, different techniques can be used to interrupt or to destabilize dysfunctional patterns. These techniques include exercises and role-play, behavior experiments, exposure, cognitive restructuring, and others.
6. *Kairos, resonance, and synchronization*. It is important that the applied therapeutic interventions match with a client's current cognitive-emotional state,



11 Deviation-amplifying feedback, sometimes also called positive feedback, intensifies or "amplifies" deviations from a stable state or attractor state. Deviation amplifying is contrary to re-stabilizing, or negative, feedback, which reduces and dampens deviations away to keep a stable state in place.

because therapeutic efforts can only have an impact when the client is open to them and processes the input in a self-related way (self-relatedness; Orlinsky et al., 2004). On shorter timescales (e.g., in direct conversations during therapy sessions), this matching pertains to aspects like synchronization or coupling of posture, rate and content of speech, pausing, and eye contact. Matching on this level is thought to be important because it creates the basis for mutual communication and influence (Osipov et al., 2007; Pikovski et al., 2001). On longer timescales, matching contains aspects like the frequency of therapy sessions (e.g., in crisis more frequent meetings might be necessary compared to more stable periods) or whether or not a specific intervention (technique) is appropriate given the state that a client is in. The term *kairos* is important in that respect because it denotes a qualified time to intervene. More concretely kairos are moments that offer certain opportunities (e.g., during critical instabilities) and facilitate innovations.

7. *Purposeful symmetry breaking*. In Synergetics, "symmetry" means that in systems far from equilibrium and close to a transition-demarcating threshold, two or more attractors[12] are potentially equally likely to be realized. As it is small fluctuations that determine their realization, it is difficult to predict the system's further development. However, there are situations in which certain patterns should be avoided and not left to chance (e.g., situations in which a client is at risk to commit suicide or at risk for relapse). Therefore, in order to steer symmetry breakings in a particular direction, certain assistance can be provided, e.g., some structural elements of a new order state can be realized in, for instance, role-play. Thus, in other words, clients can be asked to imagine desired goal states or to anticipate certain desired behaviors in order to help them to steer symmetry-breaking behaviors in a particular – desired – direction. Similar to a ski athlete who prepares himself for the competition by mentally going through the ski track, anticipating all his movements, clients can be pushed into the right direction by capitalizing on and supporting their potential of anticipating desired states.
8. *Stabilization of new patterns*. Once positive patterns are established, they have to be stabilized, automatized, and kept available. Here, techniques for stabilization and generalization of patterns play an important role, such as repetition, variation, application in different situations and contexts, or positive reinforcement. Finally, the new patterns have to be integrated into the existent sense of self and linked to present emotional self-schemata.



A crucial point in the understanding of interventions from a nonlinear dynamic system perspective is their sensitivity to the process. In other words, it is less important *what* kind of treatment approach is realized compared to *when* certain interventions take place (process sensitivity). From this point of view, manualized

12 Attractor is the pattern or "Gestalt," which can be seen if the trajectory of a system dynamics is embedded in a phase space (see "trajectory").

and pre-defined treatments may be counterproductive. This fundamental time-based sensitivity of interventions can best be illustrated by a computer simulation of psychotherapeutic change dynamics.

## The dynamic sensitivity of change processes

The simulations that we present here are based on a mathematical model of psychotherapy, grounded in established insights on non-specific factors. A thorough discussion of the mathematical model is beyond the scope of this chapter. We refer the interested reader to Schiepek et al. (2017) for a detailed description; here we will just describe the basic idea without going into the theoretical background and the mathematical details. The model includes five variables, which represent psychological states of a client within the therapeutic process (in Synergetics they can be understood as order parameters[13]). The variables are interconnected by 16 nonlinear functions. The functions are represented in mathematical terms that are integrated into five coupled nonlinear equations (one for each variable). The variables are: (E) emotions, a bi-dimensional variable representing dysphoric (e.g., anxiety, grief, shame, guilt, and anger) and positive (e.g., joy, self-esteem, happiness) emotional experiences; (P) problem intensity and symptom severity; (M) motivation for change; (I) insight and getting new perspectives; and (S) success, therapeutic progress, and a client's confidence in a successful therapy course.



Four parameters, which can be understood as competencies or dispositions of the client (in Synergetics they correspond to control parameters), mediate the interactions between those variables. Depending on their values, the effect of one variable on another is intensified or reduced, activated or inhibited. The parameters are: (*a*) working alliance and capability to enter a trustful cooperation with the therapist; (*c*) cognitive competencies, capacities for mentalization and emotion regulation; (*r*) behavioral resources or skills that are available for problem solving; (*m*) dispositional motivation to change, self-efficacy, and reward expectation. Note that motivation for change as a state variable is represented by M, motivation for change and self-efficacy as a trait parameter (the opposite of hopelessness and learned helplessness) is represented by *m*.

Because the variables are connected nonlinearly, their behavior can show signs of chaos and sensitivity to specific interventions. As simulations show, at the edge of instability, interesting phenomena can occur (Figure 4.3): small perturbations can trigger a shift in dynamic regime (in this example, of motivation for change, M), and by following inputs, the activated dynamics can be switched off (e.g., from complex regularity to chaos and back to regular oscillations). In the simulation

13 An order parameter is a measure or concept that allows for the description of the global behavior of many components or subsystems of a system. In terms of Synergetics, order parameters are global patters emerging from the interaction of many components and the other way around, constraining or "enslaving" the behavior of the components (circular causality between bottom-up and top-down effects).

runs shown in Figure 4.3 we added 20% of the possible range of the dynamics as intervention intensity (arrows in Figure 4.3). Given specific parameter values, it seems possible to switch the dynamic patterns on and off, but only at appropriate moments (Figure 4.3a). This corresponds to the "kairos" phenomenon of sensitive time windows for certain treatment efforts. Outside of these sensitive periods, similar interventions have no switching effects (Figure 4.3b). The switching effect is a proof of the bi- or multistability of the system. This means that the system is able to create two or more dynamic patterns at the same set of parameter values. Depending on the initial conditions of the process, a specific input or even small fluctuations, can lead the system to manifest one of the different available patterns. In the future, computer simulations can help to identify the parameter range where we can expect multistability. Data-driven simulations may help to estimate the probability of successful interventions.

Psychologically, dispositions (i.e., the parameters of the model; control parameters) change at a slower timescale than states (i.e., the variables of the model; order parameters). However, due to the constraining effects that control parameters have on the interaction of order parameters, a linear and continuous shift of one or more control parameters may have sustainable effects on the dynamic patterns of a system (i.e., the order parameters); in the sensitive or critical range of the control parameters changes in values produce discontinuous jumps of the dynamics (i.e., order transitions).



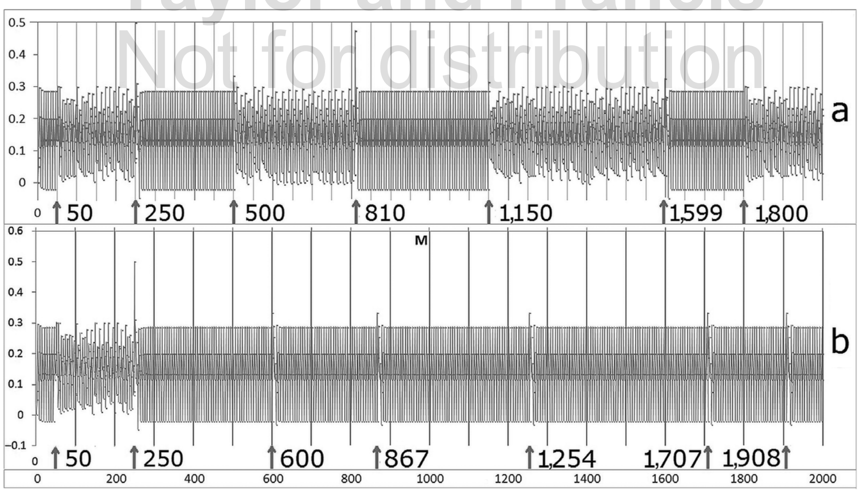


**FIGURE 4.3** Time-dependent effects of interventions. Initial conditions: E: 0.99, P: 0.57, M: –0.34, I: 0.01, S: –0.32; *a*: 0.05, *c*: 0.71, *r*: 0.78, *m*: 0.65. Here the time series of M is shown: (a) interventions (20%, arrows) at certain time steps produce instantaneous shifts between chaotic and regular oscillations; (b) interventions (20%, arrows) at other time steps create only very short deviations from regularity. The oscillatory attractor is re-established after some few iterations.

Whereas control parameters in physical experiments are susceptible to external control, psychological parameters in the sense of traits or competencies are not. Traits are merely indirectly open to external input: dispositions or competencies can be developed, but not directly influenced. Traits depend on concrete (moment-to-moment) behavior, emotions, and cognitions, that is, on the experiences a person has in numerous consecutive specific situations. Over time *learning* or *personality development* occurs through the modification of the dynamics of a system. The modulation of the control parameters (traits) is fed by (or emerges through) changes of the order parameters (states). Traits on the other hand, constrain the interaction of the state parameters. Thus, in other words, there is a circular causality from traits to states and from states to traits (see also De Ruiter et al., 2017), from control parameters to the order parameter dynamics, and from the dynamics of order parameters to control parameters (Schöller et al., 2018). In our model four evolution equations are added that describe this interdependency between control parameters (trait dynamics) and order parameters (state dynamics).

Given this circular causality, even without any specific intervention, dynamic noise applied to the variables can lead to a positive trend of the parameters (Plate 1): a spontaneous transient period is realized at the beginning (from $t = 10$ to $t = 20$), from high levels of E and P and low levels of S and M to a balanced dynamic of all variables. Evidently, without intensive or continuous stressors (i.e., increasing input on E or P, and decreasing input on S or M), the model is capable of realizing a trend, which in psychological terms might be interpreted as a personal growth or self-actualization. In the long term, this could lead to spontaneous remission. Interventions that were implemented during a certain period (between $t = 50$ and $t = 60$) on all variables have a time-limited impact on the state dynamics. However, an order transition is not triggered by these multiple interventions; the circular coupling of traits and states remains under the threshold that could trigger an order transition (Plate 1b). This is due to the dependency of order transitions on *self-organized thresholds* of the coupling strengths between order and control parameters (circular causality). If interventions are not exactly placed at the moment of critical instability, punctual interventions usually are less likely to change attractors than continuous input. In the example of Plate 2a, the interventions on success (S) at $t = 17$, 30, and 50 have no impact on the dynamic pattern. Longer periods of *continuous interventions* – in Plate 2b an intervention on S from $t = 17$ to 25 is realized – have a higher probability to change patterns. The existence of bi- or multistabilities in the dynamics of a system opens the option of order transitions with control parameter drifts following the state dynamics, not only, as classical Synergetics predicts, from control parameter drifts to order transitions.

Interestingly, sometimes unspecific events like daily hassles or happiness – in terms of the simulation: dynamic noise – can trigger order transitions. In Plate 3a, a noise level of 10% on E and P and 5% on M, I, and S has no long-term and qualitative impact on the dynamics (although from $t = 35$ to 45 a successful period occurs by chance). Running the model a second time (i.e., with other random numbers) with the same amount of noise can trigger an order transition (in this instance it takes place between iteration 30 and 45) with long-term consequences on the trait level (Plate 3b). The message from mathematics is a little bit provoking at this point: Why does psychotherapy work? Sometimes clients have good luck! Here – like in Plate 2b – the parameter drift seems to follow the state dynamics and to be a consequence, rather than a cause of the order transition. A closer look at the dynamics reveals circular causality during the transition period: small changes in the level of the variables (here due to noise) increase the level of the parameters, i.e., the client integrates new qualities of experience and continues with higher competencies. This in turn affects his experience, represented by "better" values of the variables (S and M increased, P and E reduced), until a new stable state is reached. From there, small perturbations (noise) cannot shift the system any further; the variables and parameters fluctuate around a fix point. This kind of circular dynamic emerge through the coupled equations of the state and trait parameters.

These simulation results of our mathematical model illustrate the dependency of interventions on (a) timing and (b) duration of interventions, (c) the coupling strengths between order and control parameters, and (d) dynamic noise. The effects of interventions are sensitively dependent on these system-specific and process-specific conditions (i.e., *self-organized thresholds* and *self-organized criticality*). Consequently, professionals need to work under consideration and close monitoring of the actual system dynamics. For this, clinicians need process-sensitive feedback on the ongoing dynamics, especially on the stability or instability of the client system. One way to realize this is by using internet-based devices in which clients report on their (daily) progress. To this end, the Synergetic Navigation System (SNS) has been developed, which is an internet-based monitoring system to capture the client's individual change process continuously throughout therapy and possibly in the after-care period (Schiepek, 2009; Schiepek et al., 2015; Schiepek, Stöger-Schmidinger et al., 2016). We will illustrate the application of that system in practice by means of a brief case report.



## Assessing and intervening with the SNS

Besides the idea that interventions are intended therapeutic actions, we should respect that it is always the client who determines which experiences in his life will have what kind of impact on his cognitions, emotions, and behavior. What an intervention is and what the effects of it may be will ultimately always be "defined" by the system that undergoes change. In a strict sense, interventions are not addressed to a system, but are *created* by the system, i.e., the client. Rather than being a passive recipient of a therapist's interventions and actions, the client is an active agent within his/her own treatment process (see for an illustration Lambertz & Schiepek in Haken & Schiepek (2006, p. 525, about mutually changing pacing and leading patterns within client–therapist interactions).

One important way of creating continuous self-referential interventions of the client is self-reflection, which can be systematized by self-assessments. As studies on therapy monitoring and feedback show (e.g., Anker et al., 2009), self-assessments and writing of therapy diaries can have therapeutic effects. Especially high-frequency monitoring procedures, e.g., daily self-ratings, may exert an autocatalytic effect. This is illustrated by the case of an adolescent who used the SNS as a tool for continuous self-assessment.

The client was a 17-year-old boy (Simon), diagnosed with an "initial manifestation of a paranoid schizophrenia." He felt impaired by motoric restlessness, instable mood, cycling between hopeless, dysphoric affect, and excitement, formal thought disorders, blocked thinking, manipulated cognitions from the outside, and absent-mindedness. After a period of inpatient psychiatric treatment, he was referred to an outpatient center for adolescents.

During his hospital stay Simon was asked to fill in a list of established early warning indicators for psychotic episodes. Simon was not highly motivated to fill in this set of questions on a daily basis. Oftentimes he "forgot" to fill in those questions or filled them in at the last minute on his way to the therapy session. In the first session Simon appreciated that the therapist actually entered the dialogue in an open-minded way without having studied his client record.

In the first outpatient sessions, it became clear that Simon experienced very personal early warning signals indicating worsening of psychotic symptoms, such as specific activities, thoughts, flickering visualizations, strange smells, which were not represented by the list of "textbook" indicators that he was asked to fill in during his hospital stay. As a result, he lacked motivation to complete those questions. But he was keen on figuring out the relations and contexts of his own precursors and personal experiences. Moreover, it was very important for him – probably intensified by the fact that he is an adolescent – to be perceived as an autonomous and competent individual.



Focusing on his own personal experiences, he and his therapist developed Simon's own personalized list of early warning signals, which they translated into questionnaire items, using Simon's own words. This list of items was further completed by some standardized warning signals, resulting in the following items: quantity of sleep, movement and activities during the day, time spent listening to music, time spent at computer screen, school experienced as exciting or annoying, quality of breaks, intensity of social contacts outside school, mental concentration. These items were clustered in three thematic scopes: stressors, resources, and self-care. Simon rated the items on visual analog scales, and he wrote an electronic diary almost every day. He completed this personalized questionnaire, using the SNS, on his smartphone, over a period of more than nine months. Plate 4c illustrates the evolution of "resources," "self-care," and "stressors" over the assessment period.

During the following weeks, the time series of his daily ratings were repeatedly discussed in the therapy sessions. Inspection of the time series of each item and the option of superimposing the time series within a diagram resulted in new insights (for an illustration see Plate 4a and Plate 4b). Simon recognized that sufficient sleep and respecting breaks stabilized his mood. Walking to school or using the bicycle, exercise, and relaxation time were negatively correlated with symptom severity and contributed to longer symptom-free periods. The diaries revealed interesting insights into issues that were important to him and how he interpreted his world. These issues could then be included in the therapeutic discourse, which would not have been possible without the monitoring system.

In sum, the best auto-catalytic and self-motivating effects of continuous ecological momentary assessment may be produced by using personalized process questionnaires. Real-time monitoring of individual change processes allows for detailed feedback on the nonlinear features of the change dynamics. Utilizing this feedback, therapists, together with their clients, may become aware when critical instabilities and other precursors of order transitions emerge, and based on this they may decide on the usefulness of specific interventions ("continuous cooperative process control").

## Conclusion



In this chapter, we presented a framework, based on complex self-organizing systems, to re-conceptualize clinical change and psychological interventions. In this framework, clinical improvement is not caused by treatment protocols or intervention techniques, but results from a system-wide reorganization. It is these self-organizing processes that psychotherapy should aim to facilitate. At the same time, we have to acknowledge the fact that a client's behavior and response to treatment is unpredictable, at least on the long run. This implies that in order to navigate a client's treatment process we need high frequency and personalized data of a client's change process. In sum, our theoretical framework allows us to balance particularity and generality: adapting psychotherapy to the particulars of individual clients' change processes but do so according to the generalities of a formal theory.

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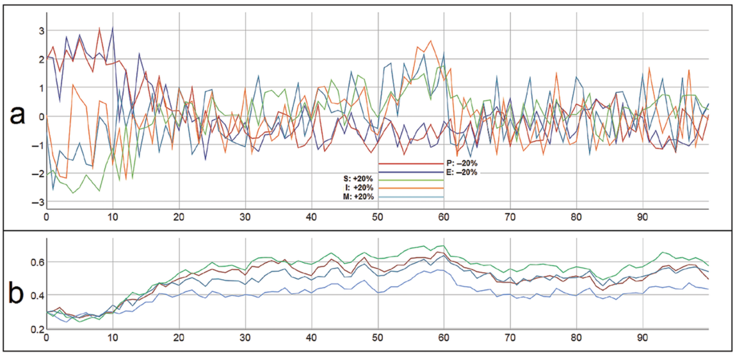


**PLATE 1** Noise-driven order transition between the 10th and the 20th iteration, accompanied by an increase of all parameters. Between the 50th and the 60th iteration, multiple interventions are introduced (+20% on M, I, and S, −20% on E and P). After this period, a spontaneous deterioration occurs since the effects of the interventions do not sustain. Parameters: *a*: red, *m*: green, *c*: bright blue, *r*: dark blue. Initial values: E: 97.6, P: 61.5, M: 7.5, I: 100, S: −40.7; all parameters: 0.30. Dynamic noise 30%, continuously.

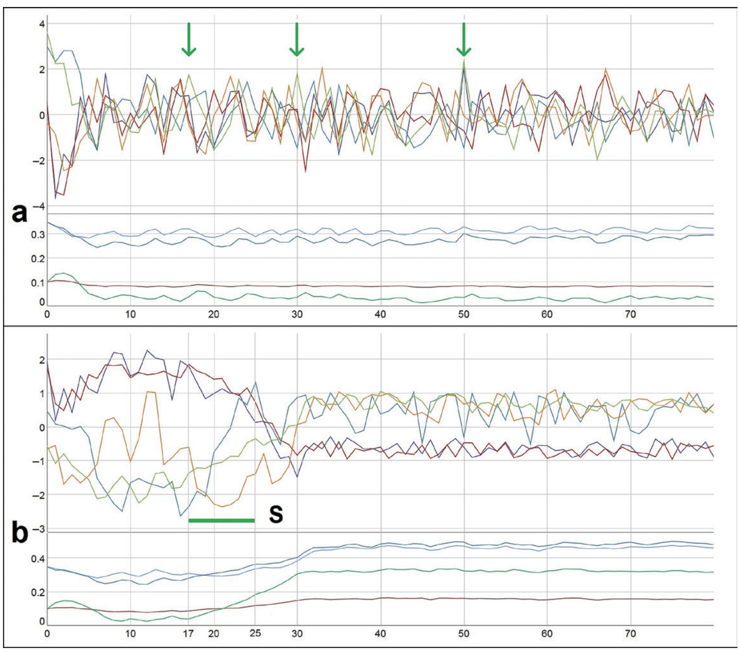


**PLATE 2** (a) Punctual interventions on S (+38%) at $t = 17$, 30, 50. (b) Continuous interventions on S (+38%) from $t = 27$ to 25. Parameters: *a*: red, *m*: green, *c*: bright blue, *r*: dark blue. Initial values of variables and parameters: E: 100, P: 79, M: 32.5, I: 50, S: 33.5; *a*: 0.10, *c*: 0.35, *r*: 0.35, *m*: 0.10. Dynamic noise 10%, continuously.

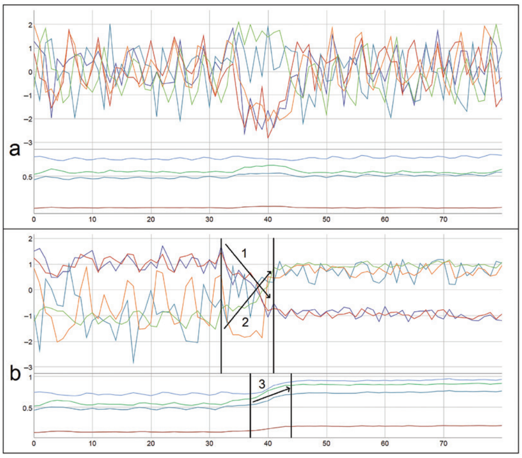


**PLATE 3** Two realizations (random numbers) of the same intensity of dynamic noise, (a) and (b). Parameters: *a*: red, *m*: green, *c*: bright blue, *r*: dark blue. In both cases, the initial values of variables and parameters are identical: E: 97.6, P: 61.5, M: 7.5, I: 100, S: –40.7. *a*: 0.10, *c*: 0.75, *r*: 0.46, *m*: 0.53. Dynamic noise 10% on E and P, 5% on M, I, and S, continuously. The order transition starts by changing order parameters (increase of S, M, and I [1], decrease of E and P [2]) and is followed by the change (increase) of control parameters [3], as is indicated by the vertical lines.

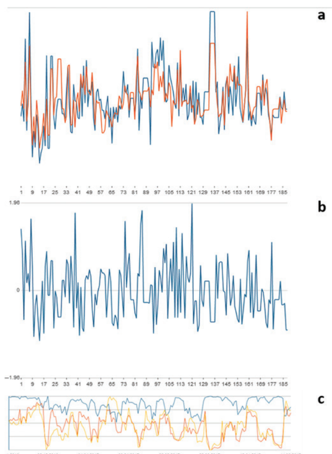


**PLATE 4** Time series of Simon's self-assessments. Length: 187 days. (a) Superimposed time series of "resources" (R, blue) and "self-care" (S, red). (b) Time series of "stressors" (St). (c) Evolution of the correlation patterns, calculated in a running window (window width: 7 measurement points). Blue line: "resources" (R) correlated with "self-care" (S); yellow line: "stressors" (St) correlated with "self-care" (S); orange line: "stressors" (St) correlated with "resources" (R).