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The Decision Sciences Laboratory

By Andrew Vazsonyi, Feature Editor

There is a growing realization that we fail to give our students a *personal knowledge* of uncertainty, chance, randomness, and probability. I am using these terms in the sense of the late Michael Polanyi, a Hungarian compatriot of mine who wrote *Personal Knowledge: Towards a Post-Critical Philosophy*. A broader and more accessible exposition is in the book by Robert and Michèle Root-Berstein, *Sparks of Genius*. I am referring to first-hand, intuitive, direct, insightful familiarity—a gut feeling for knowing.

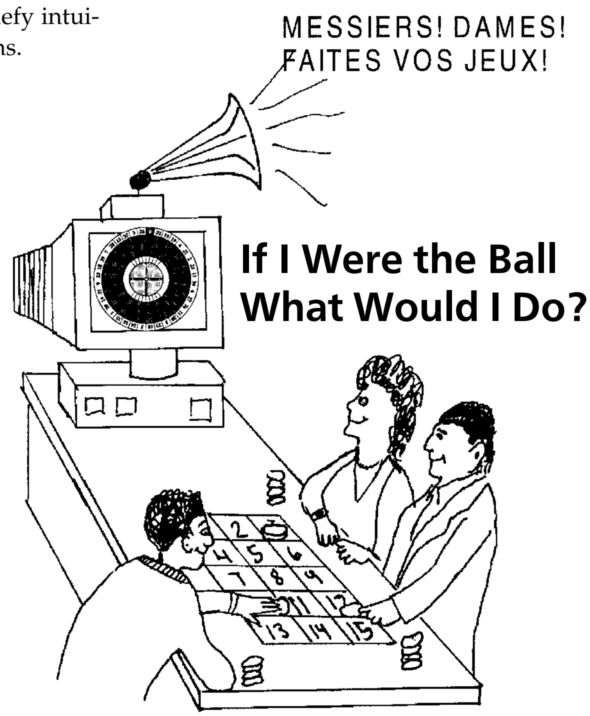
I started my intellectual life as a pure mathematician and when I became an engineer I had a lot of trouble learning about the physical world. Laboratory work provided me with a personal knowledge about the problems of engineering and classical physics. However, I failed to develop a feel for quantum mechanics because of the idea of uncertainty. Later, when I morphed into a decision scientist, I still had a lot of trouble with concepts of chance and probability. It took me years to develop a personal friendship with stochastic models, and I still have much trouble with results that defy intuitive notions of chance fluctuations.

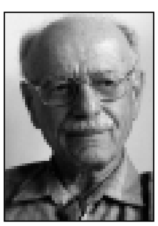
My Roulette Wheel

I have a small roulette wheel on my desk. Richard Feynman, my hero, once exclaimed, "What would I do if I were an electron?" I ask, what would I do if I were a ball bounced about? Einstein talks about "visual" and "muscular feelings" when thinking about physics. To me, probability is the wheel, the "spinner," and I have a feeling in my hand, spinning the wheel, and being bounced about. When I model a decision analysis situation, I see, feel, and spin a network of wheels in a virtual casino.

I used to conduct thought experiments with (roulette) wheels, as physicists do, and tried to develop a qualitative feel for models. I built a web of beliefs, in the sense of the philosopher W. V. Quine. The spinner is on the edge of the net; all my other personal knowledge of probability connects to this node. Decision trees tie the spinners together and help me to visualize the situation. I imagine driving my car, starting at the foot of the tree and moving to the right along the branches. At each *square* I have control, can make a decision, turn the wheel of my car. At each *circle* the cunning Goddess Fortuna takes over the wheel, and I am powerless. I have a number of alternative ways to reach the tips and the payoffs, and I can reduce a network of spinners to the normal form of a single spinner. The decision problem is to review scenarios of alternative spinners and select one with a satisficing value of the subjective expected utility.

It is hard to get friendly with spinners, so I need props. I find it useful to see a





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probability distribution associated with a spinner. I find it harder to think of the cumulative distribution, but as time goes on, I get friendly with it, too. Still, I find that many results are counterintuitive, and need much hard visualization to get some vague qualitative feelings of how spinners combine.

Enter Excel

The breakthrough came when I learned Excel and Visual Basic for Applications. Since then I have a virtual laboratory where I can experiment with stochastic models. I build parametric templates to simulate the tools and instruments of a laboratory. Each template is a virtual calculator, like the two calculators included in Windows. I do not press the keys of these; I point-and-click. Students need not be told how the calculators are designed; they don't know the electronic design of pocket calculators either. They are empowered to conduct stochastic experiments to build personal knowledge for dealing with uncertainty.

I have built templates for risk analysis and get some personal feel of how probability distributions combine. I was surprised to find how spinners combine, and how insensitive the results are to the detailed shapes of the distributions. Often I get skewed distributions, and see the difference between bells and humpbacks, although I must admit that often I rely more on my results than on my intuition. Nonlinear payoffs result in surprises.

I know that all measurements and predictions are uncertain. How do I deal with the combination of uncertainties? I am an avid and lousy golf player. I hit with the number three iron between 75 and 150 yards. But what can I say about three successive strikes? It will be between 225 and 450 yards, but can I narrow this down? Would the range 300 to 400 yards make sense? I developed a feel for diversification, regression to the mean, and the central limit theorem.

I have much more trouble with random walks and queuing theory. The Poisson and exponential distributions are hard to digest. What does it mean that the queue *reaches the steady state*? If the arrival rate equals the capacity, will the system blow up? Real-life problems deal with finite time spans, special initial conditions, and changing environments. The traditional gallery of formulas does not provide much insight. I built a template for the assembly line problem from Eliyahu Goldratt's book *The Goal* (which has sold over half a million copies). The production line is perfectly balanced; still, in-process inventories build up. I can watch on the screen how and why this happens. I can change the parameters, and see that the naïve approach for improvements does not work. I could never really understand the preposterous behavior of queues and random walks, but playing in my laboratory helps.

Animated Simulation: The Future

We train airplane pilots by simulation and there are some encouraging signs that a similar approach is coming to decision sciences. Sam Savage used a spinner in a pioneering article, (*OR/MS Today*, December 1994) and you can download his live spinner (*http://www.stanford.edu/~savage/software.htm*). Ingolfsson and Zalkind found a similar approach useful [*Interfaces*, 1999, Vol. 29(6)]. Simulation helps to make the difference between histograms summarizing the past and probability distributions forecasting the future. The mystery of prior and posterior probability, and Bayesian update can be clarified.

Many software houses provide animated simulation, and I find the work of the ProModel Corporation very suggestive.

Conclusions

Literature abounds with anecdotes about traps and fallacies concerning probability, randomness, and chaos theory. Theoretical publications provide the math of some unbelievable, counterintuitive results. The current textbooks on decision sciences are good guides in the Everglades, but are built on swamps, and the math often turns off students. To provide personal knowledge we need experimentation in virtual simulation laboratories. We also need caveats to question our intuition and show why we must learn to navigate by instruments. ■