

It's as Simple as One, Two, Three...

by **Richard P. Feynman**
as told to **Ralph Leighton**

Richard Feynman, Nobel laureate and the Richard Chace Tolman Professor of Theoretical Physics, was a bestselling author as well. When he died last February 15, the sequel to the 1985 "Surely You're Joking, Mr. Feynman," Adventures of a Curious Character was already finished. Entitled "What Do You Care What Other People Think?" Further Adventures of a Curious Character, the book recounts more Feynman tales, including this one, as told to his friend and drumming colleague, Ralph Leighton. The book, which also contains an account of Feynman's service on the Challenger commission (expanded somewhat over the article that appeared in E&S Fall 1987) will be available at the end of this month.

Feynman's curiosity also extended to drawing. He was a persistent artist, according to Leighton. "He was always amazed by the fact that a good drawing seemed to come out randomly," said Leighton. "Since he could never predict when a good drawing would appear, he drew a lot." The drawings that accompany this article also appear in the book and were part of a collection exhibited at Caltech last March at the time of Feynman's memorial service.

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When I was a kid growing up in Far Rockaway, I had a friend named Bernie Walker. We both had "labs" at home, and we would do various "experiments." One time, we were discussing something—we must have been 11 or 12 at the time—and I said, "But thinking is nothing but talking to yourself inside."

"Oh yeah?" Bernie said. "Do you know the crazy shape of the crankshaft in a car?"

"Yeah, what of it?"

"Good. Now tell me: how did you describe it when you were talking to yourself?"

So I learned from Bernie that thoughts can be visual as well as verbal.

Later on, in college, I became interested in dreams. I wondered how things could look so real, just as if light were hitting the retina of the eye, while the eyes are closed. Are the nerve cells on the retina actually being stimulated in some other way—by the brain itself perhaps—or does the brain have a "judgment department" that gets slopped up during dreaming? I never got satisfactory answers to such questions from psychology, even though I became very interested in how the brain works. Instead, there was all this business about interpreting dreams, and so on.

When I was in graduate school at Princeton a kind of dumb psychology paper came out that stirred up a lot of discussion. The author had decided that the thing controlling the "time sense" in the brain is a chemical reaction involving iron. I thought to myself, "Now, how the hell could he figure that?"

Well, the way he did it was, his wife had



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a chronic fever which went up and down a lot. Somehow he got the idea to test her sense of time. He had her count seconds to herself (without looking at a clock), and checked how long it took her to count up to 60. He had her counting—the poor woman—all during the day; when her fever went up, he found she counted quicker; when her fever went down, she counted slower. Therefore, he thought, the thing that governed the “time sense” in the brain must be running faster when she’s got fever than when she hasn’t got fever.

Being a very “scientific” guy, the psychologist knew that the rate of a chemical reaction varies with the surrounding temperature by a certain formula that depends on the energy of the reaction. He measured the differences in speed of his wife’s counting, and determined how much the temperature changed the speed. Then he tried to find a chemical reaction whose rates varied with temperature in the same amounts as his wife’s counting did. He found that iron reactions fit the pattern best. So he deduced that his wife’s sense of time was governed by a chemical reaction in her body involving iron.

Well, it all seemed like a lot of baloney to me—there were so many things that could go wrong in his long chain of reasoning. But it *was* an interesting question: what *does* determine the “time sense”? When you’re trying to count at an even rate, what does that rate depend on? And what could you do to yourself to change it?

I decided to investigate. I started by counting seconds—without looking at a clock, of course—up to 60 in a slow, steady rhythm:



1, 2, 3, 4, 5. . . . When I got to 60, only 48 seconds had gone by, but that didn’t bother me; the problem was not to count for exactly one minute, but to count at a standard rate. The next time I counted to 60, 49 seconds had passed. The next time, 48. Then 47, 48, 49, 48, 48. . . . So I found I could count at a pretty standard rate.

Now, if I just sat there, without counting, and waited until I thought a minute had gone by, it was very irregular—complete variations. So I found it’s very poor to estimate a minute by sheer guessing. But by counting, I could get very accurate.

Now that I knew I could count at a standard rate, the next question was—what affects the rate?

Maybe it has something to do with the heart rate. So I began to run up and down the stairs, up and down, to get my heart beating fast. Then I’d run into my room, throw myself down on the bed, and count up to 60.

I also tried running up and down the stairs and counting to myself *while* I was running up and down.

The other guys saw me running up and down the stairs, laughed, and asked, “What are you doing?”

I couldn’t answer them—which made me realize I couldn’t talk while I was counting to myself—and kept right on running up and down the stairs, looking like an idiot.

(The other guys at the graduate college were used to me looking like an idiot. On another occasion, for example, a guy came into my

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room—I had forgotten to lock the door during the “experiment”— and found me in a chair wearing my heavy sheepskin coat, leaning out of the wide-open window in the dead of winter, holding a pot in one hand and stirring with the other. “Don’t bother me! Don’t bother me!” I said. I was stirring Jell-O and watching it closely; I had gotten curious as to whether Jell-O would coagulate in the cold if you kept it moving all the time.)

Anyway, after trying every combination of running up and down the stairs and lying on the bed, surprise—the heart rate had no effect. And since I got very hot running up and down the stairs, I figured temperature had nothing to do with it either (although I must have known that your temperature doesn’t really go up when you exercise). In fact, I couldn’t find anything that affected my rate of counting.

Running up and down stairs got pretty boring, so I started counting while I did things I had to do anyway. For instance, when I put out the laundry, I had to fill out a form saying how many shirts I had, how many pants, and so on. I found I could write down “3” in front of “pants” or “4” in front of “shirts,” while I was counting to myself but I couldn’t count my socks. There were too many of them: I’m already using my “counting machine”—36, 37, 38—and here are all these socks in front of me—39, 40, 41. . . . How do I count the socks?

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I continued this game of counting by patterns and found I could count the lines in a newspaper article by grouping the lines into patterns of 3, 3, 3, and 1 to get 10; then 3 of those patterns, 3 of those patterns, 3 of those patterns, and 1 of those patterns made 100. I went right down the newspaper like that. After I had finished counting up to 60, I knew where I was in the patterns and could say, “I’m up to 60, and there are 113 lines.” I found that I could even read the articles while I counted to 60, and it didn’t affect the rate! In fact, I could do anything while counting to myself—except talk out loud, of course.

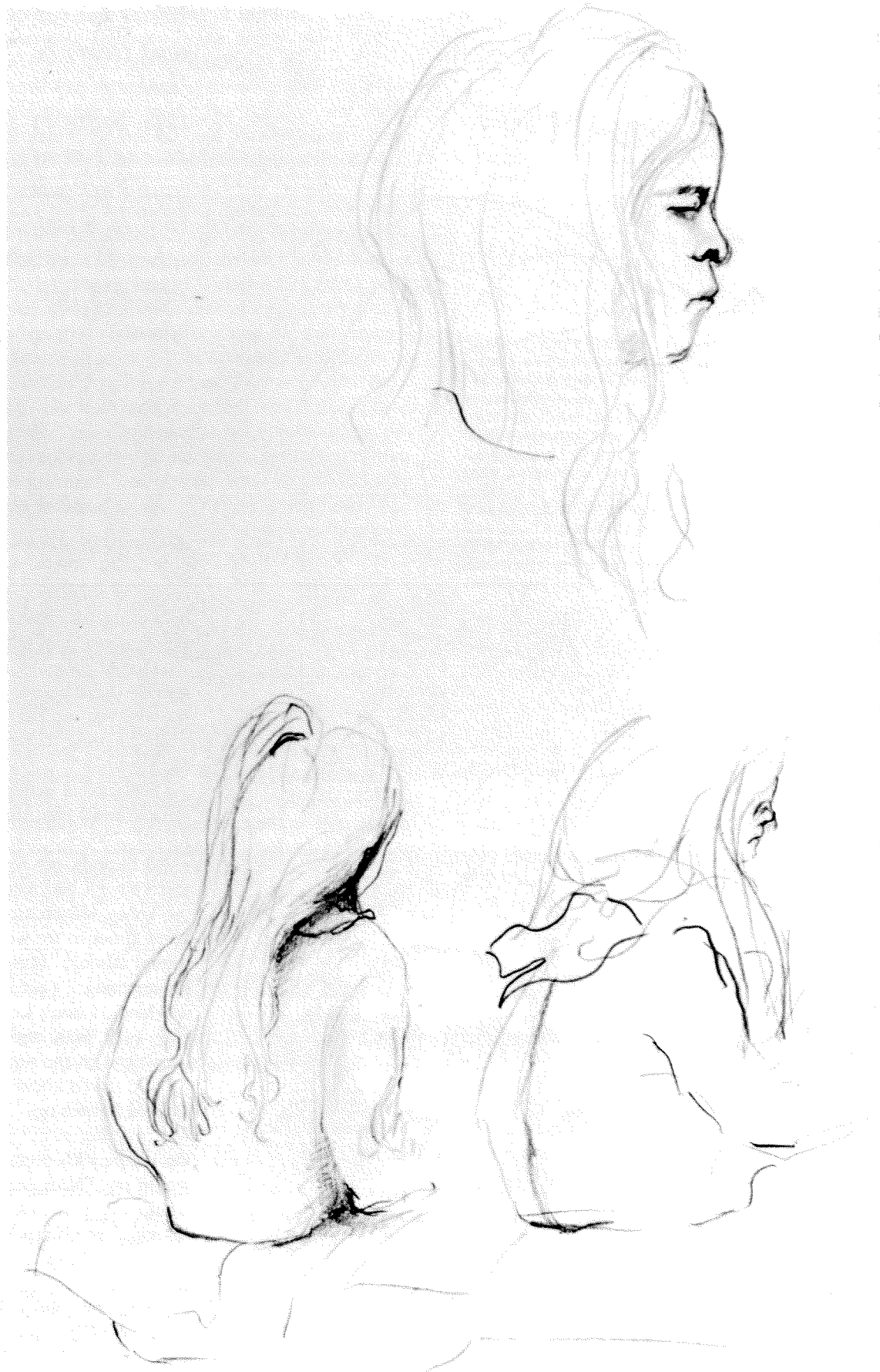
What about typing—copying words out of a book? I found that I could do that, too, but here my time was affected. I was excited: finally, I’ve found something that appears to affect my counting rate! I investigated it more.

I would go along, typing the simple words rather fast, counting to myself 19, 20, 21, typing along, until—What the hell is that word?—Oh, yeah—and then continue counting 30, 31, 32, and so on. When I’d get to 60, I’d be late.

After some introspection and further observation, I realized what must have happened: I would interrupt my counting when I got to a difficult word that “needed more brains,” so to speak. My counting rate wasn’t slowing down; rather, the counting itself was being held up temporarily from time to time. Counting to 60 had become so automatic that I didn’t even notice the interruptions at first.

The next morning over breakfast, I reported







Well, now it was clear: he's 'looking' at his tape going by so he can't read, and I'm 'talking' to myself when I'm counting, so I can't speak.

the results of all these experiments to the other guys at the table. I told them all the things I could do while counting to myself, and said the only thing I absolutely could not do while counting to myself was talk.

One of the guys, a fella named John Tukey, said, "I don't believe you can read, and I don't see why you can't talk. I'll bet you I can talk while counting to myself, and I'll bet you you can't read."

So I gave a demonstration: they gave me a book and I read it for a while, counting to myself. When I reached 60 I said, "Now!"—48 seconds, my regular time. Then I told them what I had read.

Tukey was amazed. After we checked him a few times to see what his regular time was, he started talking: "Mary had a little lamb; I can say anything I want to, it doesn't make any difference; I don't know what's bothering you"—blah, blah, blah, and finally, "Okay!" He hit his time right on the nose! I couldn't believe it!

We talked about it a while, and we discovered something. It turned out that Tukey was counting in a different way: he was visualizing a tape with numbers on it going by. He would say, "Mary had a little lamb," and he would *watch* it! Well, now it was clear: he's "looking" at his tape going by so he can't read, and I'm "talking" to myself when I'm counting, so I can't speak.

After that discovery, I tried to figure out a way of reading out loud while counting—something neither of us could do. I figured I'd have to use a part of my brain that wouldn't



interfere with the seeing or speaking departments, so I decided to use fingers, since that involved the sense of touch.

I soon succeeded in counting with my fingers and reading out loud. But I wanted the whole process to be mental, and not rely on any physical activity. So I tried to imagine the feeling of my fingers moving while I was reading out loud.

I never succeeded. I figured that was because I hadn't practiced enough, but it might be impossible; I've never met anybody who can do it.

By that experience Tukey and I discovered that what goes on in different people's heads when they *think* they're doing the same thing—something as simple as *counting*—is different for different people. And we discovered that you can externally and objectively test how the brain works: you don't have to ask a person how he counts and rely on his own observations of himself; instead, you observe what he can and can't do while he counts. The test is absolute.

There's no way to beat it; no way to fake it.

It's natural to explain an idea in terms of what you already have in your head. Concepts are piled on top of each other; this idea is taught in terms of that idea, and that idea is taught in terms of another idea, which comes from counting, which can be so different for different people!

I often think about that, especially when I'm teaching some esoteric technique such as integrating Bessel functions. When I see equations, I see the letters in colors—I don't know why. As I'm talking, I see vague pictures of Bessel functions from Jahnke and Emde's book, with light-tan *j*'s, slightly violet-bluish *n*'s, and dark brown *x*'s flying around. And I wonder what the hell it must look like to the students. □

"Safecracker Suite," a tape of Feynman recounting one of his most infamous exploits (interspersed with Feynman and Leighton on drums) may be ordered by writing to Box 70021, Pasadena, California 91107. Cassette tape is \$10; CD, \$15. All proceeds go to cancer research.

"What Do You Care What Other People Think?" will be available in bookstores at the end of October, or it can be ordered directly from the publisher.

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