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Why bad science persists

Incentive malus

Poor scientific methods may be hereditary

IN 1962 Jacob Cohen, a psychologist at New York University, reported an alarming finding. He had analysed 70 articles published in the *Journal of Abnormal and Social Psychology* and calculated their statistical "power" (a mathematical estimate of the probability that an experiment would detect a real effect). He reckoned most of the studies he looked at would actually have detected the effects their authors were looking for only about 20% of the time—yet, in fact, nearly all reported significant results. Scientists, Cohen surmised, were not reporting their unsuccessful research. No surprise there, perhaps. But his finding also suggested some of the papers were actually reporting false positives, in other words noise that looked like data. He urged researchers to boost the power of their studies by increasing the number of subjects in their experiments.

Wind the clock forward half a century and little has changed. In a new paper, this time published in *Royal Society Open Science*, two researchers, Paul Smaldino of the University of California, Merced, and Richard McElreath at the Max Planck Institute for Evolutionary Anthropology, in Leipzig, show that published studies in psychology, neuroscience and medicine are little more powerful than in Cohen's day.

They also offer an explanation of why scientists continue to publish such poor studies. Not only are dodgy methods that seem to produce results perpetuated because those who publish prodigiously prosper—something that might easily have been predicted. But worryingly, the process of replication, by which published results are tested anew, is incapable of correcting the situation no matter how rigorously it is pursued.

The preservation of favoured places

First, Dr Smaldino and Dr McElreath calculated that the average power of papers culled from 44 reviews published between 1960 and 2011 was about 24%. This is barely higher than Cohen reported, despite repeated calls in the scientific literature for researchers to do better. The pair then decided to apply the methods of science to the question of why this was the case, by modelling the way scientific institutions and practices reproduce and spread, to see if they could nail down what is going on.

They focused in particular on incentives within science that might lead even honest researchers to produce poor work unintentionally. To this end, they built an evolutionary computer model in which 100 laboratories competed for "pay-offs" representing prestige or funding that result from publications. They used the volume of publications to calculate these pay-offs because the length of a researcher's CV is a known proxy of professional success. Labs that garnered more pay-offs were more likely to pass on their methods to other, newer labs (their "progeny").

Some labs were better able to spot new results (and thus garner pay-offs) than others. Yet these labs also tended to produce more false positives—their methods were good at detecting signals in noisy data but also, as Cohen suggested, often mistook noise for a signal. More thorough labs took time to rule these false positives out, but that slowed down the rate at which they could test new hypotheses. This, in turn, meant they published fewer papers.

In each cycle of "reproduction", all the laboratories in the model performed and published their experiments. Then one—the oldest of a randomly selected subset—"died" and was removed from the model. Next, the lab with the highest pay-off score from another randomly selected group was allowed to reproduce, creating a new lab with a similar aptitude for creating real or bogus science.

Sharp-eyed readers will notice that this process is similar to that of natural selection, as described by Charles Darwin, in "The Origin of Species". And lo! (and unsurprisingly), when Dr Smaldino and Dr McElreath ran their simulation, they found that labs which expended the least effort to eliminate junk science prospered and spread their methods throughout the virtual scientific community.

Their next result, however, was surprising. Though more often honoured in the breach than in the execution, the process of replicating the work of people in other labs is supposed to be one of the things that keeps science on the straight and narrow. But the two researchers' model suggests it may not do so, even in principle.

Replication has recently become all the rage in psychology. In 2015, for example, over 200 researchers in the field repeated ▸▸

100 published studies to see if the results of these could be reproduced (only 36% could). Dr Smaldino and Dr McElreath therefore modified their model to simulate the effects of replication, by randomly selecting experiments from the "published" literature to be repeated.

A successful replication would boost the reputation of the lab that published the original result. Failure to replicate would result in a penalty. Worryingly, poor methods still won—albeit more slowly. This was true in even the most punitive version of the model, in which labs received a penalty 100 times the value of the original "pay-off" for a result that failed to replicate, and replication rates were high (half of all results were subject to replication efforts).

The researchers' conclusion is therefore that when the ability to publish copiously in journals determines a lab's success, then "top-performing laboratories will always be those who are able to cut corners"—and that is regardless of the supposedly corrective process of replication.

Ultimately, therefore, the way to end the proliferation of bad science is not to nag people to behave better, or even to encourage replication, but for universities and funding agencies to stop rewarding researchers who publish copiously over those who publish fewer, but perhaps higher-quality papers. This, Dr Smaldino concedes, is easier said than done. Yet his model amply demonstrates the consequences for science of not doing so. ■

Wireless communication

In a whole new light

Lighting fixtures that also transmit data are starting to appear

FLICKERING lamps are normally a headache-inducing nuisance. But if the flickering happens millions of times a second—far faster than the eye can see or the brain respond to—then it might be harnessed to do something useful, like transmitting data. That, at least, is the idea behind a technology dubbed Li-Fi by its creators.

Li-Fi works with light-emitting diodes (LEDs), an increasingly popular way of illuminating homes and offices, and applies the same principle as that used by naval signal lamps. In other words, it encodes messages in flashes of light. It can be used to create a local-area network, or LAN, in a way similar to the LANs made possible by standard, microwave-based Wi-Fi.

Such LANs would, Li-Fi's supporters believe, have two advantages over standard Wi-Fi. One is that light does not penetrate walls. A Li-Fi LAN in a windowless room is thus more secure than one using Wi-Fi, whose microwave signals pass easily through most building materials and can thus be listened to by outsiders. The other advantage is that light does not interfere with radio or radar signals in the way that microwaves sometimes do. Li-Fi can therefore be installed in hospitals, nuclear plants and other sites where Wi-Fi might create dangerous interference with electronic kit.

One business about to benefit from this selectivity is commercial aviation. Though aircraft avionics have been hardened over the years, to reduce the risk of interference from radio and microwave signals, using Li-Fi would make absolutely certain. It would mean that LANs could be set up in

Once upon a time

the cabin, distributing entertainment to passengers and permitting those with Li-Fi-equipped phones and computers to contact the outside world.

This arrangement would also save on weight, as passenger-entertainment systems would no longer have to be fed by cables. To this end Airbus, a big European aircraft-maker, let Velmenni, an Indian firm, spend six months earlier this year installing and testing a Li-Fi network in a mocked-up passenger cabin of one of its planes. Velmenni hopes to use passengers' reading lights to broadcast the signal. Luciom, a French firm, is even further advanced. In January 2017 it will begin installing Li-Fi on passenger jets built either by Airbus or by its American rival, Boeing (a non-disclosure agreement forbids it from saying which one).

In the longer run, though, it is buildings that Li-Fi's manufacturers have their eyes on. PureLiFi, a British firm that sells components to lighting manufacturers, plans to use the same cable to carry power and data to the LEDs themselves. That should make the system simple to install. PureLiFi is also designing LEDs that radiate data even when dimmed, so that a film can be streamed into a room and shown with the lights down.

Installing a Li-Fi LAN, then, should not be too difficult. But for the technology to succeed, computers, phones and other signal-receiving devices will also have to be modified, so that they can pick up and reply to optical transmissions. To give that capability to existing kit engineers at Luciom have made a dongle that plugs into a standard USB port. This dongle contains both an ordinary LED (though it is one that emits infra-red flashes, which are invisible to the human eye) to send data to the LAN, and the opposite of an LED—a photodiode that converts light into electricity rather than the other way around—to receive data.

PureLiFi, looking further ahead to a time when Li-Fi has become routine, is miniaturising such components with the intention of embedding them into devices at the point of manufacture. Nor is it alone in this desire. Zero.1, based in Dubai, says it has managed to tweak the cameras in the latest smartphones to run Li-Fi. Perhaps more pertinently, the intentions of Apple, the world's most valuable listed company, were revealed earlier this year when it emerged that the term "LiFiCapability" is buried in the code of the iOS 9.1 operating system used by one of its most successful products, the iPhone.

Li-Fi may spread outdoors, too. Sunlight spoils its signals during the daytime, but in the hours of darkness Li-Fi-enabled streetlamps should work perfectly well. Gabe Klein, an entrepreneur who was once the boss of Chicago's transport department, says the city has begun testing the idea of adding Li-Fi to the LED-based street lighting now being installed there. One potential beneficiary of this idea, if it succeeds and spreads, is Trópico, a Brazilian streetlamp-maker. According to Daniel Auad, Trópico's owner, the Li-Fi-enabled streetlamps the firm is now working on should sell for about $325 a piece—a premium of only $75 over the non-enabled variety.

The technology may even be co-opted as a navigation tool in places, such as many buildings, that signals from the satellite-based global-positioning system cannot reliably penetrate. In this case the flicker- ▸▸