Chaos of the Mind

During psychotherapy, the mind may flow to the currents of chaos

By DANIEL PENDICK

Almost two years after her husband's sudden death, the woman sought counseling and embarked on a series of weekly psychotherapy sessions to quell the unusually prolonged aftershocks of her loss. She also agreed to participate in a new study charting the flow of thoughts and emotions that people experience when talking to their therapists.

During the woman's sessions at the Langley Porter Psychiatric Institute at the University of California, San Francisco, two researchers monitored complex, seemingly random changes in her heart rate – patterns they believe reflect deep psychological processes.

The scientists, Dana J. Redington and Steven P. Reidbord, are using nonlinear dynamics – better known as chaos theory – to recover potentially important information that conventional electrocardiogram analysis fails to capture. This marks the first use of nonlinear dynamics to study mind-body states during psychotherapy, Redington says.

Redington, a University of California, San Francisco, psychophysiologist well-versed in the mathematical art of nonlinear dynamics, hopes this research will yield a new understanding of how people shift between mental states. This may someday help therapists more effectively guide their patients toward recovery, he says.

"We're trying to use physiology – the way patterns in the body occur in time – to give us more information about what's going on in the person's head and see how we might use that to make the person more healthy," Redington explains.

Nonlinear dynamics might also provide a sturdy mathematical foundation for psychodynamics, the long-standing theory that people behave and feel in certain ways in response to conflicting psychological forces, says Reidbord, a medical center psychiatrist and former research fellow at Langley Porter.

"If we can analyze in greater detail the moment-by-moment changes, the pushes and pulls, the flow, from one mental state to another, then we will really be doing a better job of describing psychodynamics," Reidbord explains.

Extraordinary claims, perhaps, but then chaos theory is no ordinary way of looking at things. This mathematical construct, which scientists use to explore nature, has gained numerous proponents during the past 20 years, cutting across disciplines as diverse as meteorology, physics, population biology, literary criticism, and, since the early 1980s, psychology.

"Chaos" is a somewhat misleading description of the complex, unpredictable, seemingly random behavior that some natural systems exhibit – misleading because this complexity can mask underlying order. Redington cites the computer programs used to generate streams of random numbers (SN: 12/19&26/92, p.422) as an example of seemingly disorderly behavior.

At first glance, these numbers look like the result of a random, patternless roll of the electronic dice. But in reality, the dice are loaded. Analyzed correctly, the numbers reveal a subtle structure that reflects the simple equations at the heart of random number generators. What seems random in this case proves predictable and rule-based.

Redington and a number of other researchers envision the brain – an exquisitely interconnected bundle of neurons that plays host to human thoughts and feelings – as a nonlinear system. And although the flow of these thoughts and feelings may seem random at times, the underlying processes that generate them are not, Redington argues.

"Human beings and human behavior are not random phenomena," he explains. "Then there is something controlling the behavior [of the human mind], and that's what we're trying to catch."

Nonlinear dynamics seems ideally suited. "The wonderful thing about nonlinear dynamics is that it's a very good framework to describe complex systems in a very simple and elegant way. That's a lot better than trying to describe what humans do in very simplistic terms."

Despite its ability to inspire scientists and scholars, nonlinear dynamics imposes rigorous requirements. "The problem is that you need a lot of very precise data to do a good mathematical analysis," Reidbord explains. "And in psychology, it's hard to come by."

Redington and Reidbord believe they have found in the human heart rate a rich, possibly meaningful source of information about people's shifting psychological states. They want to find out if the amount of variability, or complexity, in the rate at which the heart beats from second to second reflects a person's particular mental state, spanning the spectrum from meditative calm to raging anxiety.

"The heart in a normal human being is not a pump in a pool," Redington asserts. "It is a pump that is heavily connected to the brain. And it just turns out that [because of] the types of connections, what you think affects your heart."

But heart rate is not a sealed, noise-proof pipeline to our deepest thoughts, motivations, and perceptions. Posture, breathing, and distracting noises can affect heart rate, too, making it more difficult to discern the influence of mental states on the heart.

This is why Redington and Reidbord chose the therapist's office as their laboratory. During a psychotherapy session – an intimate conversation conducted in a controlled, safe environment – measures of the heart rate become "cleaner," Redington says, and "extraneous influences on heart rate, such as physical exercise and metabolism, wash out."

"With the person relaxed and comfortable, typically the changes that you see in the heart are more closely coupled with what's going on in the mind," Redington emphasizes.

With these principles in mind, the researchers have conducted a series of studies on patients in psychotherapy. They reported the results of their preliminary studies in the May 15, 1992 Biological Psychiatry and in the October 1992 Journal of Nervous and Mental Disease. Their most recent study, which also includes information on the behavior of a psychiatrist's heart rate during therapy sessions, will appear in an upcoming issue of the Journal of Nervous and Mental Disease.

For their first study, Redington and Reidbord enlisted the cooperation of a 33-year-old woman who had referred herself for therapy to the Langley Porter Psychiatric Institute. She spent one of her sessions with button-size sensors stuck to her wrist and inner forearms. Through these devices, the researchers recorded changes in the intervals between her heartbeats. Visible but inconspicuous video cameras recorded her encounter with the therapist. During the 50-minute session, the conversation wandered; so did the woman's heart rate.

Plotted in the typical fashion – as a trace that wiggles up and down – the data they collected would not have revealed the overall complexity of the woman's heart rate. For this, the researchers had to plot the information in a mathematical universe called "phase space," which plots the heart rate in three dimensions to highlight the amount of variability.

In these three-dimensional diagrams, second-by-second changes in heart rate form a continuous series of points. A truly random heart rate, Redington explains, would fill the phase space with an amorphous cloud of data points in no particular order. Conversely, a completely stable heart rate – that of a person under deep anesthesia, for example – would fill only a small, point-like region of the phase space.

"Our data look like something in between these extremes," Redington says.

In a computer-assisted game of connect-the-dots, the researchers identified recurrent patterns, or trajectories, in the behavior of the patient's heart rate in phase space. For example, trajectories the researchers classified as type IV show the most complex, spontaneous behavior. In these trajectories, the heart rate wanders through widely separated regions of phase space. This behavior resembles the "random walk" of a truly unpredictable process.

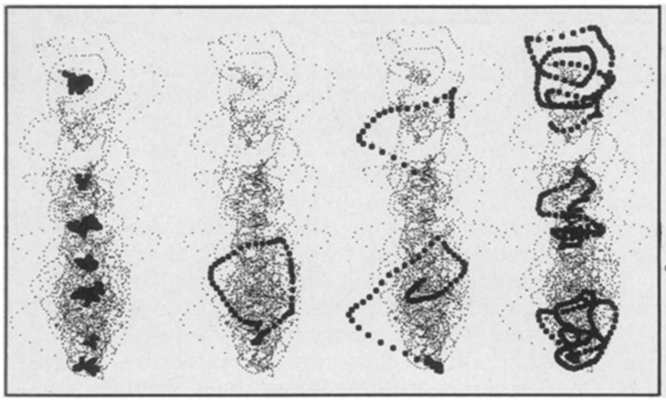
But most intriguing to the researchers, type IV trajectories tend to emerge when the patient seems most focused on the emotions and thoughts at issue during the session – a desirable mental state psychologists call "therapeutic engagement." In contrast, less complex, more point-like trajectories seem to correspond to times when the patient seems more defensive or anxious.

These complex heart-rate patterns may also reveal important information about the mental state of the therapist, Redington notes. In a study slated for publication in an upcoming JOURNAL OF NERVOUS AND MENTAL DISEASE, the researchers show that type IV trajectories in the therapist often coincide with moments when the therapist experiences strong feelings of empathy for the patient.

"There appear to be interesting patterns in the physiology that may index, or reflect, what's going on inside the head," Redington notes.

The therapist can also affect the behavior of the patient's heart rate. By making what psychiatrists call an "intervention" – offering an insightful interpretation of something the patient has recounted, for instance – the therapist sometimes seems to trigger sudden changes in the complexity of the patient's heart rate.

At these moments in therapy, "there's a dramatic shift in the patient's physiology," says Redington. "It's as if the therapist has metaphorically slapped the patient on the back. And now all of a sudden, the patient is responding in a new way, learning a new way to behave."


Redington and Reidbord

Darkened points indicate four different patterns, or trajectories, in the same phase-space plot of changes in a patient's heart rate during psychotherapy. Type IV trajectory (far right) exhibits the most complex, spontaneous, random-like motion in the phase space and may reflect specific kinds of mental states patients experience during therapy, say researchers.

What do these dynamic changes say about patients' shifting mental states during psychotherapy? At this early phase of their research, Redington and Reidbord hesitate to tag the trajectories they've observed with specific meanings. In subsequent work, Reidbord says, they will switch to analyzing the phase-space plots with computer-based, numerical methods to avoid the somewhat subjective typing of trajectories by visual inspection.

However, using nonlinear dynamics to study psychological phenomena may prove "intrinsically more difficult" than earlier applications, warns cardiologist Ary L. Goldberger at Harvard Medical School in Boston, who is noted for his research on the chaotic rhythms of the heart (SN: 9/5/92, p.156). Moreover, in all disciplines, not just psychology, the use of chaos theory remains "enormously complicated and controversial," Goldberger says.

"I think the interpretation of the data must be done with great caution," he notes.

Redington and Reidbord say they have indeed proceeded cautiously in their research, largely out of respect for the intrinsic difficulties of training the telescope of nonlinear dynamics on psychological phenomena. In past and ongoing research, they have taken an "ultraconservative approach," which includes collecting heart-rate data carefully and applying the mathematics of nonlinear dynamics rigorously, Redington says.

The researchers, however, are certain that nonlinear dynamics is the appropriate means for exploring the complex interconnections of physiology and mental states and for pursuing their goal of describing mathematically the "pushes and pulls" that shape human thought and action.

"When you look through a telescope, you start to see in much finer detail, you're better able to describe things," says Redington. "And that's exactly what I think nonlinear dynamics is all about." □

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and few of the string theorists have time to keep up with anything else in physics, least of all with high-energy experiments."

Nonetheless, he continues, "string theory provides our only present source of candidates for a final theory.... It is a pity that it has not yet been more successful, but string theorists like everyone else are trying to make the best of a very difficult moment in the history of physics. We simply have to hope either that string theory will become more successful or that new experiments will open up progress in other directions."

The attempt to construct string theory has also led to fruitful collaborations between physicists and mathematicians. Mathematicians can take advantage of the intuitive insights that physicists bring to the solution of mathematical problems, and physicists benefit from the rigor that mathematicians bring to what initially may be little more than speculation.

"This kind of jumping ahead when you don't really know what you're doing is really useful," Greene says. "If you wait for the mathematical rigor to be there, it might take a long time, and by that time the question you started with may not be important anymore."

"I think that over the last decade it has become apparent that we mathematicians can actually learn a lot in interacting with physicists if we suspend disbelief for a while," Morrison says. He describes some of the mathematical surprises emerging from recent developments in string theory in the January JOURNAL OF THE AMERICAN MATHEMATICAL SOCIETY.

In 1989, Schwarz remarked, "It is very satisfying to witness the growth of interaction between mathematicians and physicists after a long period of separation. I think it is fair to say that the study of string theory holds great promise for the unification of particles and forces, but it has already done a great deal to unify disciplines."

Those remarks still ring true. □