NATURE'S THREADS

We all have a strong intuitive grasp of cause and effect and an ability to spot patterns, and we use that knowledge every day to make decisions about the events around us. We also have the ability to reason about causes and understand the mechanisms behind a relationship, allowing us to predict what will happen in new situations. Capturing cause and effect in mathematical models and understanding the way we make those decisions has proved much more difficult. Despite the causal nature of most research, causal models sit in a no-man's land between statistics, computer science, philosophy, psychology and practical business needs. So how do we build causal thinking into business decisions? In the first of a two part article we look at some of the principles of causal reasoning.

What's it all about?

Causal reasoning. Sounds a bit off-putting doesn't it? Perhaps not the sort of thing that you'd want to get involved with. Fair enough...but do you measure customer satisfaction? Employee satisfaction? Conduct any other research? Why?

Most research questions, indeed most questions, are ultimately causal. We measure customer satisfaction because we believe it is caused by things we can control (product quality, service delivery etc) and because we believe it causes things we're interested in but cannot directly control (loyalty, sales, profit etc). In doing so we have made at least two separate causal judgements: that what we do causes customers to be satisfied or dissatisfied, and that how customers feel causes their behaviour towards us. Similar judgements are at work with employee surveys and most other research.

So we can't get away from causal judgements - we're making them anyway so we might as well face up to what we're doing. The other thing to notice is that causal reasoning doesn't have to be scary, it can be very straightforward. One of the most admired causal studies ever conducted didn't use any complicated computer models or new statistical methods, because it was conducted in 1855. John Snow managed to demonstrate the causal link between polluted water supplies and cholera, capitalising on a natural experiment provided by the existence of different water companies.

Snow's cholera study

In 1854 there was a cholera outbreak in London. Two years earlier the Lambeth water company had moved its intake pipe upstream in order to get a purer source, but the Southwark and Vauxhall company left its intake pipe in relatively contaminated water. Water suppliers had been chosen by households pretty much at random, and in many cases even houses on the same street had different suppliers.

Snow's findings are powerfully convincing:

> *The following is the proportion of deaths to 10,000 houses, during the first seven weeks of the epidemic, in the population supplied by the Southwark and Vauxhall Company, in that supplied by the Lambeth Company, and in the rest of London.*

Table IX.

	Number of houses	Deaths from Cholera	Deaths in each 10,000 houses
Southwark and Vauxhall Company	40,046	1,263	315
Lambeth Company	26,107	98	37
Rest of London	256,423	1,422	59

The mortality in the houses supplied by the Southwark and Vauxhall Company was therefore between eight and nine times as great as in the houses supplied by the Lambeth Company; and it will be remarked that the customers of the Lambeth Company continued to enjoy an immunity from cholera greater than the rest of London which is not mixed up as they are with the houses supplied by the Southwark and Vauxhall Company. [1]

Life is a perpetual instruction in cause and effect.
Ralph Waldo Emerson

Not only was it a compelling case for clean water supplies, but it also made a powerful argument in favour of the theory that cholera was propagated by a germ - at the time only one of several theories.

The lesson to learn is that we should not be afraid to recognise the causal nature of our studies. There is no automatic necessity to adopt sophisticated techniques; causal theories can be tested and supported by the simplest of statistical techniques, like Snow's, as long as the study is well designed and properly carried out. It is the study design, not the statistical techniques, that allows proper and meaningful conclusions to be reached. We'll return to causal research in part 2, but what about the judgements we make in everyday life?

Judging cause and effect

Knowing that water always boils when we heat it to 100°C, we would be confident that if we take a kettle and heat it to 100°C, it will boil. We believe that heating the water to 100°C causes it to boil. Yet knowing that the cock crows every morning as the sun comes up would not lead us to believe that the cock crowing causes the sun to rise. Why not? If that seems like a silly question it's because it is - to us. We humans clearly have an inbuilt ability to determine cause and effect relationships, based on something cleverer than the fact that two things happen at the same time.

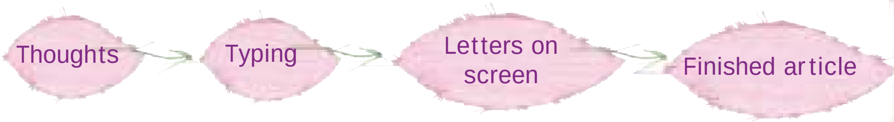
The interesting thing is that no-one knows for sure how we do this. The philosopher David Hume pointed out that the basis for reasoning about all causal relations consists purely of sensory input (i.e. things we see, hear, feel, smell and taste) providing evidence of association. It follows, therefore, that some internal process makes a causal assumption about some associations based on information not contained in the sensory input itself. Hume proposed that causal relations are inferred from:

- **The spatial and temporal contiguity of the candidate cause and effect -** The two events happen close enough to each other in location and time. Interesting evidence about the time aspect is covered later on.
- **The temporal priority of the cause -** Causes precede effects. Philosophers have struggled with this idea, but humans appear to use it to good effect.
- **The constant conjunction between the cause and effect -** Effects reliably follow when the cause happens, and do not tend to happen without the cause.

These rules would be enough to mirror our conclusions about boiling water and sunrise, but is that all there is to it? Probably not...but no-one has yet discovered all the rules.

We make causal judgements all the time. I'm making a causal judgement when I assume that pressing keys on a keyboard will result in letters appearing on the screen, which will in turn lead to a fully laid out magazine article. The fact that these are judgements is proved by the fact that those assumptions are occasionally violated, notably if my computer was to decide to ditch its hard drive permanently. That knowledge also proves how good we are at learning from experience!

In more formal terms we could hypothesise a series of causal connections that would look a bit like this:



This kind of graph is called a Bayes Net, and is a very general way of capturing and modelling our understanding of causal relationships. Ovals represent events or variables, arrows represent a causal link from one to another. Another such net might be:

Which reflects a very different process. We make instant perceptual causal judgements about why, for instance, a plate smashes when it is dropped on the floor. We also go through a much more long-winded process of causal reasoning for effects that are not instantaneous, like smoking causing cancer.

A good way to understand how the mind works is to see in what circumstances the rules it uses fail. Mind Hacks, a book that approaches the features of the mind in exactly this way, gives an interesting example of causal judgements going wrong:

Make a pendulum, using whatever you have lying around...I'm using the cord from my camera with my keys as a weight. You'll also need another small object; I'm using a large red bottle lid from a drink bottle.

Hold the pendulum up in front of you and set it swinging left and right. Now take the other object in your free hand and wave it around at the side of the pendulum. It doesn't feel like anything special, does it? Now move the other object (in my case the bottle cap) in time with the pendulum, trying to keep it a fixed distance, say 5 inches, from the swinging weight. If you get the timing right, you should get the unmistakable impression that the object in your free hand is pulling the pendulum weight along and then pushing it back. This happens even though your body has direct evidence that the two events are causally unrelated: the pendulum moves by itself and your own hand moves the unconnected object.

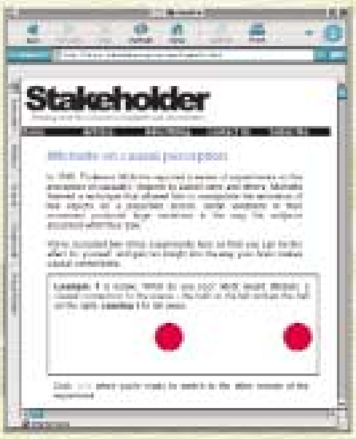
Notice that you don't just see the two things as moving together. You get a feeling, manufactured by your perceptual system and delivered direct into consciousness, that one thing causes another." [2]

"Nature uses only the longest threads to weave her patterns, so that each small piece of her fabric reveals the organization of the entire tapestry."
Richard Feynman

A couple of key features of our brains are shown here. First causal reasoning and causal perceptions are separate things. We can know that one thing does not cause another, but our perceptual system makes its own causal judgements based on heuristics that are normally effective in the real world, and are probably similar to the ones proposed by Hume.

As Hume suggested, timing seems to be key to the perception of causality (remember this perception is different from reasoning). If events are separated by more than 140 milliseconds (about 1/7th of a second) we tend to see them as separate, any less than that and we see a causal link.

For an example of the importance of timing direct your browser to: http://www.stakeholdermagazine.com/michotte.html



Is there a causal relationship between the two balls? It all depends on the timing.

Causal perceptions round-up

1. Probable causation can be indicated in a number of ways. One is sequence - in other words if something happens and something else happens immediately after it is likely that one thing caused the other. For example even a person with no experience of firearms would correctly assume that if I fire a gun at someone and they fall over that there is a causal relationship between the two. The nature of the relationship may be subject to misunderstanding but the relationship would be correctly identified.

2. The temporal one-way street for causation is something that is a difficulty for philosophers and quantum physicists, who want to understand why time flows in one direction, but is very useful for decision making and in practical causal modelling.

3. One of the interesting, and revealing, mistakes that humans are prone to making is that we don't believe in coincidence. This is why we are so easily duped by phoney magicians, spiritualists and astrologers. The phrase post hoc ergo propter hoc or "after this therefore because of this " is used when this logical fallacy creeps into more rarefied environments.

Hume contended that we can never see cause and effect, but use inductive reasoning to deduce its existence from correlations. This is why we can sometimes be misled, just like statistical techniques. The old mantra that "correlation is not causation" is a valuable one in scrutinising judgments if not in making them.

4. Humans also have an ability to learn. The more often an event is followed by a potential effect the more strongly it is seen to be a cause. This links neatly to the idea of probabilistic causation covered next time.

In part 2 we'll look in more pragmatic terms at the techniques that have been developed to assess and measure causal relationships, including their pitfalls and potential benefits. S

Bibliography

[1] John Snow, On the Mode of Communication of Cholera, London 1855
[2] Tom Stafford & Matt Webb, "Mind Hacks: Tips and Tricks for Using Your Brain"
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