Problems with Scientific Research

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1 ABSTRACT

This paper presents a current problem facing scientific research: in order to be published (and funded), researchers are pressured to find new and surprising results in their field of study. This is due to the current nature of journals, the lack of experimental details that make exact replication nearly impossible, no incentives to verify other researchers' work, and the ineffectiveness of peer-review. This paper also serves to present possible solutions to this problem, involving predictive learning and philosophical principles. Finally, a real-world example is presented to show how these solutions would affect the outcome of how the data is presented and published.

2 PROBLEM DESCRIPTION

The problem science has been facing over the past two decades is that research goes unverified. In the past, there were fewer scientists, fewer papers published, and less competition among researchers. Scientists were under little to no pressure to fabricate or otherwise publish misleading results in the mid-twentieth century. But now, things have changed.

In the United States, there are currently 6.9 million scientists, accounting for 4.9% of total employment [3]. With more researchers than ever, there has been a sort of "scientific explosion" with the number of papers that have been published in research journals [2]. Competition among scientists has also increased significantly. The number of publications a scientist has all too often determines her/his quality as a researcher [4]. This is especially true for funding. The organizations that grant researchers and professors funding want to see that they have published a large number of interesting work. Furthermore, in order to get published, a scientist must make a surprising or shocking discovery, so that journals will accept it because most journals want to include the most significant and startling scientific discoveries. Thus, scientists tend to cherry-pick their data to make their experiment seem more promising, and in the extreme case, they fabricate data in order to publish something more interesting rather than admitting that their hypothesis was false [1].

Even though a researcher may be completely honest with their data and results, he/she may be unintentionally giving misleading conclusions. For example, suppose that there are 1,000 hypotheses and that 10%, or 100, are true. Assume that the false positive rate is 5% and has a power of 0.8. This means that the tests produce 45 false positives, and they only confirm 80 of the true hypotheses, producing 20 false negatives. The researcher sees 125 true hypotheses, 45 of which are not [5]. So, although the researcher's data can be honest, the researcher must be wary of these false positives. This is why we say that data *support* a hypothesis rather than *prove* a hypothesis. Scientists should not assume that their results prove what they wanted to prove; additional tests for verification must be done before anything substantial can be concluded.

Peer-review also does not accomplish its intended goal. After a paper has been sent to journals for possible publication, journals send that paper to other researchers in the same field in order to determine the legitimacy of the experiment and results. However, those researchers very often fail to catch mistakes regarding the paper's methodology and data [4]. It seems that peer-reviewing is an antiquated process that only serves to add an almost meaningless label to a paper.

The ability for researchers to publish results that do not tell the full story is a huge problem in academia. Misleading data and results can cause problems when other scientists try to build off of that research. There is also a large sociocultural component to producing accurate results. Doctors rely on the truthfulness and accuracy of medical journals, for example, when determining which medications they should give to patients. Thus, there are many personal and health implications when dealing with flawed data.

3 SOLUTION APPROACHES

There are three major areas that, if improved, would decrease the effect that misleading results has on both other scientists and the public. These areas include journals, funding, and peer-review.

Journals should accept papers that are not interesting or disprove their hypothesis [1]. A good paper should be defined as one that is scientifically rigorous and follows the scientific method, proving and verifying all their claims and supporting it with their data that is unbiased and untainted. Journals should accept *good* papers as opposed to ones that merely support shocking or surprising hypotheses. In addition, journals should accept papers that verify or disprove other papers rather than demanding new and interesting work [1].

Funding is also a big issue when it comes to what is published. The corporations and institutions that give funding to professors and researchers want to see new and exciting work, but if they also funded less interesting projects and research that seeks to confirm or deny the hypothesis of another paper, then researchers would have the financial capability to verify other researchers, and scientists would be less likely to feel pressured to publish misleading or surprising results. Further, the funding is typically given to scientists who have published the most papers, since this is usually an indicator of a better researcher [4]. However, if the best researchers were defined by the quality of their work rather than the quantity, scientists would be more focused on producing honest and scientifically rigorous work [4].

Peer-reviewing is another practice that needs to be changed. The process should be more rigorous than it currently is. Typically, the peer-reviewer does not notice critical mistakes in a paper [4].

Reviewers should have more incentive to find mistakes in the papers that they are reviewing. Reviewers should also check that papers have rigorously followed the scientific method and all their data is displayed and interpreted without picking out just the data that supports the hypothesis. Papers that are reviewed for rigor and accuracy of data should be more likely to be accepted by journals and more likely to be funded. This would encourage scientists and researchers to contribute more to their field of study since their contributions would be true and meaningful.

In addition to the changes regarding journals, funding, and peer-review, there are steps that the researcher could take in ensuring accurate data: predictive learning and some philosophical principles.

3.1 Predictive Learning

Vapnik-Chervonenkis theory (VC theory) is based partially on the idea that learning processes are consistent. This theory can be extended to hypotheses and their experimental methodologies. Scientists should make their experimental design very clear in their papers, describing in detail everything they used and exactly how they collected their data. This should make it easily replicable for other scientists to verify the data and results from the experiment.

In addition, scientists of all fields should have at least a basic understanding of statistics. They should know that data always contains some false positives and false negatives that can affect what is concluded from the data. Also, when performing statistical analyses, it is important to discuss the implications of what standards are used for the experiment (e.g. using a p-value of 0.01 versus a p-value of 0.05). In this example, the chances of a correlation in the data occurring by chance is one in one-hundred versus one in twenty. This is important because it means that a researcher cannot conclude that her/his data make the hypothesis true; it can only be used *in support of* the hypothesis, and there is also a chance that it could be completely wrong.

3.2 Philosophical Criteria

There are two main philosophical principles that can be used to help this problem facing scientific research: Popper's falsifiability and Occam's Razor.

Popper's falsifiability states that a distinctive feature of any scientific theory is that its hypotheses can be tested. Popper implies that if its hypotheses cannot be tested, then it cannot be a scientific theory. This is important for researchers when coming up with a hypothesis to explain some type of event or occurrence suggested by the data. If the hypothesis is unable to be tested, then it will be impossible to verify the validity of that hypothesis, and it will be impossible for other scientists to agree or disagree with the hypothesis since there is no way for any sort of data to support it.

Occam's Razor states that the simplest explanation is preferred and probably correct rather than a more convoluted explanation. With the current way things are and how journals prefer the most shocking and surprising results, it seems that scientists will try to make their data support a complex theory that sounds more interesting. Thus, when scientists make conclusions about the data, they should try to think of the simplest explanation for it rather than creating an overly complex explanation that would make their results look interesting.

Peer-reviewers should also take Occam's Razor into account when reading other papers; they should consider alternative hypotheses for the data and reduce the complexity in the explanation. In addition to theories being simplified, the experimental design should also be simplified as much as possible. This would make replication much more feasible, meaning that scientists would be more likely to verify the results of the experiment rather than having to worry about getting the intricacies of the experiment correct.

4 TESTING

The following scenario is used to illustrate how these possible solutions would improve the quality of research and ensure the validity of conclusions that are made from data.

Take the medical/pharmaceutical field, for example. Suppose a scientist hopes to prove that medicine X helps cure disease Y. To prove this, the researcher designs an experiment in which he/she tests drug X on one hundred participants who are shown to have the disease through test Z. In a blind study, fifty of the participants are given drug X, and the other fifty are given a placebo over a one-month period. At the end of the one-month period, the participants are then tested again to see if they still have disease Y. At the end of the study, the researcher finds that 10 participants that were given drug X still have disease Y, and 30 participants that were given the placebo still have disease Y. The researcher concludes that drug X is effective in curing disease Y and publishes data that only shows that in a study of fifty people with disease Y, there was an eighty percent success rate with only ten people still having the disease after one month.

With the aforementioned proposed solutions, this paper would certainly not get published. If this paper were sent to peer-reviewers, they would not accept the lack of rigor in this experiment. Peer-reviewers would demand all the data be open for review, and they would see that there was a forty percent success rate with the placebo, which would make the drug seem much less effective than it actually is.

With more funding for verification studies, more researchers would likely perform studies to verify drug X's effectiveness. They would also likely realize that test Z, the test that determines if a person has disease Y, is not one hundred percent accurate; in fact, it has a much higher false positive and false negative rate than what was expected. This would mean that some of the participants never had the disease or that the test reported that some people had been cured when they actually still have the disease. This would suggest that drug X is even less effective than the original researcher thought.

Finally, if the researcher had more knowledge about statistics, he/she could have performed more statistical analyses on the data like determining the p-value. The p-value would have shown the researcher that the correlation in participants who were cured from the disease between the two groups was not significant. It would have indicated that the statistical chance of random correlation was actually quite high and would require more tests to determine if drug X actually did anything to cure the disease. Also, if more journals accepted negative results (i.e. papers that don't support their hypotheses), then this paper could have been published to show that drug X does not have a significant effect on the disease. This conclusion could have shown other researchers what *didn't* work, so that they could have tried other solutions rather than hoping that drug X had a promising start in curing disease Y.

This illustrates how the proposed solutions would have made a difference with the example scenario described above. Rather than proving that drug X was very significant in curing disease Y, the researcher would have instead stated that drug X may be able to cure disease Y in a small portion of the population, but more research must be completed in order to verify this result. This benefits society since there would be more accurate and truthful results from scientific studies, and there would be less confusion about what works versus what doesn't work.

5 CONCLUSION

In conclusion, the problem with modern science has been introduced along with factors like journals, funding, and peer-review and how they play a role in the problem of unverified scientific conclusions. Several solutions have been discussed, including VC theory, Popper's falsifiability, and Occam's Razor. Finally, a fictitious scenario from the medical and pharmaceutical field is given to illustrate how these solutions would attempt to fix the problem of unverified and flawed results. It is further noted that a change in the way things are currently designed, such as the antiquated peer-review system, would also have a positive impact on publishing truthful, accurate scientific data.

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