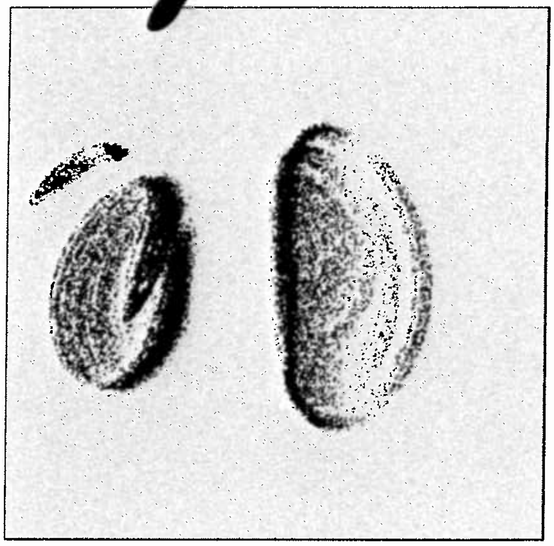
Nonlinear Science Today



The strange attractor (see Fig. 1 inside).

Metaphors for Psychoanalysis

*F. Verhulst**

The concepts of mathematics are expressed in a language describing ideas, statements, and structures. Because of the force of mathematical thinking and its amazing effectiveness both in mathematics and in applications, this language can also play a part in fields outside of those which permit more or less precise quantitative treatment such as the natural sciences and economics. To illustrate this, we shall discuss an example of the use of the language of nonlinear dynamical systems in psychoanalysis.

The ideas of a "model" and of "modeling reality" are familiar to applied mathematicians; most pure mathematicians have a rough idea of what modeling is about. Not so well known is the use of metaphors and the indispensable part they play in scientific thinking. Mathematics can also make a valuable contribution in this regard.

Using Language Is Part of the Creative Process

We are familiar with the concept of language as a means of communication, but its role is much more fundamental than that. To put the formulation of a problem into words and to formulate useful descriptions and statements—in mathematics, definitions and theorems—are part of the creative mental process itself.

One of the most essential parts of creation and problem solving is to come up with the right use of language. To have at one's disposal the right words enables one to see much more and perceptivity reaches a higher level; of course, this has been known for some time (see, for instance, [9]).

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PUBLISHED BY
SPRINGER-VERLAG
VOLUME 4, NUMBER 1 1994 $10.00

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A well-known observation of the language of the Innuit people illustrates this idea: The Eskimos have many words for snow. We have only a few words, and consequently we perceive a few kinds of snow only. The Eskimo children who are learning all these words can in this way distinguish between many types and *are seeing* therefore all kind of variations of snow.

In creative activity, in whatever discipline, one uses metaphors. Above, we described our perceptions as "reaching" a higher level. Was our perceptivity actually remaining in a downward level? What does "remaining" mean in this respect anyway? These are all metaphors; a little bit overworked metaphors, in this case, but nonetheless useful.

Models of Reality

In the natural sciences the term "model" usually refers to mathematical objects which we can study. For instance, a simple model like the quadratic or logistic equation models the restricted growth of a single population like an isolated culture in a laboratory or an isolated population of rabbits on an island. The term " model," however, is used in many other ways. A teacher may use the word model for synthetic constructions of a regular polyhedron, a human skeleton, or organ. A biologist or a medical researcher may use a relatively simple experimental setup as a model for a complicated real-life phenomenon. The use of the word "model" with so many different meanings can be confusing, and, as we shall see, it also may cause a lot of irritation.

The word "model" as we shall use it here is a schematic presentation of reality connecting the main quantities by laws which take the form of mathematical equations. In this formulation models are *mathematical* models; they pose qualitative questions, sometimes extremely difficult ones, and at the same time their nature is essentially quantitative. By producing figures and numbers we obtain a quantitative approximation of reality which is as accurate as possible.

Mathematical models are never to be confused with reality itself; they represent a very simplified view of an artificially isolated part of reality. Even in the natural sciences this causes basic problems. An interesting illustration is provided by the phenomenon of the "electron." Most people think of an electron as a very small particle with a charge. Such a particle may orbit atomic nuclei or may flow collectively as a current. The indication "electron," however, is more like a metaphor than a model of reality. James Gleick [5] gives a transparent description of this struggle with language in physics.

> The atom of Niels Bohr, a miniature solar system, had become an embarrassingly false image. In 1923, on the tenth anniversary of Bohr's conception, the German physicist Max Born hailed it: "the thought that the laws of the macrocosmos in the small reflect the terrestrial world obviously exercises a great magic on mankind's mind"—but already he and his colleagues could see the picture fading into anachronism. It survived in the language of angular momentum and spin—as well as in the standard high-school physics and chemistry curriculums—but there was no longer anything plausible in the picture of electrons orbiting a nucleus. Instead there were waves with modes of resonance, particles that smeared out probabilistically, operators and matrices, malleable spaces with extra dimensions, and physicists who forswore the idea of visualization altogether.

Still, the metaphor of an electron as a small particle with a charge has its restricted uses.

The Use of Metaphors

Is it necessary to use metaphors? It turns out that in ordinary language, but also in scientific discussions and theories, metaphors are unavoidable. Using a metaphor, as Aristotle [1] said, "consists in giving the thing a name that belongs to something else." Whatever the protests of puritanically minded philosophers, it is impossible to describe and to theorize about new things without referring to well-known things. We can only understand or place something if it is or seems to be like something we know already.

Think of the expression "natural selection" which we have used since Darwin's time to indicate processes of change and survival of species. Nature, however, is not a person, and nature certainly cannot select. Or take the computer with its "memory"; a better expression would be "data storage device," but we could hardly take that seriously. The computer "reads," "stores," "uses a language," etc., and these are only a few examples of the enduring power of metaphors; see also Anne Eisenberg [4].

Models as we use them in science have qualitative and quantitative aspects; metaphors are purely qualitative. This is why metaphors are more suitable for disciplines in which a quantitative approach does not make much sense. Still, one should realize that even the most sophisticated mathematical models in the natural sciences are nothing more than metaphors with advanced quantitative elements added. Again, although these models describe reality, they should not be confused with it.

We mentioned already the confusion arising out of the use of the word "model" in different meanings. Ten to twenty years ago, quite some excitement arose in the media on the possible implications of catastrophe theory. Some of the mathematicians involved claimed important applications to economy and sociology—for instance, prison riots—and even the word "prediction" was used in this context. Of course, people found out that there is no such thing as a mathematical model of economy or sociology in catastrophe theory, i.e., not in the sense of both qualitative and quantitative modeling as we know it in physics or engineering. To the embarrassment of most mathematicians, people started to talk about "the emperor's new clothes," and the negative effects of these events can still be felt in discussions between mathematicians and journalists. Even among some applied mathematicians, singularity theory, which forms part of catastrophe theory, still has a name with undeservedly bad connotations. In catastrophe theory small variations in the parameters of a system may suddenly lead to large changes or jumps. Some of the confusion and irritation could have been avoided if, right from the beginning, it had been made clear that in these "applications of catastrophe theory" no traditional mathematical modeling was involved but simply the use of metaphors. Whether these metaphors are of interest is of course another matter.

Metaphors from Chaos Theory

Chaos provides us with a number of new metaphors such as self-organization, strange attractor, homoclinic tangle, etc., which may play a part in all kinds of disciplines. There are now examples of the use of these metaphors in the fields of meteorology, management and politics, ecological studies, and many others. The enrichment of the use of language in these fields is a serious gain—again which triggers new ideas and which also permits the perception of phenomena previously overlooked or considered elusive. Well-chosen new metaphors lead to new ideas which, in their turn, lead to a new perception of reality.

We shall now consider an example of its use in psychoanalysis. In psychology many metaphors are used which have been derived from mechanics. Examples include the displacement of a problem, attachment, a balanced or stable person, a split personality, to bring up material from the subconscious, confused state. These metaphors have even become so current that they are used and experienced as purely psychological terms. The psychoanalyst Michael Moran [6] has tried

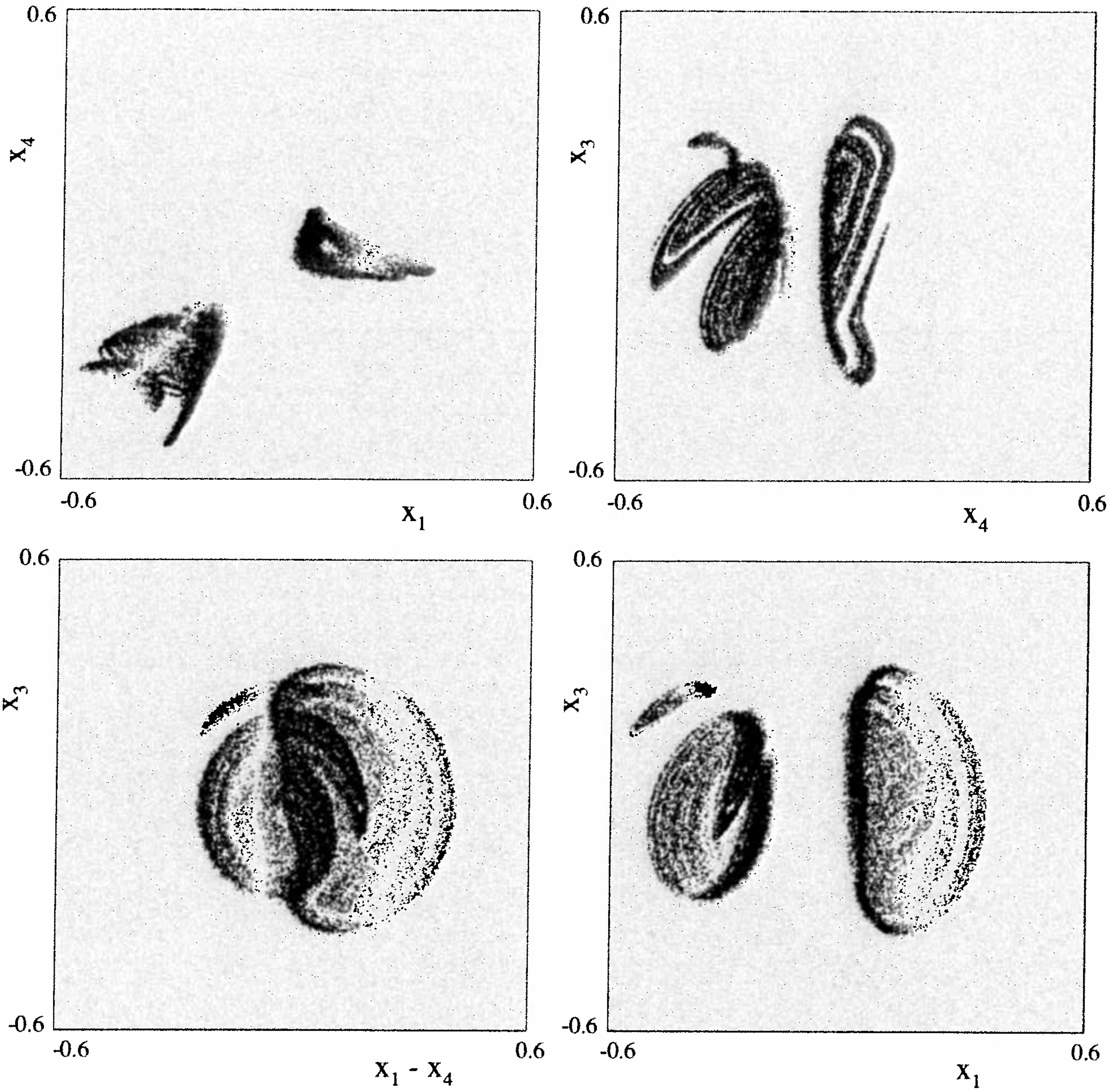

Figure 1. Poincaré section of a typical case in drillstring dynamics [8]. The strange attractor is shown from four angles and is clearly structured with densely folded and nested sets. Its Kaplan–Yorke dimension, which is related to the Hausdorff dimension, is 3.78. The correlation dimension is 2.85.

to add a number of metaphors from chaos theory to this; see also the article by Vann Spruiell [7] which contains many references.

A Model of the Mind as a Dynamical System

In his paper Moran explains that psychoanalytic models of the mind can be viewed as nonlinear dynamical systems. A patient who is being treated has a state of mind experiencing many interactions: between the patient's emotions and feelings, verbal associations, the presence and the interventions of the psychoanalyst, the physical experience of lying on a couch, and a number of other effects. These interactions cannot simply be added to describe the mental state of the patient; they influence each other and together determine the state of a dynamical system. Furthermore, there is strong and sometimes also sensitive dependence on initial values: these are the early childhood experiences which determine to a great extent the present, in a deterministic but, because of the complexity, not in a predictable sense.

One can also find patterns in mental processes that repeat themselves continuously but not in a precise periodic way. Also, in these patterns one finds a scaling effect as in fractal structures: Seemingly small actions, remarks, or a single dream can characterize on a microscale mental processes in which a fundamental structure is displayed in small things.

The similarities between models of mental processes and dynamical systems go beyond even this. We know that dissipative nonlinear systems like the Lorenz system may contain a strange attractor (it turns

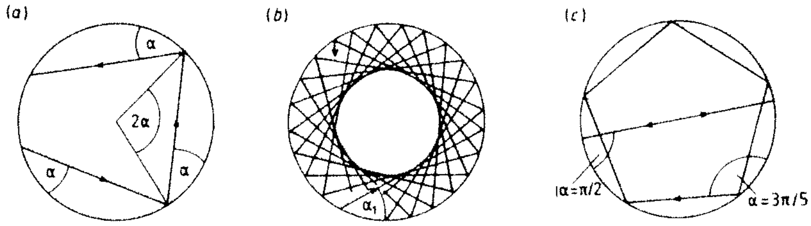

Figure 2. Billiard orbits in a circle (after Berry, 1981); typical orbits close or fill an annulus. In (a) we have the basic orbit geometry, in (b) a never-closing orbit filling an annulus, and in (c) a 2- and a 5-periodic orbit.

out to be important to explain to psychoanalysts that "strange" here does not mean "external to the system" but "curious"). This is a lower-dimensional set in the state space consisting of one or more special solutions where the other solutions are both being attracted to and repelled from; however, as all solutions are bounded and there are no stable equilibrium or periodic solutions, they have no other option than moving in the vicinity of this strange attractor.

Moran compares the concept of strange attractor with the patient's fixed collection of unconscious fantasies about himself and his environment. In psychoanalytic observation and research, no matter how complex the behavior of the patient, this collection of unconscious fantasies always turns out to play a fundamental role.

This strange attractor is, of course, very complex. It is possible that only a small part of the attractor is very active, i.e., one small part of the attractor is frequented often by the solutions of the dynamical system while the other parts are being neglected. In a (mathematical) dynamical system this can be recognized by computing both the Hausdorff dimension and the correlation dimension. The first gives us a geometric measure of the dimension of the set; the second, a dimension in which more is expressed of the dynamics of the neighboring solutions. An example from mechanics showing this phenomenon can be found in [8] (see Fig. 1). If this is the case with our strange attractor representing the patient's unconscious collection of fantasies, it is possible that the dynamics could cause serious disorders. Think, for instance, of a paranoid state of mind or a compulsive repetition of actions and behavior which involves notable lack of freedom. In such a case the unconscious dynamics is dominated by a part of the collection of unconscious fantasies.

In terms of chaos theory this means that his strange attractor contains a small subset that is visited relatively often by the solutions. What we could try in terms of therapeutic interventions for our patient is to change, by well-timed perturbations, the coupling between this active part and his mind as a whole and, in this way, the corresponding behavioral pattern.

If these perturbations persist long enough, the pattern of orbits becomes more complex, other parts of the strange attractor will be visited more often and, as a consequence, more variations of behavorial patterns are possible. With regard to the interventions being well-timed, one has to estimate and to allow for the defenses of the patient, which are determined by the strength of the coupling of the overall dynamics to the dominant subsystem. In this way psychoanalytic practice can be seen as direction to a higher level of complexity and less rigidity.

The strange attractor is a determining force for activities of the mind; as in any chaotic system, the behavior of an individual is unpredictable, but the presence of a specific strange attractor—a collection of unconscious fantasies typical for a certain individual—also puts bounds to unpredictability. From a certain individual one cannot expect any arbitrary behavior as the structure of his strange attractor puts limits to his erratic or seemingly random behavior.

Moran gives an appropriate warning here: We should not view this dynamical system approach to the mind as reductionist thinking. Mental processes are *not* being *reduced* by this approach to mechanistic brain activities. The intention is only that, by the metaphoric comparison of psychoanalysis and chaos theory, psychology is being enriched with a new language, permitting the formulation of new ideas and concepts.

Treatment Inspired by Dynamical Systems Theory

If this similarity between nonlinear dynamical systems and mental states is correct, chaos theory can be applied to psychoanalytic treatment. Or perhaps we should turn it around: if it makes sense to apply metaphors, derived from chaos theory, to psychoanalytic practice, then the similarity is clearly there. Moran postulates our patient who has a collection of unconscious fantasies, only a small part of which is active and which determines in a negative way his behavioral pattern and state of mind. It is easy to think of an example from psychoanalytic practice of the type Moran may have in mind.

A patient can have the urge to actions like frequent hand washing. This may be a reaction to strong internal conflicts. The conflicts may, for instance, arise between a strong aggressive impulse, the anxiety about this, and the ban on this aggressive impulse. The anxiety takes here the shape of hosophobia, and washing hands is the "solution." This causes lack of freedom and lack of space in the personal life of the patient which derives from an unconscious fantasy which is both attractive and frightening and hence repelling. The symptom, frequent hand washing, may in this way be a compromise between contradictory and conflicting tendencies. The force of this process causes the frequent repetitions and also lack of freedom.

Structural Instability and Timescales of Instability

This looks like an interesting idea and it may be fruitful. Also, it is not so difficult to think of other metaphors derived from dynamical system theory which might be of interest to psychology. Both the idea of (in)stability in a given system and the idea of structural instability in a set of systems may provide us with useful examples.

Billiard dynamics, for instance, produces a good illustration. As we know, the dynamics of the circle billiard is very regular. There exists an infinite number of stable periodic orbits (see Berry [2]): the simplest one is reflection of the ball between two opposite points, and, because of the circular symmetry, there is already an infinite number of these. There are also an infinite number of periodic orbits hitting the circle at three different spots, and this statement holds for any number of spots. If the angle that the chords make with the circle is an irrational submultiple of π, the corresponding orbit will fill an annulus.

Of course, the dynamics of the circle billiard is too regular to be generic. As a conservative system, it is characterized by a two-dimensional area-preserving map containing an (uncountably) infinite number of n-periodic orbits which for each n are imbedded in an infinite set of periodic solutions. This is a degenerate case, and small perturbations of the circular symmetry will generally destroy this property leaving a (countably) infinite number of isolated periodic orbits.

Berry [2] discusses a small perturbation of this circular symmetry by splitting the circle and inserting small segments (the stadium); there is a dramatic change as this causes the orbital pattern to be ergodic and completely irregular (see Bunimovich [3]). If the inserted segments are very small, i.e., the two halves of the circles are still very close together, it takes a very long time before we notice this large-scale irregularity. Still, a small perturbation like this produces, in the long run, a dramatic effect.

In this conservative form of billiard dynamics there is no strange attractor present, but still we can think of this dynamical system as a metaphor for a situation in which the presence of a small disorder leads, in the long run, to serious mental instability. Think, for instance, of a disorder causing a split personality—the extreme case is exemplified by the personalities of Dr. Jekyll and Mr. Hyde united in one person—which may initially be a small effect but which becomes noticeable over the years.

The example of the circle billiard demonstrates convincingly that a regular and rather harmonious dynamical system may show qualitatively completely different behavior when its structure is changed, even in a very small way. A second aspect of this is that, in the case of a small perturbation, it takes a very long time before we will observe its effect but, finally, this will always happen.

One might hypothesize that this corresponds to some extent with the development of mental instabilities over long periods of time as observed in psychoanalytic practice. Such an instability, originating from an early age, may for years be hidden from an observer. It was caused by a perturbation which contributed to the formation of the dynamic unconscious—and the unconscious contains all kinds of ingredients that are partially conflicting, such as memories of experiences, and processes having a dynamic of their own. The influence of such a perturbation may become more and more apparent in the behavior of a person over the course of many years.

A Changing Perspective of Psychoanalytic Theory

Another interesting aspect is that, using these metaphors, the effects of psychoanalysis can both be better understood and be better defended. In testing to what extent scientific theories are correct, the emphasis is on the predictability of phenomena. Originating in the 17th century, this concept has become one of the most important elements of modern science. A recurrent and important objection to the theory and methods of psychoanalysis stems from the lack of predictability of human behavior and mental states. This holds not only for groups but also for individual patients whom one knows quite well.

In chaos theory, however, full knowledge of the laws leading to deterministic process may still lead to unpredictable behavior. Although we know all small-scale processes which are active and their relationships, we still cannot predict what may happen in an individual case. To understand better what is going on in complex systems containing deterministic chaos, completely new methods are being developed.

If we find this already in physical-mechanical systems, then what can we expect from complex dynamical systems as they are found in psychology—certainly not good predictability in individual cases. The objectives of psychology and psychoanalysis are very different. The matter of first importance in the latter is understanding the basic psychological mechanisms and guiding processes of change and healing.

A New Role for Mathematicians

Mathematicians usually show remarkable social stage fright. Although mathematics plays the key role in modern science, most mathematicians are afraid to popularize, engage in public discussions, and, generally, present a clear and interesting profile to colleagues in other disciplines and to the general public.

Basic ideas used in dynamical systems theory such as structural stability, strange attractors, and sensitive dependence on initial values can be extremely important to concept formation in other disciplines. Mathematicians can help NOT ONLY in creating MATHEMATICAL models but also in creating qualitative models, i.e., metaphors. Of course, there is a danger that the mathematical language will be abused, and of charlatanism, but this danger is much greater when mathematicians are not involved. Mathematics and mathematicians have much to offer.

Acknowledgments

The author owes much to discussions with Mrs. Karin Mispelblom, psychoanalyst. Comments by Henk Broer, Philip Holmes, and Meredith Wiggins are gratefully acknowledged.

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