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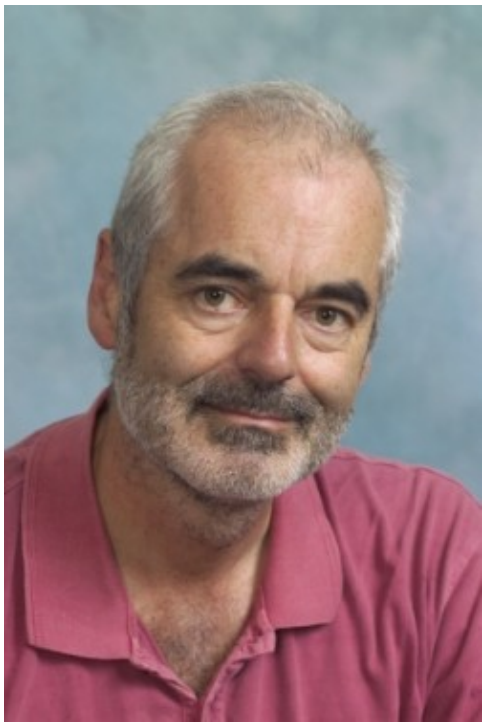
Features

Understanding uncertainty

by Marianne Freiberger

What's the risk of passive smoking? Or climate change? How big is the terrorist threat? And should we trust league tables? These questions concern all of us, but it's not always easy to make sense of the barrage of media information. Maths and statistics are powerful tools in understanding risk and uncertainty, so it's no surprise that David Spiegelhalter, the new Winton Professor for the Public Understanding of Risk, is based at the Centre for Mathematical Sciences at Cambridge University. Spiegelhalter plans to create a wealth of resources for the general public and experts alike, and he'll also be a regular contributor to Plus with his very own column starting in December. He met up with us to chat about risk, uncertainty, and his plans as Winton Professor.

Death and statistics



David Spiegelhalter

Spiegelhalter's background in the medical arena is impressive. His work with Great Ormond Street Children's Hospital investigating a series of deaths during operations led him to help with the high−profile inquiry into the Bristol Royal Infirmary, and also the inquiry into the mass−murdering GP Harold Shipman.

Spiegelhalter is not a physician, but a mathematician and statistician. His previous work covered more obviously mathematical fields, like computer−aided diagnosis and artificial intelligence, but how was his expertise relevant to the various inquiries? "With Shipman, for example, we have a GP who managed to murder well over 200 of his patients before he was caught," he explains. "People quite reasonably asked if he could have been identified a little bit earlier. We statisticians were given the data that was available at the time or could have been available to see if he could have been identified more rapidly."

This research did not just focus the number of Shipman's patients that died. More importantly it was about deciding how a warning system based on mortality rates should work in principle. "There are 26,000 GPs in the country and you can't send in the police every five minutes because of a few deaths. In designing a system you have to be very cautious about false alarms." This is a complex statistical issue. To decide whether a GP's mortality rate is abnormal, you first need to know what's normal, but a general measure like an average national mortality rate is simply too crude. What to expect from an individual GP depends on what sort of patients he or she looks after: how old, how ill they are and so on. Deciding how to adjust for these factors, and how to set thresholds for "blowing a whistle", requires sophisticated statistical techniques and detailed analysis of existing data.

There are many applications for this type of statistical monitoring and surveillance systems. In the wake of the anthrax attacks in the USA, for example, the US government funded research into systems that can search public health data for signs that a bio−terrorist attack has taken place. In the UK inquiries like that into the Bristol Royal Infirmary have had a great impact on the medical sector. "The Bristol inquiry was very serious about statistical analysis. The team was given a lot of time and input into the final report. The report led to the formation of the Healthcare Commission, the independent regulatory body for the NHS and private clinics in

the UK, for which I now also work as a statistical consultant. The commission has huge powers to inspect and investigate clinics. Because of scandals like Bristol and Shipman, the medical profession for whom I have a huge amount of respect can no longer say 'just leave it all to us'."

Should we trust league tables?

The change in attitude has led to a higher degree of transparency. Mortality rates of paediatric centres are now freely available on the Web. When it comes to heart surgery, you can even find figures for individual surgeons. Making this information public is a political decision, of course, and has not been uncontroversial. Spiegelhalter has put a lot of thought into how such information should be presented to the public. "A lot of work I've been doing is against the idea of league tables; the inappropriate ranking of hospitals, surgeons, or schools. League tables may be politically attractive, but are statistically rather spurious. This is one of the ideas I'd like to carry over into my new job as Winton Professor."

What is uncertainty?

The pivotal word in Spiegelhalter's new job title is "risk", but he'd like to broaden his remit to include all forms of uncertainty. His work will include issues like school league tables, because though not about risk in the first instance, they are about the uncertainty that comes with ranking an institution.

But how do you quantify uncertainty? Traditionally, probability theory has dealt with processes whose uncertainty is due to randomness, for example the lottery or a game of dice. In fact, it was a gamblers' dispute that first started the development of the theory of probability in the 17th century. In many real−life examples, though, things are very different. Mortality during surgery is not (one would hope) a random event, but a result of a number of inter−dependent factors that are unique to the patient. Much of our uncertainty lies in our ignorance of what these factors are and how they collude to cause someone to die.

Heads or tails?

This doesn't mean that all the stats and probability theory goes out of the window. There is a school of thought, called *Bayesian statistics*, which embraces the idea that uncertainty is essentially in the eye of the beholder. Though controversial at first, it has gained increasing acceptance over the decades. "The idea of Bayesian statistics is that you can't really separate human judgement and uncertainty," says Spiegelhalter. "I take a view that is sometimes called subjectivist or personalist: that uncertainty is not really a property of the thing you're looking at, but a property of your understanding of it. For example, before I toss a balanced coin, I think we'd both agree on the chance of a head coming up being 50:50. Now suppose I toss it, look at what comes up, but don't show you the coin. Then *my* probability has changed because of the new information I have, but *yours* is still 50:50. So probabilities don't just depend on the event, but on who is making the judgement and what they know (or think they know). In a Bayesian framework probabilities can be associated to almost anything that is unknown to you, from whether you're going to live to 100 to who is going to be the next president of the USA."

This opens up all areas of life to statistical treatment, carefully balanced with human judgement. "Take MRSA for example. Each night there are about 100,000 people being cared for in English hospitals, and about 18 of those will be diagnosed with MRSA infection. That figure is pretty constant, so at a national level you can make stable predictions of how many people will contract the disease. But to assess an individual's risk is another matter. You could say it's 18 in 100,000, but that's just for an average person. In reality everyone is unique. The risk will vary according to where a patient lives, what kind of ward they're in, how old they are, and many other factors. Maybe they are an MSRA carrier and it's very likely that they'll get the disease."

"That doesn't mean that you have to throw out the statistics completely. You can refine your statistical models according to hospital, or age, or location, and that's what's being done in practice, for example in heart surgery. It's this that makes the area so interesting: you *can* use historic information and statistical analysis, but that's never going to be the complete answer. There may always be some unique factors you have to take into account."

Understanding risk

The MMR vaccine true risk or scaremongering?

When we read about uncertainty in the papers, we're not often told much about the methods that were used to assess it. Sometimes, for example when it comes to the terrorist threat, the assessment hinges on purely human judgement of the available evidence. In other cases, such as climate change, there is a huge body of science that together with statistical evaluation gives rise to predictions with specified degrees of uncertainty (although these are still controversial). When it comes to medical issues, risk is often quantified using purely statistical analyses, as happens in clinical trials. But sometimes people panic without any sound scientific reason, as was arguably the case with the MMR vaccine. We can't be expected to peruse scientific papers during breakfast, yet it's important to know if and when to trust the headlines.

In his position as Professor of Public Understanding of Risk, Spiegelhalter will develop extensive web−based resources that can help people understand the issues surrounding risk and the science used to assess it. "So many issues come up all the time what is the risk of your child being abducted, how risky is smoking, are Wi−Fi networks in schools damaging children, should women drink at all during pregnancy. These are real population risks and they are susceptible to probabilistic analysis. It's a matter of carefully weighing up the evidence, working out the uncertainties and quantifying them if possible. But people do it in different contexts and using different language. I'd like to bring all of this together in one common structure."

The website, to be developed over the next year, will not only cover current issues coming up in the media, but also provide resources explaining the science behind risk assessment. The science and maths will be explored to various levels of depth, aimed at everyone from complete novices to experts. Spiegelhalter particularly hopes to engage people who don't have an extensive science background, for example students and teachers ("There will be lots of cool animations and good graphic design"), non−expert journalists, and people who simply want to get to grips with the claims that appear in the media.

The website will not, however, tell people what to think or do. "I don't believe in wagging the finger at people saying 'if only you understood probability theory, you wouldn't do such ridiculous things'. I am also not going to take a line on any of the controversial issues that we'll cover. It will be a place where people can come and see the arguments and get references for the relevant literature. My role is not to take a strong view on any of the issues covered."

But what about those league tables? "Oh, except league tables! That's the sort of thing that one has to have a

good go at. League tables are an inappropriate use of evidence and an inappropriate form of communication that should be clearly identified. Say you've got a whole lot of schools with thirty kids in each class doing their SATs every year, and these schools are ranked according to the results. That's almost meaningless because every year each different set of thirty kids will vary. You can actually build statistical models to see how volatile the rankings will be from one year to the next. If you do insist on ranking, it's quite possible to express the uncertainty of each rank. So if someone is top of the league table, you can work out the probability that they really are the best. That kind of thing is quite fun and I'd like to illustrate it on the website."

If you don't want to wait for the website to be up and running, you might be lucky enough to catch Spiegelhalter giving one of the many talks he's planning for the next year. The talks will be held at schools and other interested organisations, and will try to "engage interest in uncertainty, probability and statistics, which are all wonderful and fascinating." Details will be included in the free *Plus* newsletter. Alternatively, you can read about these wonderful and fascinating things in Spiegelhalter's *Plus* column, which will start in our December issue.

About this article

The new Winton Professorship has been created in perpetuity in the Statistical Laboratory of Cambridge University, thanks to a £3.3 million donation from The Winton Charitable Foundation.

Marianne Freiberger is Co−Editor of *Plus*.

Plus is part of the family of activities in the Millennium Mathematics Project, which also includes the NRICH and MOTIVATE sites.