Dynamical Systems Research in Psychotherapy

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In psychotherapy research, the first applications of dynamical systems research (DSR) date back to the 1990s. Over time, DSR has developed three main lines of research: the study of oscillations in synchronization; the study of oscillations between stability and flexibility of process variables (S–F oscillations); the mathematical modeling to analyze the evolution of psychotherapy process.

Keywords: psychotherapy research ; dynamic systems

1. Introduction

Scientific contributions based on a systemic approach within psychotherapy research have increased over time. A special section focused on dynamical systems research (DSR) has developed within the International Society for Psychotherapy Research. The scientific contributions within this framework have undoubtedly brought an important methodological advancement in the field. However, such contributions have often struggled to obtain full recognition within the broader landscape of psychotherapy research due to the difficulty in connecting the empirical results to their clinical implications. In short: DSR has often been perceived as a set of sophisticated mathematical methods devoid of any clinical relevance. The purpose of this work is to overcome this difficulty. In fact, this contribution constitutes the first comprehensive review on the topic, made with the aim of clarifying the connections between the empirical literature of DSR in psychotherapy and clinical practice.

DSR is not an exclusive line of research of psychotherapy but, rather, represents a general scientific advancement. In fields such as biology or medicine, for example, there are extensive discussions on the problem of the recent lack of new scientific discoveries. The problem of scientific reductionism has turned out to be the issue underlying the lack of new results in various branches of science [1]. In fact, until recently, the predominant idea was that the collective behavior of a complex system, regardless of its scientific domain, could be understood and predicted by studying the dynamics of all its subunits, considering each one in isolation. However, this approach of analysis proved to be insufficient when studying emerging behaviors, i.e., all the properties of the system arising from the interaction among its different internal components. Emergent properties highlight the need to focus scientific research on the most suitable level of abstraction, in such a way as to maximize the variability of the scientific phenomena explained. Recent evidence of the importance of this topic is the contribution by Sadri [2], in which the author performed a manual systematic review of 32,000 articles from the last 150 years of scientific research in the field of drug discovery. The results clearly show the inadequacy of the current paradigm, which is based on a “target-based” approach that aims to search for molecules that directly modify the gene responsible for a pathology, in favor of a “phenotypic-based” approach, which prioritizes, in selecting and optimizing molecules, higher-level phenotypic observations that are closer to the sought-after therapeutic effects using tools based on a systems approach to science. In fact, phenotypic variability is not directly linked to single genes taken in isolation, but is determined by the emerging properties of complex genetic networks. Along this line, the most recent review of data on evolutionary processes highlighted the role of epigenetic factors and genetic networks, active during embryogenesis, in orchestrating variation-inducing phenomena underlying evolution, much more than the genome only [3]. With the transition from analyzing elements in isolation to complex networks, all the scientific literature based on the dynamic-systems approach develops.

In psychotherapy research, this fundamental transition, from studying a complex system by dividing it into simple components to the use of macro-parameters aimed at explaining the behavior of the entire system at hand, began in the 1990s. The first contributions belonging to DSR studied the applicability of self-organization principles to the psychotherapy process (e.g., [4][5]). Self-organization processes are a prerequisite for DSR, and they are particularly important for the introduction of the concept of circular causality on which the Palo Alto school of psychology also worked extensively [6]. In fact, the notion of self-organization emphasizes the process through which complex interactions between different elements of a system spontaneously generate a new property in the system itself. In clinical terms, with

researchers' patients researchers can sometimes talk about “family climate” to refer to that set of affective dynamics that have served as fertile ground for the formation of the patient’s defensive strategies. In fact, often there is not a single event that produces psychopathology, but a set of conditions that resonate with a specific family member. Another synonym for self-organization is emergence. This term also underlines the lack of a single external agent responsible for the spontaneous generation of a new property of the system. In summary, spontaneity and the lack of a single external cause are the main characteristics of self-organization processes.

The applicability of DSR to psychotherapy has two main advantages. First, as in other sciences, it avoids scientific reductionism, which is particularly evident in the field of psychotherapy due to the multitude of different theoretical approaches. The concepts underlying DSR constitute a common fertile ground on which the clinical aspects, specific to each approach, can be developed. This ensures that research in psychotherapy can acquire a trans-theoretical and trans-disciplinary strength: that is, it can be enriched through scientific contributions coming from research based on different theoretical approaches and different scientific fields. Secondly, DSR promotes an empirical, methodological, and theoretical framework for the study of change within the psychotherapeutic process: Empirical, because the study of change within complex systems has produced a vast body of literature; methodological, because the methods used within the DSR are very innovative within psychotherapy research; theoretical, because the results of the literature have produced models of change that are studied within the psychotherapeutic process [7].

The importance of DSR for the study of change in the psychotherapy process is reflected in the lines of research that have developed over time: namely, the study of oscillations in synchronization; the study of oscillations between stability and flexibility of process variables (S–F oscillations); and the study of mathematical models to analyze the macro-parameters characterizing the psychotherapy process. These three lines of research represent the three main vertices of the study of change processes in psychotherapy and, importantly.

2. Preliminary Requirements for Dynamical Systems Research (DSR)

There are two main requirements to set up a research work based on dynamical systems. The first refers to the length and frequency of the data time series. To monitor change processes within a time series, a homogeneous sampling frequency of data is needed. If possible, one measurement per day, or one every two days, should be taken. One measurement per session is also sufficient as long as the length of the time series is adequate: a minimum of about 40 time points. The second requirement refers to the choice of variables to analyze. To make DSR, the variables must be able to monitor change processes within psychotherapy. However, in this field, the problem of different therapeutic approaches arises, with their different language and corresponding different operationalizations of the variables probably being the most significant in supporting therapeutic change. For example, in a systematic review which ONLY considered the patients’ characteristics that proved to be predictors of the outcome of cognitive-behavioural therapy (ONLY) for eating disorders (ONLY), the authors found 6 mediators, 13 moderators, and 20 predictors of outcome [8]. The review excluded any relational and therapist-related variables, as well as, obviously, any other therapeutic approaches and diagnoses.

In addition, nonindependent variables are increasingly included in moderation or mediation studies, violating the assumptions of statistical models based on analysis of variance [9]. The problem of nonindependence of process variables is particularly serious due to the nature of researchers' clinical work. For example, both in empirical and clinical terms, it is absurd to consider variables of the therapeutic relationship as independent with respect to variables referring to the psychotherapeutic technique. Yet, it is enough to insert “mediation” as a keyword in one of the most accredited journals in the field of psychotherapy research to be able to observe how, for example, the “psychodynamic techniques”, the “therapeutic alliance”, and the “interpersonal and intrapersonal distress” can be considered constructs independent of each other, probably because the researchers measured those variables by using three different questionnaires. It is difficult to study the complex phenomenon of psychotherapy by reducing it into small independent components based on researchers' need for simplification. This scientific reductionism, derived, on the one hand, from the theoretical–clinical fragmentation of psychotherapy and, on the other, from empirical oversimplification, produces a fragmented and sterile scientific corpus. How, then, do researchers choose the variables to analyze and avoid problems of scientific reductionism? It is of help to include second-order variables, abstracted from the original variables, in the study. researchers will see in the chapter on “stability–flexibility oscillations” (S–F oscillations) most of the parameters that can be measured starting from process variables, provided that the latter respect the frequency and length requirements mentioned above. These parameters, as the title of that chapter underlines, refer to two main dimensions: the stability and flexibility of the psychotherapeutic system. They lie at a higher level of abstraction than the original process variables. For example, seven subscales of a questionnaire can be correlated with each other, and the absolute values of the Pearson coefficients summed up. In this way, a score of stability or rigidity of the network made up of the seven subscales is obtained. This “stability score” is at a higher level of abstraction than the original process variables. Obtaining these

parameters facilitates the comparison between results of different studies, avoids problems of scientific reductionism, and produces truly independent variables suitable for all types of models based on analysis of variance.

Years ago, researchers called this type of approach based on the abstraction of second-order parameters “A Statistical-Mechanics-Inspired Approach to Psychotherapy” to underline the origins of this line of research [10][11]. In fact, statistical mechanics is the branch of physics that investigates the possibility of extracting a small number of relevant “macroscopic” parameters for the study of the mechanical and thermodynamic behavior of systems composed of a large number of particles.

3. Preliminary Concepts

As mentioned in the introduction, the study of the dynamics of change within the psychotherapy process constitutes the main focus of DSR. The key model of change on which the literature is based is the *order-to-order transition* (e.g., Schiepek et al., 1997, one of the first contributions on the topic) [12]. It is called order-to-order because it describes the transition from a stable dysfunctional state to a new stable state that is more functional than the previous one. The clinical work of psychotherapists is entirely focused on trying to promote, in the patient, a more functional psychic organization than that present at the time of the request for help. These transitions occur through moments of destabilization of the previous psychic organization. These moments of destabilization are often called *critical fluctuations*, and represent unstable states in which new patterns of feeling, thinking, and behaving (i.e., new information) are introduced into the patient–therapist relationship. This new information is then reintrojected in the patient as soon as he1 obtains access to the new stable state. Therefore, the sequence characterizing order-to-order transitions is the following: (a) presence of a stable state or dysfunctional psychic organization; (b) entry into an unstable state of transition characterized by the inclusion of new patterns of feeling, thinking, and behaving in the therapeutic relationship; (c) emergence of a new and more functional stable state in which the new information is reintegrated into the patient. A given dysfunctional psychic organization is characterized by a level of anxiety directly proportional to the severity of psychopathology. The more severe the psychopathology, the higher the anxiety, and the greater the degree of distortion that the psychopathology produces to the reality perceived by the patient. Sometimes the literature uses the term “*attractor*” to identify the presence of a *stable state*. Although the two terms are very similar, there is a difference, in that the attractor can be made up of one or more stable states. For example, the oscillations between depressive-manic states generate the psychopathological attractor called bipolar disorder.

In accordance with the literature, the unstable state at point (B) is characterized by an increase in the correlation and variability of the system at hand (**Figure 1**) (see Gorban et al., 2021 for a review) [13].

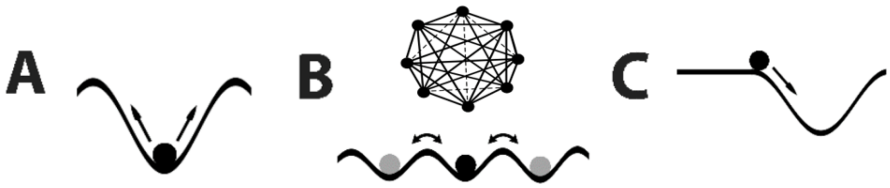

Figure 1. Dynamics of change according to DSR. (**A**) Patient in current stable dysfunctional state. (**B**) Patient-system opening up. Increase in correlation and variability. (**C**) New information reintegrated and patient-system in a more functional stable state. Decrease in variability and presence of new correlations, different from those characterizing the initial state. Parts of the figure are taken from Olthof and colleagues [14].

At point (A), the patient-system resides in the current stable dysfunctional state. At point (B), it opens up to new patterns of feeling, thinking, and behaving. At point (C), the new information is reintegrated and it resides in a more functional stable state than the initial one.

As can be seen in the figure, point (B) is characterized by two different aspects. Increase in correlation, upper panel: the patient’s narratives acquire coherence, the core problematic theme emerges with ever greater clarity, the same dysfunctional relational modality permeates the different domains of the patient’s life (professional, emotional, familial). The patient’s current psychic organization becomes more integrated and correlated with other aspects of his functioning. This greater understanding of the patient’s functioning allows him to lighten the burden of anxiety associated with the current stable dysfunctional state. This allows the patient greater openness towards new patterns of feeling, thinking, and behaving. Increase in variability: in the bottom panel, the possible valleys that could host the ball multiply, that is, the variability of the patient’s narratives increases, laying the foundations for a change that will occur in (C).

The stable states at point (C) can be of two types. They may be structurally the same as the previously dysfunctional state, but present less distress, or they may be structurally different from the previous stable dysfunctional state. In the first case, researchers are faced with a *first-order change*; in the second case, researchers are faced with a *second-order change* [15]. An example of the former is the patient who resolves his phobic symptom and manages to board the plane, or enter the elevator, or participate in gatherings with many people. An example of the latter is the patient who manages to restructure the phobic organization of his personality. First-order changes are more frequent and involve the patient's body of *knowledge*, whereas second-order changes are rarer, as they imply a general restructuring of the current psychic organization (i.e., the way of *being* of the patient).

The process of psychotherapy is a catalyst for first- and second-order changes with the final aim of promoting, within the patient, the ability to come into contact and experience a highly diversified range of relational modalities. In fact, the patient who begins psychotherapy presents a rigid and repetitive way of experiencing the relationships that surround him. As the therapeutic relationship progresses, the patient gradually obtains access to an increasingly wider range of relational modalities (e.g., [16][17]). The patient is healthy when he is courageous enough to feel happiness, sadness, desperation, physical and mental pain, tenderness, light-heartedness, and the other emotional colors that make life worth living. Order-to-order transitions, stable states and attractors, unstable states and critical fluctuations, first-order changes, and second-order changes are the basic notions allowing a full understanding of the empirical and clinical depth of the research presented below.

4. High–Low Synchronization

Studies on synchronization in psychotherapy mainly include three areas: the study of physiological synchronization between patient and therapist, measured mainly through skin conductance, ECG, EEG, fMRI (see Kleinbub et al., 2020 for a review) [18]; the study of nonverbal synchronization, measured mainly through postural and gaze movements of patient and therapist (see Koole and Tschacher, 2016 for a review) [19]; and the study of verbal synchronization, measured mainly through the prosodic elements of language (e.g., see Orsucci et al., 2016; Scheidt et al., 2021 for a review) [20][21]. Initially, findings in the literature from these three areas supported a simple equation: the higher the synchronization among patient and therapist, the better the psychotherapy outcome. This simple model also seemed to be supported by the results of studies that established a linear positive correlation between therapeutic alliance and synchronization (see the work by Koole and Tschacher for a review). Therefore, from this perspective, high synchronization between patient and therapist was associated with a good therapeutic alliance, which in turn was responsible for the successful outcome of psychotherapy. It is not known what the therapist should do in this model once a good therapeutic alliance has been established. However, as research on this topic progressed, much conflicting evidence emerged. For example, higher synchronization has been observed in poor-outcome dyads, and interpreted as the therapist's struggle to promote the good development of therapy (e.g., [22]). Current studies show how high synchronization is not always associated with the good development of a therapeutic relationship. In fact, a more accurate hypothesis is grounded on the idea that two tendencies exist simultaneously, one to synchronize with others and the other to move out of synchrony and act independently (see Mayo and Gordon, 2020 for a review) [23].

From a clinical perspective, the model based on the linear association between high synchronization and good outcome of therapy due to good therapeutic alliance is unsound. The psychotherapy process develops if new information and points of view are introduced, often unexpectedly for the patients, producing moments of rupture and repair of the therapeutic alliance (e.g., [24]), and, more likely, moments of rupture and repair of synchronization. It is for this reason that the literature on synchronization acquires clinical depth if applied to the understanding of the dynamics of change within the psychotherapy process, i.e., to investigate how new information is processed within the therapeutic dyad. There are two particularly brilliant examples in the literature on this topic. The first, in chronological order, is by Villmann and colleagues [25], and focuses on the relationship between the physiological entropy of patient and therapist and the language used by the patient within a 37-session psychodynamic psychotherapy. Specifically, the authors highlight how, in the period in which the patient processes new information ("connecting phase", high abstract language, and high emotional language), the physiological entropy of patient and therapist is high. Subsequently, the patient reintegrates the new information, moving to the "reflecting phase", characterized by high abstract language, low emotional language, and low physiological entropy. Since entropy is a measure of variability, the results suggest an "opening" of the therapeutic dyad towards new information coming from the "connecting phase", followed by a reintegration of these novelties within a new point of view (i.e., new stable state). The entire oscillation can be summarized as follows: (a) Flexibility phase, in which entropy is high, emotional language is high, a new perspective is entering within the psychotherapeutic relation; (b) Stability phase, in which entropy is low, emotional language is low, abstract language is high, the new perspective is worked through until it is fully integrated. In this study, the analysis of synchronization of physiological variability plays a vital role in the

understanding of the characteristics of this change dynamic. A further example comes from the work by Stukenbrock and colleagues [26], which focuses on gaze synchronization in moments when therapists deliver interpretations to patients. Fifty sessions of two different therapeutic dyads were analyzed. The results clearly show how therapists look away from their patients during the interpretation, recovering eye contact only when the most audacious content of the interpretation is made explicit. Hence, the initial distance (gaze avoidance) is used by the therapist to “grasp” the new information to introduce it into the therapeutic process, finding the most suitable words and modality of delivery. The following proximity (recovery of eye contact) is used to observe the patient’s reaction to the new content previously expressed. The study of low–high synchronization oscillations, in relation to the dynamics of processing the new contents conveyed by the interpretation, produces extremely relevant clinical results. It would be interesting to delve deeper into this line of research by analyzing the dynamics of successful and unsuccessful interpretations separately; in other words, interpretations whose emotional content is subsequently reintegrated or rejected by the patient.

Finally, another rather forgotten application of physiological measurements within psychotherapeutic sessions is associated with the patient’s anxiety. The patient’s physiological arousal, being an expression of the activity of the sympathetic branch of the autonomic nervous system, constitutes an efficient thermometer of the patient’s internal anxiety. This application of physiological measures in psychotherapy is potentially very clinically relevant, and should certainly be developed more. For example, it could be studied in relation to the interpretations reintegrated or rejected by the patient. In this case, the hypothesis could be that an emotional content causing too much internal anxiety is rejected by the patient. On the other hand, with a more macro-analytical design, it could be studied in relation to first- and second-order change processes to identify when the level of internal anxiety prevents such changes, i.e., when it prevents the reintegration of new information.

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