

Wolfgang Tschacher · Hermann Haken

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# The Process of Psychotherapy

Causation and Chance

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# Preface

We have written this book to address people with a profound interest in all approaches to psychotherapy, as well as those interested in a general theory of psychotherapy. We allow two threads of reading, one that is accessible to practitioners and psychotherapists and one that includes mathematical sections and “Info-Boxes,” for advanced psychotherapy researchers and graduate students.

In this book, we have developed an encompassing model of the process of psychotherapy, based on the current state-of-the-art psychotherapy research. Therapeutic interventions are staged in the therapist-client relationship and become effective by the interplay of deterministic (“causation”) and stochastic forces (“chance”). This is modeled using the Fokker-Planck equation and by applying principles of complexity theory. Modern theory in psychotherapy is thus complemented by a structural-mathematical framework. Using this framework, we developed statistical tools, which can be applied to empirical time series of psychotherapeutic processes. We provide numerous empirical examples of such applications, expecting that the approach adopted in this work has the potential to advance psychotherapy research and psychotherapy in general.

Our modeling approach emphasizes that psychotherapy must explicitly focus on the time dependence of states, i.e., on the dynamics of systems. We need to consider both causation and chance in our model of change processes, and we argue that one-sided theories are insufficient for fundamental reasons. Weighing the benefits of various dynamical modeling approaches, the Fokker-Planck equation is chosen as a framework. The dynamics may even be of an emergent type (novel patterns and attractors may be formed during the change process); thus, we also consult synergetics, i.e., the theory of self-organization (Chap. 1).

We prefer to view psychopathology as a hierarchical system of continuous variables. Psychopathology must be conceived of as dimensional rather than categorical, and all dimensions range from “normal” to “disordered.” Disorders are constituted by variables that denote signs and symptoms of dysfunctional thought, emotion, and behavior. The disorders are clustered in spectra of pathology (Chap. 2).

Consistent with this hierarchy of psychopathology, we assume there is also a hierarchy of psychotherapeutic interventions, ranging from technical and specific to contextual and nonspecific. “Common factors” of psychotherapy are defined as the nonspecific qualities and contexts, which are generated by specific intervention techniques and at the same time prepare the context for techniques to be delivered. The common factors (e.g., “self-efficacy”) thus constitute a level above the techniques (e.g., “role play”). Intervention in psychotherapy is generally understood as an interplay of common factors and techniques, not their antagonism (Chap. 3).

The Fokker-Planck equation describes the joint action of deterministic and stochastic processes (Chap. 4), thus acknowledging our guiding principle of considering both causation and chance. We discuss deterministic interventions (Chap. 5) and stochastic impacts (Chap. 6) on the background of the four major clusters of therapy modalities (behavioral, psychodynamic, humanistic, systemic). Stochastic impacts can be modulated by boundary regulations and by the filtering of environmental fluctuations. The processes underlying the various therapy modalities are quite different, consistent with the diverging philosophies involved, yet they can be fit in our modeling framework. We find that interventions of all modalities are commonly mixtures or sequences of stochastic and deterministic effects, where deterministic interventions may also be unspecific and contextual (Chap. 7). We transform the antagonism between specific and unspecific factors (the “medical model” versus the “contextual model” of psychotherapy) into a more appropriate schema of three types of interventions: deterministic, contextual deterministic, and stochastic.

When depicting psychotherapy, we need to model the therapeutic alliance, which is seen as the core of treatment. We formulate a one-dimensional “minimal model” of therapeutic action, which views the change of client states, e.g., the client’s psychopathological symptoms, as a function of therapist states and therapist-client coupling constants. Using principles established in synergetics, we elaborate under which conditions a therapist in principle can have an impact on the client. We then capture the therapist-client interaction explicitly as an interpersonal exchange, extending the mathematical model from one-dimensional Fokker-Planck equations to a two-dimensional “minimal model.” This extended model predicts oscillatory and synchronized behavior and thereby supports the current empirical research on interpersonal synchrony, which is commonly based on cross-correlations of the therapist’s and the client’s time series. We connect the cross-correlational approach of synchrony research to the theoretical coupling terms of the two-dimensional minimal model (Chap. 8).

We subsequently extend our mathematical model to allow the classification and analysis of empirical data produced by therapy systems, creating a toolbox of computer algorithms and running them on exemplary time series. For the analysis of one-dimensional time series, we develop and demonstrate algorithms by which we can reconstruct the attractor landscape based on the time series data (hence, the deterministic term of the Fokker-Planck equation) and the proportion and location of chance events (the stochastic term of the equation). In addition, we also present

algorithms that allow estimating the strength and shape of coupling in the two-dimensional model (Chap. 9).

In the outlook (Chap. 10), we summarize our findings by stressing the importance of a decidedly dynamical approach, which can even cover the temporal scale of a few seconds, pertaining to the “now” of consciousness. This “high-resolution” approach becomes possible by analyzing variables that represent processes of embodied cognition and emotion. We spell out which interventional types derive from the minimal model to define the “Archimedes” role of the therapist. Therapist personality—resilience and mindfulness—are essential therapist variables; the therapist must also be “slow” compared to the client. This allows the modification of client states by the leverage of an Archimedes-like unmoving mover. We also include the state of research on the synchronization of the therapeutic alliance and discuss the concepts of free energy, affordance, and embodiment. As is often true, there are numerous open questions, and we call for systematic empirical research that we hope will be instigated by the elaborate model and practical toolbox presented in this book.

Bern, Switzerland  
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# Contents

<b>1</b>	<b>Causation and Chance: Integrating the Dynamical Systems Approach with Statistical Thinking</b> . . . . .	1
1.1	The Goals of This Book . . . . .	1
1.2	Why Use Mathematical Models and Mathematical Formulae? . . . . .	3
1.3	Modeling the Dynamics of a System . . . . .	5
1.4	Measurement in Psychology . . . . .	9
1.5	Statistics . . . . .	13
1.6	Causation: Deterministic Processes and Goals . . . . .	16
1.7	Chance and Causation . . . . .	17
	References . . . . .	18
<b>2</b>	<b>Psychopathological Problems and Disorders</b> . . . . .	21
2.1	Taxonomies of Psychopathology and Their Shortcomings . . . . .	22
2.2	Alternative Conceptualizations of Psychopathology . . . . .	24
2.3	Toward a Dynamical Quantification of Psychopathological Disorders . . . . .	26
	References . . . . .	29
<b>3</b>	<b>Interventions in Psychotherapy</b> . . . . .	31
3.1	The Current Discussion in Psychotherapy Research . . . . .	31
3.2	Therapist Effects . . . . .	36
3.3	A Hierarchical Model of Therapeutic Factors . . . . .	37
	References . . . . .	40
<b>4</b>	<b>The Fokker-Planck Equation</b> . . . . .	41
4.1	The Goal of This Chapter . . . . .	41
4.2	The Gaussian . . . . .	41
4.3	Deterministic Processes: Causation . . . . .	44
4.4	Stochastic Processes: Chance . . . . .	49

4.5 Joint Action of Deterministic and Stochastic Processes:  
Causation Plus Chance . . . . . 51

4.6 The Significance of Fokker-Planck Modeling . . . . . 53

4.7 How Can We Measure the Fokker-Planck  
Parameters  $x_0, k, Q?$  . . . . . 54

References . . . . . 58

**5 Application to Psychotherapy: Deterministic Interventions . . . . . 59**

5.1 A Prototype of a Deterministic Technique for Behavior  
Change . . . . . 59

5.2 The Varying Prerequisites of Different Psychotherapy  
Approaches . . . . . 61

5.3 Discussion of Deterministic Interventions  
in Psychotherapy . . . . . 68

References . . . . . 70

**6 Application to Psychotherapy: Chance Interventions . . . . . 71**

6.1 Psychotherapeutic Interventions into the Stochastic  
Term of the Fokker-Planck Equation . . . . . 71

6.2 Regulating the Social Boundary of a System . . . . . 72

6.3 Regulating the Stochasticity of Emotional Processing . . . . . 74

6.4 Regulating the Stochasticity of Cognitive Processing . . . . . 75

6.5 The Functionality of Stochastic Interventions . . . . . 76

6.6 Deterministic and Stochastic Interventions Versus  
Specific Techniques and Common Factors of Psychotherapy:  
How Are They Related? . . . . . 77

References . . . . . 79

**7 Application to Psychotherapy: The Mixture of Deterministic  
and Stochastic Interventions . . . . . 81**

7.1 Different Types of Psychopathological Problems . . . . . 81

7.2 Stages of Psychotherapeutic Change: Stochastic,  
Deterministic, and Contextual . . . . . 88

7.3 Modeling Interventions of Psychotherapeutic Change . . . . . 89

References . . . . . 92

**8 The One- and Two-Dimensional Fokker-Planck Equation . . . . . 93**

8.1 A “Minimal Model” of Therapeutic Intervention,  
Assuming the Slaving Principle . . . . . 93

8.2 The “Minimal Model” of Therapeutic Interventions  
with Oscillations: Evolution Equations in Two Dimensions . . . . 100

8.3 Empirical Studies on Synchrony and Social Coupling . . . . . 107

8.4 Formulation of the Two-Dimensional Fokker-Planck  
Equation . . . . . 115

References . . . . . 118

**9 Modeling Empirical Time Series . . . . . 121**

9.1 Modeling Psychotherapy Process . . . . . 121

9.2 Estimating the Deterministic Term of the One-Dimensional Fokker-Planck Equation from Empirical Time Series: Causation . . . . . 123

9.3 Estimating the Stochastic Term of the One-Dimensional Fokker-Planck Equation from Empirical Time Series: Chance . . . . . 125

9.4 Estimating the Coupling of the Two-Dimensional Fokker-Planck Equation from Empirical Time Series: Synchrony . . . . . 126

9.5 Examples of Fokker-Planck Parameter Estimation in Time Series . . . . . 131

9.5.1 Example 1: Body Motion of Two People (Two-Dimensional System) . . . . . 131

9.5.2 Example 2: Respiration Time Series (One-Dimensional) . . . . . 132

9.5.3 Example 3: Simulated Autoregressive (Markov) Process (One-Dimensional) . . . . . 135

9.5.4 Example 4: Electrocardiograms (Two-Dimensional) . . . . . 136

9.5.5 Example 5: Simulated Bimodal Autoregressive (Markov) Process (One-Dimensional) . . . . . 139

9.5.6 Example 6: Respiration (Two-Dimensional) . . . . . 140

9.6 Fokker-Planck Terms of Two-Dimensional Time Series . . . . . 144

9.6.1 Example 1\*: Two Simultaneously Monitored Movement Time Series . . . . . 144

9.6.2 Example 4\*: Two Simultaneously Monitored Electrocardiograms . . . . . 146

9.6.3 Example 6\*: Two Simultaneously Monitored Respiration Time Series . . . . . 147

9.7 Discussion of Time Series Estimation . . . . . 149

References . . . . . 151

**10 Outlook . . . . . 153**

10.1 Focusing on Dynamics . . . . . 153

10.2 Focusing on Phenomena of Synchronization . . . . . 155

10.3 Focusing on the Archimedean Function of the Therapist . . . . . 157

10.4 Focusing on Embodiment . . . . . 159

10.5 Focusing on Free Energy . . . . . 160

10.6 Focusing on Affordances . . . . . 161

10.7 Chances and Limitations . . . . . 163

References . . . . . 165

**Index . . . . . 169**

## About the Authors

**Wolfgang Tschacher** received his PhD in psychology at the University of Tübingen, Germany. After psychotherapy training in systemic therapy, his academic career continued with his habilitation in psychology and *Venia Legendi* at the University of Bern, Switzerland, and professorship there in 2002. He is based at the University Hospital of Psychiatry and Psychotherapy in Bern, where he founded the Department of Psychotherapy Research, and currently is head of the Experimental Psychology unit. His main interests are in quantitative psychotherapy research, time series methods, and experimental psychopathology, with an emphasis on dynamical systems, embodied cognition, and phenomena of cognitive self-organization. He acted as president of the European chapter of the Society for Psychotherapy Research (SPR) and is member of the directorate of the Society for Mind-Matter Research. He is the organizer of the “Herbstakademie” conference series on systems theory in psychology. Dr. Tschacher has published about 200 scientific publications and 16 monographs and edited volumes on psychology, psychiatry, and cognitive science (WT is still proud to have been, in 1992, the main editor of *Self-Organization and Clinical Psychology* in the Springer Synergetics series).

**Hermann Haken** studied mathematics and physics in Halle and Erlangen, Germany, where he completed his dissertation in mathematics. After habilitation at the University of Stuttgart, he became a professor of theoretical physics and director of the Institute of Theoretical Physics and Synergetics. His fields of work comprise laser physics and nonlinear optics, solid-state physics, statistical physics, group theory, and bifurcation theory. He is the founder of the interdisciplinary field of synergetics, which elaborates on self-organization as an emergent quality of complex dynamical systems throughout the sciences. He has published about 600 scientific publications, 26 textbooks, and monographs on physics, synergetics and complexity science, psychology, and neuroscience. His work has been translated into Chinese, Italian, Japanese, Russian, Spanish, and further languages. He received multiple awards as well as honorary doctorates from universities in Germany, Spain, China, and the USA.

# Chapter 1

## Causation and Chance: Integrating the Dynamical Systems Approach with Statistical Thinking



### 1.1 The Goals of This Book

With this volume, we wish to lay a novel ground for modeling and understanding the process of psychotherapy. Psychotherapy is focused on changing a client's state, and such change is expected to arise from and in the context of psychological interventions. We do not believe that therapeutic interventions are technical or mechanical, nor do we assume they are incidental—instead we claim that they are mixtures of both, and it is therefore mandatory to integrate causation with chance. Deterministic “technical” interventions commonly go hand in hand with stochastic forces and events. We need both aspects in the modeling of change due to psychotherapy. On top of the deterministic and stochastic forces, there is a third type—contextual interventions. These are indirect influences that affect the process of psychotherapy by altering the context in which it further evolves. Such influences can be expressed by contextual parameters of different qualities, i.e., by the affordances that act on the therapeutic system.

Generally, our goal lies in the modeling of psychotherapy *process*. This implies that we wish to represent the reality of what happens in the therapy setting (and also between therapy sessions) under explicit consideration of the dimension of time. We are convinced that some kind of quantification is necessary for any kind of modeling. That is to say, we do not believe in a strict dichotomy between quantitative and qualitative modeling, as is sometimes claimed in the discussion of psychotherapy. “Qualitative,” i.e., narrative and single-case approaches, would then focus on description, assuming that “qualitative” means that we can sequentially describe and show what is present and what is not. Yet such description presupposes the distinction between categories, in other words, a basic kind of quantification at the nominal or categorical level. Therefore, as soon as one can categorize events, one can implicitly also count the number of categories. As soon as one can distinguish the recurrence of one category over the recurrence of another, one obtains time series of categories. This of course is the very basis of quantification and of statistics.

Mathematics enters the scene inevitably even when we deal with categorical qualities. Mathematical modeling is no end in itself but simply an instrument that allows describing how different quantities can be related and how the change of a quantity can be expressed. Thus even the qualitative description of subjective experiences is amenable to mathematical modeling.

It is a fundamental observation in psychotherapy and psychopathology that states often come as *stable* states. When somebody or something sets forth to change these states, the change may be only temporary because apparently a “force” is present that draws the system back to its previous original state or forward to a specific novel kind of stability. Dynamical systems theory calls such stable states “attractor” (Guckenheimer & Holmes, 2002). We will have to deal with phenomena of stability when we address causation in the context of psychotherapy.

Each day, we live in a world of coincidences, of uncontrolled and unforeseen events. Such chance events can deeply affect our lives, and they persistently probe the stability of all of our deterministic attractors. This is true also in the context of psychotherapy. Interventions can have the effect of shielding against, or welcoming, chance. Chance diffuses attractors. Therefore we additionally have to deal with stochastic forces and consequently must explicitly address chance.

Another common observation is that stable states and patterns, i.e., attractors, may newly arise in psychotherapy processes—novel behaviors, thoughts, and emotions may emerge from the social interaction and communication in the therapy setting. Such pattern formation is the topic of self-organization theory or synergetics (Haken, 1977). Several mathematical models have been formulated in this field, some of which will be applied to psychotherapy in this volume. The widespread phenomenon of self-organization in what we call contextual interventions rests upon a co-occurrence of causation and chance.

The core of psychotherapy is the social interaction and communication between therapist and client, which altogether makes up the therapeutic alliance (Horvath, Del Re, Flückiger, & Symonds, 2011). Hence we have to model not only the change of relevant single state variables but also the two-dimensional system of therapist and client state variables. In doing so, we may encounter a new type of attractor that can become manifested as therapist-client synchrony. We will have to describe this “minimal model” of dyadic psychotherapy to account for empirical observations of synchrony, coupling, and entrainment in the therapy setting (Ramseyer & Tschacher, 2011).

Finally, we will not rest contented with the theoretical and mathematical modeling of all these mentioned phenomena—we acknowledge that there is a particular need for practical tools and algorithms in addition to just theory and calculus. In the practice of psychotherapy research, premises of mathematical models are not always met: Measurements are usually not infinitely smooth and frequent, and resulting time series can also be truncated or nonstationary. We have developed tools for the assessment of realistic time series and describe their application to real measurements. These tools concern the major goals that we listed above: They allow for assessing the deterministic ingredients and the stochastic ingredients of processes. They can depict causation and attractors and approximate the stochasticity of a time

series. Moreover, algorithms were developed for the approximation of the coupling in the two-dimensional alliance system of client and therapist. These can be used to quantify the synchrony of the client's and therapist's behavior, hence their collaboration toward beneficial therapy outcome.

## 1.2 Why Use Mathematical Models and Mathematical Formulae?

Mathematical equations are not overly popular among psychotherapists, not even among psychotherapy researchers. There may be a number of reservations and objections against mathematical modeling. We feel that we should deal with such objections early in this introductory chapter of our book.

The first objection that may come to mind is this: Psychotherapy deals with human subjective emotions, thoughts, and behaviors. As at least the emotions and thoughts are largely private events, how can they be captured mathematically?

The second objection: Psychotherapy addresses problems in the life of a client. The client enters therapy with his or her own particular biography. Thus the object of therapy is a narrative—how can we express semantic and narrative contents by mathematical terms?

The third objection: Mathematical equations are tautological, i.e., what is expressed on the left-hand side is exactly the same as that on the right-hand side of an equation. When an equation is transformed and worked with, it still remains tautological (unless an error occurred). No new evidence can result from a formula, so why bother at all?

The fourth objection: There already exist the field of mathematical psychology and a history of explicit mathematical formulations of learning theory in behaviorism. Why not use the framework of mathematical psychology and instead start with a completely novel *ansatz*?

The fifth objection: Mathematical equations are actually everyday business in all statistical regression models, in the form of the *t*-test, analysis of variance, factor analysis, etc. The mathematical structure of statistical methods in current psychology may be largely hidden from view, as researchers commonly use prefabricated statistical software, but nevertheless most published research is based on regression equations. Why not also base our treatment on such regression models?

We wish to reply to all these objections briefly, leaving aside the philosophical intricacies connected to some of the points.

First, emotions and thoughts are experiences in a first-person perspective, and as such cannot be modeled directly and objectively in a third-person perspective. Our approach therefore depends on the transformation of such experiential facts into quantities using measurement theory and scaling assumptions. In Sect. 1.4 we provide some information on this foundational prerequisite of modeling in psychotherapy. We must rely on operationalization as the fundament of psychological

measurement, and in this respect our assumptions are the same as the assumptions of all empirical research in psychology. These assumptions amount to the idea that emotions and thoughts are embodied and thus not so “private” after all—there are perceptible signs of emotions and thoughts that can be used for their operationalization and hence measurement. In addition to being the prerequisite for measurement, the embodiment of emotions and thoughts is the very basis of social (and thus also psychotherapeutic) interaction.

Second, it is true that we can do justice to narrative data only to a certain extent. The narrative content of a client’s story concerns semantics, and our mathematical treatment can only concern quantitative variables. This is the problem of pragmatic information in contrast to “meaningless,” but measurable, Shannon information (Haken, 2006). The problem may become tractable by considering the “intentional-like” properties of self-organizing systems (Tschacher, 2017), yet this is largely beyond the scope of the present book (we will come back to it in Chap. 10). Our brief reply is here the same as to the first objection—we need to deal with quantities that translate the semantics to scales based on operationalization conventions. As we have pointed out in the initial section on the goals of this book, we do not believe there is a clear demarcation between qualitative and quantitative approaches.

Third, mathematical models are admittedly tautological. Yet we intend to profit from what may be called the beneficial side effects of tautological transformations. Such side effects are that by using mathematical models, we find out what *cannot* be concluded from the premises we originally made. Therefore, while tautology may not tell us anything new, mathematical models will definitely point out what is not tautological, i.e., what is plainly a wrong conclusion or statement. In addition, the retained tautological structures of an equation, after any number of legitimate transformations, may inform us about which possible interpretations rest within the scope of the premises that we initially made. In a philosophical sense, mathematical tautologies of equations may serve as structural descriptions of a wide range of very different objects—equations connect variables, and these variables can denote any aspect of reality (mental, behavioral, emotional, always depending on our operationalizations). Maybe it is structural science that will ultimately connect categorically disparate things such as the mental and the physical realms (the mind-body problem). We have put forward this view in the context of psychotherapy before (Tschacher, Haken, & Kyselo, 2015).

Fourth, there is a tradition of mathematical models in psychology, such as the psychophysics of Gustav Theodor Fechner (1889) or the neo-behaviorist modeling of reinforcement by Clark Hull (1952). While this tradition would provide good vantage points for modeling, we chose a more general approach that is not restricted to the intraindividual relationship between physical stimuli and mental ratings (psychophysics) nor to the relationship between response and stimulus intensity, drive, habit strength, and inhibition (neo-behaviorism). We wished on the one hand not to be constrained by the stimulus-response scheme and on the other hand to be open to explicitly model temporal changes and time series. We therefore chose a very general approach that frames the change of probability of (any) state variable as

a combination of chance events and causal influences, the Fokker-Planck equation (Risken, 1996).

Fifth, the standard linear regression models that are in use throughout psychological research are mathematical models with deterministic and stochastic components, which is basically also true for the Fokker-Planck approach. Such regression models are however predominantly applied to cross-sectional samples, whereas our interest lies with modeling the temporal evolution of single systems. We are decidedly focusing on the dynamics, on psychotherapy process taken literally. Cross-sectional analysis may be warranted too but only, subsequently, as a second step.

### 1.3 Modeling the Dynamics of a System

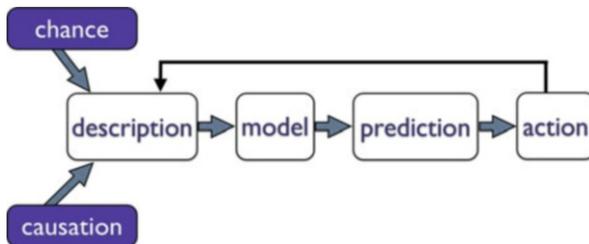
Almost all sciences have one problem in common—how can we make sense of the processes we observe? Be it the behavior of billiard balls colliding, or the execution of voluntary movements of our body, or the behavior of people interacting in a psychotherapeutic setting, the task is comparable: We have to *model* the dynamics of the entities of interest, using the variables we can connect with these entities. We need a description of the dynamics. Once we have arrived at a valid and reliable model of observed processes, we can apply this model to predict the future development of the observed systems. Seen in this way, the fundamental task of science is to predict the future by using the models we have made of the past. Prediction must always be grounded in description.

For this prediction to be successful, some assumptions must be made that we shall mention briefly. The first assumption is that causation reigns at least to some extent: There are regularities, rules, laws, or correlations, which underlie the processes we have observed for later modeling. This is the deterministic assumption: The dynamics of a system follows deterministic rules. Our second assumption is that in almost all applications, there is a limit to such determinism—all prediction is curbed by chance events.

Chance, i.e., randomness and stochasticity, can enter the description of psychotherapy processes in many different ways.

- First, our measurements may be imprecise, resulting in an imperfect description; the measurement apparatus may not allow sufficient temporal and spatial resolution.
- Second, we may have encountered nonstationarity: The causal laws that were in effect in the past, during the modeling period, may not be exactly the same laws that later govern the period to be predicted.
- Third, we may have neglected important variables, which have influenced our measurements of the past processes—we may have neglected some relevant processes in the observation, or may not have cast the processes in appropriate variables.

**Fig. 1.1** Modeling the dynamics is based on description, and results in prediction, on the basis of which the agent can act. Prediction accuracy informs new description and modeling



- And fourth, again, our general assumption is that we are dealing with processes that can be quantified at all. Psychology addresses both behavior (quantifiable motor and physiological processes) and experience (subjective-qualitative emotional and cognitive processes). As already mentioned, to model the latter qualitative processes, we have to define operationalizations, by which the qualities can be translated into numerical or categorical scales (see the next section in this chapter). We must acknowledge that some experiences, and maybe even the very core of experiencing—consciousness—cannot be transferred into quantities completely (Chalmers, 1996). In principle, some important facts may not be directly measurable, but they of course delimit our prediction efforts.

The interplay between description and prediction and the role of causation and chance in this interplay are not only fundamental in modeling the dynamics of psychotherapy. At a different time scale and level, this interplay provides a principle for understanding how people function in the real world (so-called active inference, or the refference principle: Hobson & Friston, 2014; von Holst & Mittelstaedt, 1950). Thus generally, our description of the world, which gets cast in a model, leads to predictions, which in turn inform new descriptions (Fig. 1.1).

In the context of scientific modeling, different sciences have developed different methods that they use for quantitative modeling, and sometimes scientific disciplines have also produced different terminologies even for more or less identical modeling approaches. Thus, a zoo of modeling methods has evolved, and we will give a short overview of them. This will also equip us with the reasons why we will subsequently focus on only one of these approaches, the Fokker-Planck equation, in this book. We will sketch the basic assumptions of the various methods and how the methods proceed when the goal is to model an observed time series of a state variable  $x$ .

**Fokker-Planck Equation (FPE)** The FPE is a general modeling approach that combines the deterministic and stochastic contributions to a temporal development. The FPE casts the time-dependent change of the probability distribution of  $x$  into a linear partial differential equation. Partial differential equations describe the change of a state as a function of more than one variable. The FPE was derived by the physicists Adriaan Fokker and Max Planck (Max Planck supervised Fokker's thesis on problems of statistical physics and Brownian motion of a particle). It was previously applied to problems in physics and in synergetics. Because of its potential

to model the temporal evolution of a statistical probability distribution, the FPE may be used conveniently in arbitrary fields of dynamical science.

**Chaos-Theoretical Models** Chaos theory assumes that erratic and unpredictable processes in nature are nevertheless produced by deterministic dynamics. A justification for this assumption is that the output of some nonlinear mechanisms can be sensitively dependent on very small changes of input variables. Thus what looks like stochastic fluctuations may in fact be the result of chaotic behavior. The fingerprint of many chaotic regimes is that they produce “strange” attractors with fractal properties—the dimension of such attractors is not a natural number. A common procedure of chaos theory is to find this fractal dimension. Chaos of continuous variables is only possible in three- or higher-dimensional systems. Therefore, a one-dimensional time series is considered to be a projection of a higher-dimensional system and can be embedded in a state space of appropriate dimensionality by a method called state space reconstruction. The strange attractor can then be characterized by Lyapunov exponents. There have been a number of attempts to apply chaos theory to psychology and psychotherapy (Schiepek et al., 1997; Tschacher, Scheier, & Hashimoto, 1997; Tschacher, Schiepek, & Brunner, 1992).

**Fourier Transformation** An empirical time series may be considered to be the sum of many regular oscillations of different frequencies, expressed, e.g., by sine functions. In all applications, discrete Fourier transforms must be applied because time series are not continuous but sampled at discrete time intervals. By Fourier analysis, the time series is decomposed in the frequency domain, and we can describe (in a periodogram) how much a single frequency, or a frequency band, contributes to the empirical signal. This kind of analysis is straightforward when it is known that the measured time series has originated from unknown periodic oscillators, such as in electroencephalograms (EEG). The Fourier description gives exact information in the frequency domain at the expense of exactness in the time domain (cf. Heisenberg’s uncertainty principle). Deterministic and stochastic influences can be distinguished. Apart from the EEG literature, some recent applications of wavelet analysis were done in projects on interpersonal synchrony (Palumbo et al., 2017).

**Autoregressive (AR) Models/Markov Models** A time series of the variable  $x$  can be decomposed in the time domain by computing autocorrelations at each lag, i.e., the time series is correlated with a copy of itself displaced by 1, 2, . . . ,  $L$  time steps. The result is an autocorrelation function, which displays the resulting  $L$  correlations. AR models give an account of the linear deterministic component (contained in the autocorrelation function) and the remaining stochastic component of an empirical time series. This modeling approach has entailed the most frequent time series applications in psychology, especially in multivariate data, where autocorrelations and cross-correlations are computed by so-called vector autoregression (VAR). Such modeling has been applied to psychotherapy processes (Tschacher & Ramseyer, 2009). In addition, most current research on interpersonal synchrony in social interaction is based on cross-correlations (Ramseyer & Tschacher, 2011; Tschacher, Rees, & Ramseyer, 2014).