3.4 Regression to the mean – A Bewildering Effect of Random Variation

Randomness can play tricks on us and can give rise in some curious oddities. A good example is the phenomenon of 'regression towards the mean', also called 'reversion to the mean'. It is important to be aware of this phenomenon when designing clinical trials since it is commonly encountered. It is really important to be able spot it easily and intuitively and so avoid being fooled. To paraphrase its statistical description, an extreme event will nearly always be followed by a less extreme event. While this bland description captures its essence, it does not portray very well this lurking malicious trap. To portray the issue in its proper light only a concrete example will really do: here we invoke the noble game of pub darts.

Terrible darts players

Imagine that you are a very bad darts player, so can land a dart on the board, but exactly where it lands is truly random. As a result, the simple laws of chance will best describe the score you obtain from throwing three darts. Imagine then that you are playing with several friends, who are just as hopeless. After the first five rounds it is possible to calculate an average or mean score for all the players. This average is roughly the same for each the player so here we will simply refer to this as the 'average' score without specifying what it is, apart from noting that it is not particularly high (but is far from zero) and does not change much over time.

On the sixth round one friend scores extremely well; alas, you score a little below the average. However, the very next round your friend, seriously fired up but still hopeless, has a disappointing score that is only a bit above average, as do you. Later, on the seventeenth round you have a stunning win and a massive score. However, on the following round your triumph crumbles to below average so you lose the game and slink off to the bar to get in a round of lemonades.

The above scenario is familiar and easy to understand. It is plain why one or two high scores happened and why they are not repeated – they were just random flukes. Over the long term the average score of a player does not change much even though the occasional fluke or low score happens as it is averaged over a lot of games and balance by some low scores. Nevertheless, as you keep playing you may win a game with a fluke and lose one or two embarrassing low scores. There is no formal cause for your unusual high or low score – it was chance, and you had nothing to do with it. Note that here we assume that that skill levels of the darts team never increases although, of course, in a real pub with practice it may well.

Punishment, reward and intolerant teachers

To take the example a little further, imagine on the next day at the pub you have acquired a darts teacher who is utterly ineffective but no-one knows that. This teacher yells at any 'student' who scores badly and praises those scoring well. The laggards immediately improve after the yelling at, but high achievers go down after the praise. A newcomer to the establishment has been watching the proceedings, and in between sips of lemonade he concludes that the teacher's praise doesn't seem to work but that yelling at bad players does. However, we know better: we saw exactly the same pattern of improvement and regression in your darts scores the previous day when the teacher was not around.

Our perspective thus allows us to see this 'regression to the mean' for what it is, but away

from the pub it is striking how we seem almost hardwired to see things the way that onlooker does.

Invisible randomness

The problem always with randomness (i.e., non-systematic variation around the mean) is that we often are blind to the magnitude of its effects and the role they play. We tend to look for explanations that involve simple causes, especially of human agency. So the good scores we get are ascribed to positive thinking, our hard effort, or our rabbit foot lucky charm, but we then forgot to keep thinking positively or took our eye off the ball, or the foot.

The human brain is so good at spotting patterns that it has no problem spotting patterns that do not exist, indeed many brains resist the very notion that random chance exists. Temporary successes in many fields of endeavour, even in research (who knows) can be susceptible to the warm embrace of good fortune followed by the cold shower of reversion to the mean. Thus prizes can be awarded to the outstanding, who then go on to disappoint. This is not due to a jinx but our underestimation of how large a part randomness plays in performance. This happens with clinical data as well.

An aside: Francis Galton

Regression to the mean was discovered and described by Francis Galton in the 19th century. As part of his otherwise unfortunate dedication to eugenics his measurements of height of parents and their children noted that child heights usually lay between the mean of their parents and the population height mean. He thus stumbled upon the ideas of simple regression that now play a fundamental part of statistical analysis.

Influences on clinical trial design

It is now widely understood that when setting up a randomised clinical trial the best design (as perhaps the name suggests) is to randomise the subjects at the outset, and to do so rigorously. This does make intuitive sense since it means the control and treatment group will always be equivalent.

If, however, we consider what might happen if this is not done in a disease treatment trial – if, at the start, the treatment group actually had worse symptoms than the control group then any apparent improvement may just be regression to the mean and not a treatment effect. Random blinded allocation minimises this, which is why it is so crucial.

Effects of regression to the mean can also be compounded by putting study subjects into groups based on initial (baseline) parameters. So, if patients are allocated to a study based on one measurement being above a threshold, some may be false positives at the start because they were by chance higher than typical for them. This can be avoided using allocation based on more than one parameter to reduce effects of reversion to the mean.

What to do

Reversion to the mean is usually tackled by using careful protocol strategies to avoid it, such as those outlined above. This is why the many time consuming tasks of double-blind patient allocation to treatment/placebo, pre-registration of trial protocols and other irksome duties need committed and careful adherence. Statistical analysis and estimation techniques exist to prevent problems around reversion to the mean; one useful and readable resource is noted below.

Further entertainment

There is much literature on this subject much of which is highly readable, in particular from giants in the field Professors Daniel Kahneman, Amos Tversky and Dan Ariely.

Ref- *Barnett A, Van Der Pols J, Dobson A, (2005)* Regression to the mean: what it is and how to deal with it*,* International Journal of Epidemiology *p215-220*

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