Survey this

The other day when I encountered yet another customer satisfaction survey, something seemed vaguely familiar. As this is election season in the United States (when is it not?), the results of political polls are reported *ad nauseam* on every news outlet. Those too rang a familiar bell. So I began to think about what a survey does, or tries to do. Something more fundamental than just collecting opinions seemed at play.

Watching the news reports, the first thing to notice, if one is a skeptic who always looks for the fine print—which I am, is the quoted margin of error in the footnotes. Typically, an error such as ~4.5% is quoted, or ~3% for the better surveys. It becomes obvious that those surveys polled 500 and 1000 respondents, respectively. As a graduate student pulling an all-nighter in the lab watching the counts from the decay of a radioactive source accumulate ever so slowly in my multichannel analyzer, I was painfully aware of the statistical accuracy required before I could head home. This was worse than "a watched pot never boils." It was the revenge of Siméon Denis Poisson and his damnable statistics. I thought root N by N would be the end of me.

But enough about the character-building experiences of my youth. Apparently the answers provided by respondents to a survey are random independent countable events, just like radioactive decay. That might have satisfied my curiosity, but the analogy seemed somewhat flawed. It did not fully explain the survey *déjà vu* I had experienced. Therefore, I decided that a *Gedanken* experiment was in order.

Let's say that you abstain from sweets altogether. You are subjected to a survey of eating habits and one of the questions is, "Do you prefer chocolate or vanilla ice cream?" No room for nuance is offered and an answer is mandatory. Based on no logical criteria at all, but perhaps based on the dessert's color, its alphabetical preeminence, or just the flip of a coin, you choose one of the alternatives. This measurement of your fully undetermined preference has forced you into one of two ice cream camps. In the language of quantum mechanics, you were just subjected to the calamitous, but thankfully painless, process of wave-function collapse.

And thus came the epiphany. These polls remind me of physics in general and quantum principles in particular—how appropriate, since both pursuits contend with an unforgiving uncertainly principle!

We can stretch my *Gedanken* a bit further. You and your identical twin literally live poles apart. She has a sweet tooth, and at dinner on a recent visit between the entrée and the coffee, she orders chocolate ice cream for dessert. You have the fruit and cheese, just to maintain your superiority in such matters, but her likely addiction to tryptophan does not escape your notice. In your younger days, you and your sister used to change places in this circumstance to see if the waiter noticed, but the exchange energy

after a full meal was too great to contemplate the prank. Nevertheless, the potential was there.

By the time the food preference survey arrives, a detailed memory of that visit has faded, but you choose vanilla without hesitation. No delay and no second thoughts. What just happened? Obviously, that interaction with your sister left the two of you entangled, and now we know you are both subject to Fermi–Dirac statistics, because the Pauli exclusion principle had put you squarely in the vanilla state opposite to your sister's chocolate.
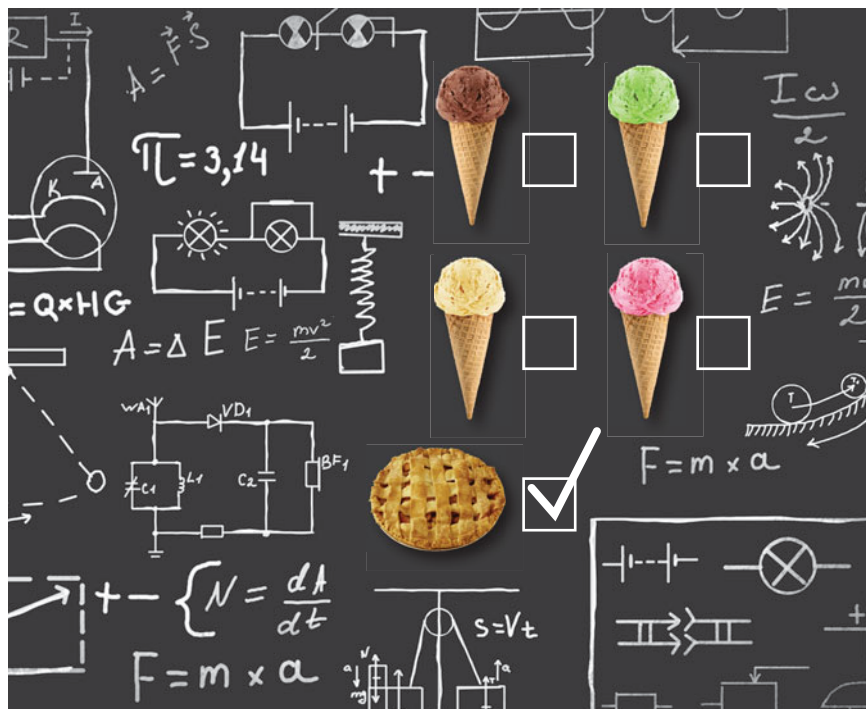
I should be satisfied. Posited and confirmed: Being both a student of physics and a victim of surveys was most assuredly the underlying cause of my *déjà vu*. Yet there is an irresistible temptation to see how far the analogy can be pushed. The chocolate-or-vanilla question defines a two-state

As the chalkboard confirms, there is more here than just des{s}erts!

system—the spin-up or spin-down case. What if there had been a multiple choice question of more than two flavors? What if acceptable responses included, "I don't know" or "None of the above" or both? And what if there were an open-ended question that simply asked, "What's your favorite ice cream flavor?"

In other words, how would it feel to have your own personal state vector broken down into its components as projected onto the axes in Hilbert space defined for you by the question, where the matrix representing the survey question's operator is diagonal? Any discomfort you experience when confronted by a pollster's question must be due to that forced orthogonalization. And we have not even broached the question of the order in which questions are posed. If successive questions were asked of me, I would want to know if their corresponding operators commute. Staying in the gastronomical realm, it matters greatly whether the main course fish or meat question follows or is preceded by the red or white wine question.

I could go on, but I think we've established a clear basis to state our main conclusion. The claimed similitude between quantum mechanics and surveys not only accounts for my own subconscious reaction (i.e., the hidden variables have been exposed), but it is, at least anecdotally, validated by the previous analysis.

Then the final question must be, "Why do those two entirely disparate domains turn out to be cut from one and the same cloth?"

That is a deep question—as deep as some others we've encountered here.* We can show that this question is but one example of a larger classic puzzle. Broadening the context, let's note that many of our pursuits bear underlying similarities to each other, and they all surrender to our preordained mathematical constructs. Have you ever wondered why the ideas and formalisms of statistics; the calculus with its differential and integral equations; matrix representations; abelian and non-abelian groups and set theory in general; and non-Euclidean geometries, to name just a few subfields, actually preceded the phenomena to which they are applied and for which they seem to provide exquisitely useful tools and comprehensive explanations?

Students of philosophy will recognize that we have reached that quite unsatisfying perennial conundrum pitting objective and subjective reality against each other. I won't go there except to point out that the invention of quantum mechanics and of those surveys has one thing in common, and that common denominator is us. They and a long list of other phenomena we think we understand about our universe are all essentially the same, because we made the language that explains them all. Next time someone asks, I will choose chocolate and try not to think about why.

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*It's not as impossible a puzzle as that once posed by the late Professor Robert W. Cahn (University of Cambridge) when he asked why Posterminaries is a proper noun, why it must only ever appear in its plural form, and why its spelling dispenses with the grammatically necessary double *t*? Unanswered questions that shall outlive us all.

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